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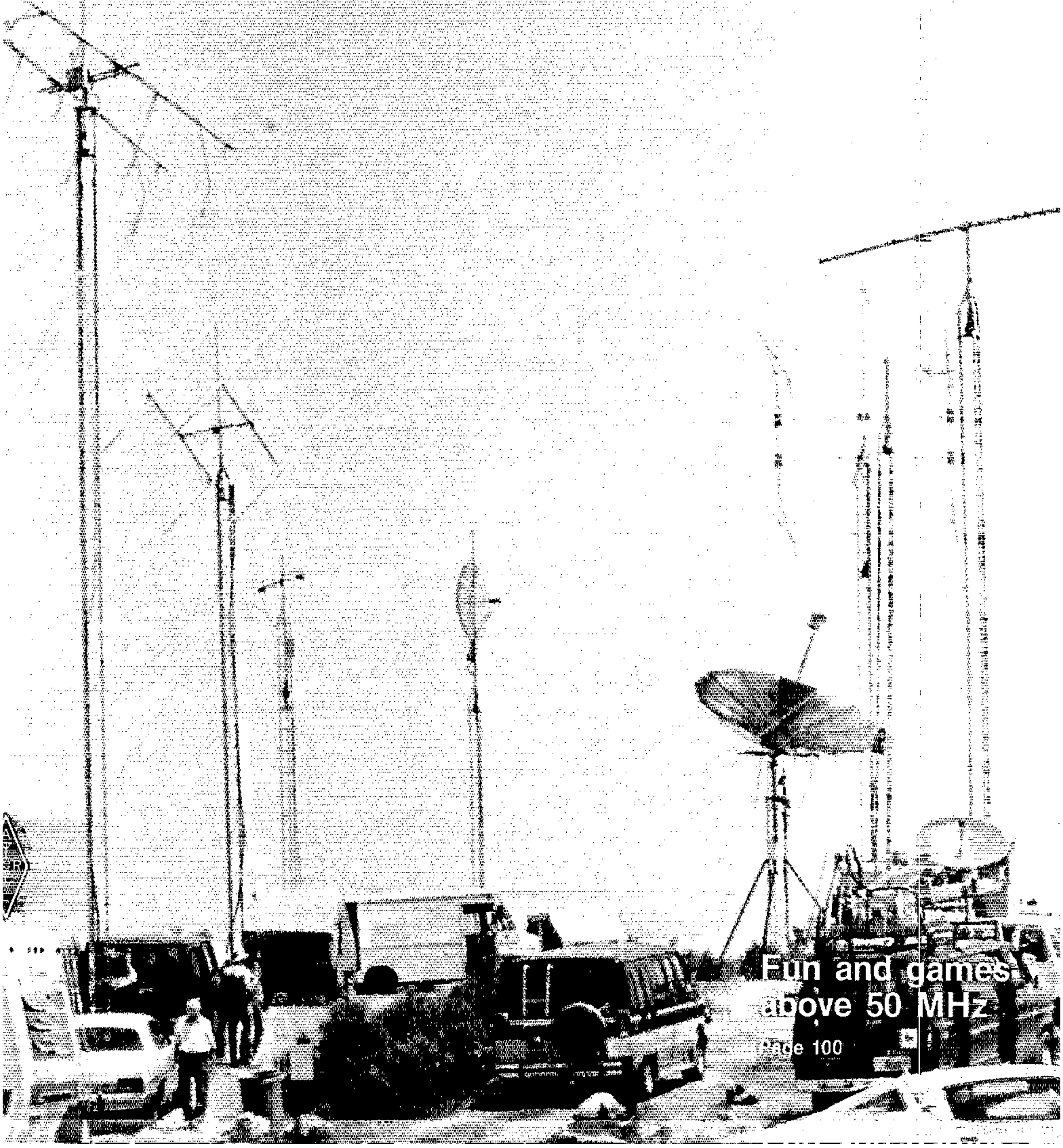

Fun and games above 50 MHz

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QST

May 1984 *Volume LXVIII Number 5*

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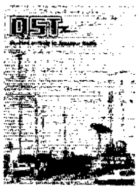


OUR COVER
If you're into VHF/UHF, you'll want to hone your system for the VHF QSO Party June 9-11 (Rules are on page 100). The W3BBS setup, with antennas for 220, 432 and 1296/2304, was good for second place in the multiop category last year. *(photo courtesy WA3IAO)*

TECHNICAL

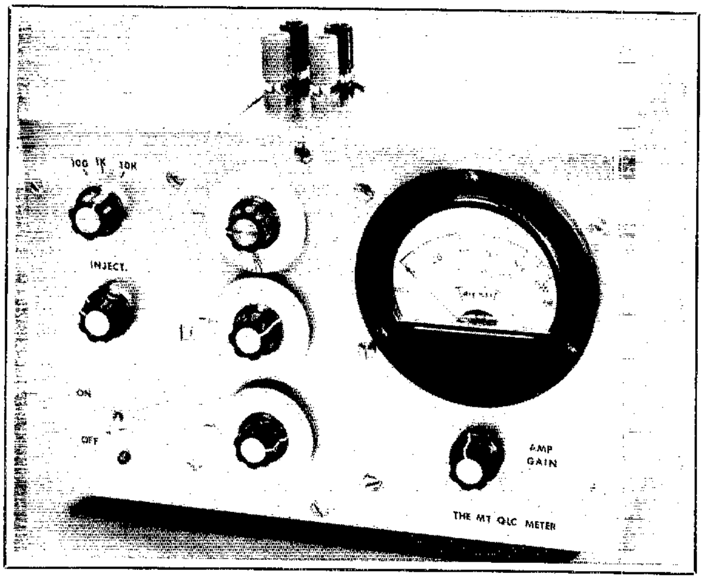
BEGINNER'S BENCH

NEWS AND FEATURES

OPERATING

DEPARTMENTS

A Crystal-Controlled Q Meter



Now you can measure coil Q as well as inductance and capacitance without straining your budget. This piece of test equipment will be a welcome addition to your bench.

By Frank Noble,* W3MT

Inductors and capacitors in tuned circuits cyclically store and return energy without losing much of it. The quality factor, Q, is proportional to the ratio of energy stored to energy lost per cycle. Since capacitors are quite efficient, it is customary to assign all losses to the coil.

Coil Q is affected by coil geometry, the type and size of wire used to wind the coil, the type of insulation used, the coil-form material, and the core (if any) and the coil proximity to other conductors. The number of factors involved requires some means to measure Q rather than attempting to calculate it. Commercial Q meters do this. Unfortunately, the cost of one of these instruments is beyond the means of most of us. This article is intended to provide you with a Q meter of reasonable cost, complexity, size and accuracy.

Q Measurement

In the circuit used here, Q is measured by the reactance-variation method.[1] First, the circuit is resonated and the meter set to full scale. The circuit is then detuned to the high-capacitance side of resonance to obtain a reading of 70.7% of full scale, and the capacitance, C2, is noted. Then, the circuit is tuned to the 70.7% point on the low-capacitance side of resonance, and the capacitance, C1, is recorded. The Q is determined from the ratio of the sum to the difference of these capacitances as shown in Fig. 1. Q values from 10 to 500 are readily determined.

Table 1
Q-Meter Constants and Variables

ω_o (radians/s)	ω_o^2 (radians/s)	f_o (MHz)	L (μH) C (pF)	Range Switch Position	C Range (pF)	L Range (μH)
10^8	10^{16}	15.915	100	100	40-440	0.227-2.5
3.16×10^7	10^{15}	5.0328	1K	1K	40-440	2.27-25
10^7	10^{14}	1.5915	10K	10K	40-440	22.7-250

Inductance Measurement

Since

$$L = \frac{1}{\omega_0^2 C} \qquad \text{(Eq. 1)}$$

where

$\omega_0 = 2\pi f_0$
f_0 = frequency
C = capacitance
L = inductance

the calculation of inductance is made easier by selecting frequencies for which $\omega_0^2 = 10^n$, where n is an integer. This is shown in Table 1.

As an example, when the RANGE switch is in the 1K position and the meter peaks when C = 200 pF, the inductance is 1000/200 = 5 μH. The capacitance used to tune the unknown coil is comprised of three variable capacitors having ranges differing by factors of 10. This is required so that coils of widely different inductances and Q values may be tuned with ease.

Capacitance Measurement

Capacitances in the 0-400 pF range may be measured by substitution. A coil with an inductance slightly greater than 2.27 μH is tuned to resonance in the 1K range. The capacitance value is noted. The unknown capacitance is then connected to the C terminals, and the tuning capacitance is decreased to re-establish resonance. The difference between the two dial readings is equal to the unknown capacitance.

Hardware

Refer to Fig. 2. Note that a crystal oscillator is used instead of an LC VFO. This is because it

[1]Notes appear on page 14
*10004 Belhaven Rd., Bethesda, MD 20817

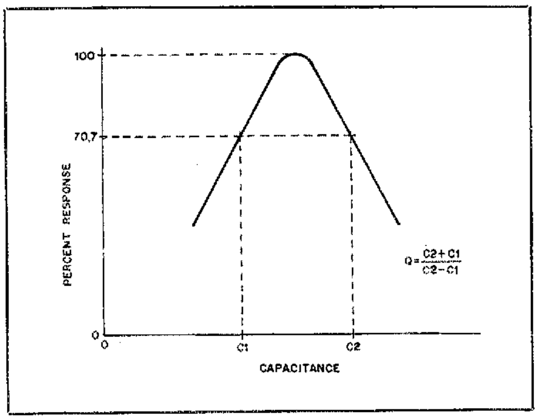
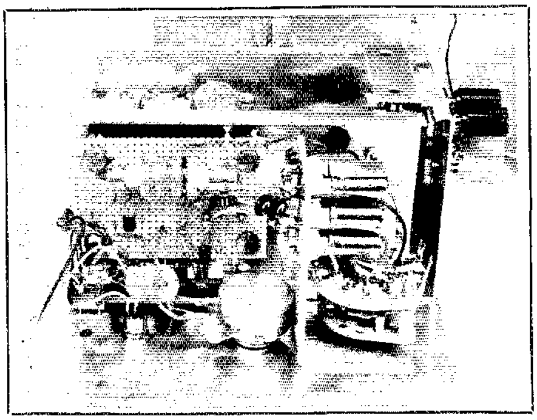


Fig. 1 — Resonance curve showing the relationship of Q to relative response and capacitance.



The oscillator compartment is shown at the left. Crystals and range switch are to the right.

- produces a frequency that is known to a high degree of accuracy.
- will not exhibit large frequency changes with time.
- is less sensitive to pulling when the test circuit is tuned.
- is less expensive to build than LC oscillators.
- is easy to get working properly.

A JFET Pierce circuit with diode clamping is used because it is forgiving and does not need a tuned circuit. Separate feedback capacitors are used with each crystal because crystals have "personalities" and require some trimming to obtain a good output waveform at a given output voltage. In my unit, the high-frequency crystal has a good waveform and

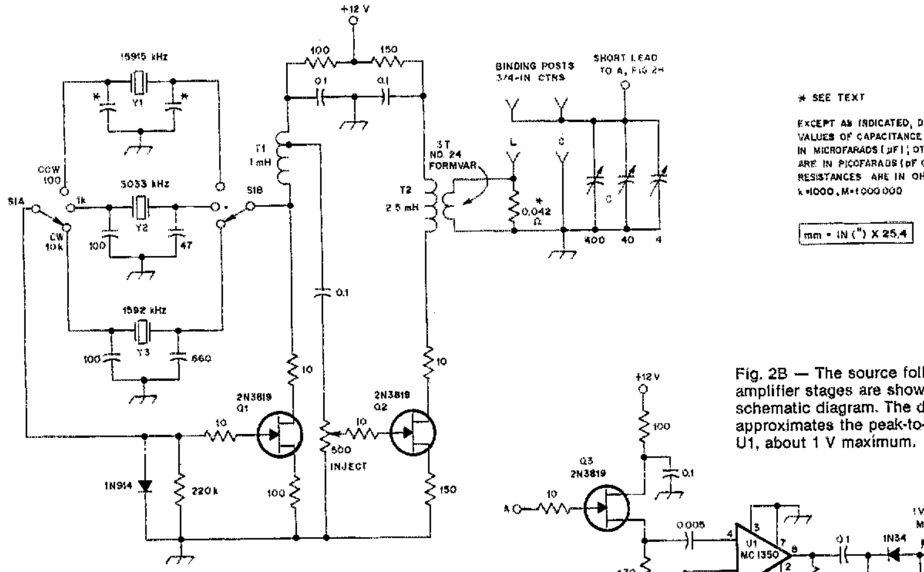
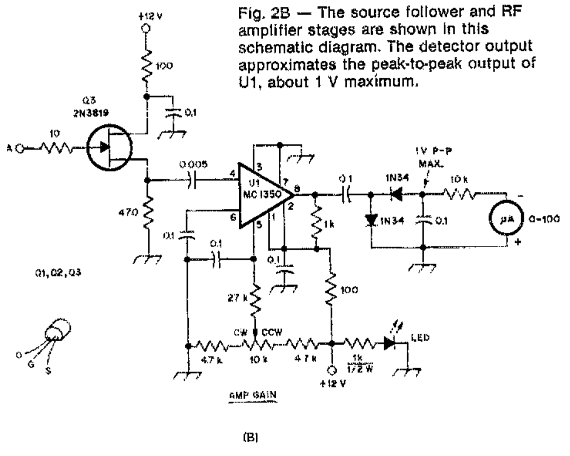


Fig. 2A — Y1-Y3, incl. are HC-6/U-type fundamental-mode crystals having 0.005% tolerance and 32-pF load capacitance ratings. They are available from JAN Crystals, 2400 Crystal Dr., P.O. Box 06017, Fort Meyers, FL 33906-6017. T1 is a three-pie RFC on a ceramic form and is tapped one pie up from the cold end.[4] The tap and lead are reinforced by filling the space between the adjacent pies with quick-setting epoxy. T1 and T2 should be kept separated from each other and preferably be at right angles to one another. T2 is a four-pie RFC on a ceramic form. The secondary winding is placed in the space above the first pie from the cold end of the choke. Anchor the secondary winding with epoxy cement. Q1-Q3, incl., are Radio Shack 276-2035 N-channel FETs.

Fig. 2B — The source follower and RF amplifier stages are shown in this schematic diagram. The detector output approximates the peak-to-peak output of U1, about 1 V maximum.



reasonable output without the aid of additional capacitors. So, I trimmed the other two crystals to provide the same output voltage and waveform. Different oscillators and crystals will require somewhat different values of capacitance. A high-frequency scope is required to properly perform this trimming. The unbypassed source resistor improves the waveform. Output is taken from a tap on the drain RF choke. Assuming unity coupling in the choke, the 500-ohm INJECT potentiometer reflects as 4.5 kΩ at the drain, which is a reasonable load for the oscillator. The low-resistance potentiometer is required to minimize capacitance effects at the high frequencies employed here.

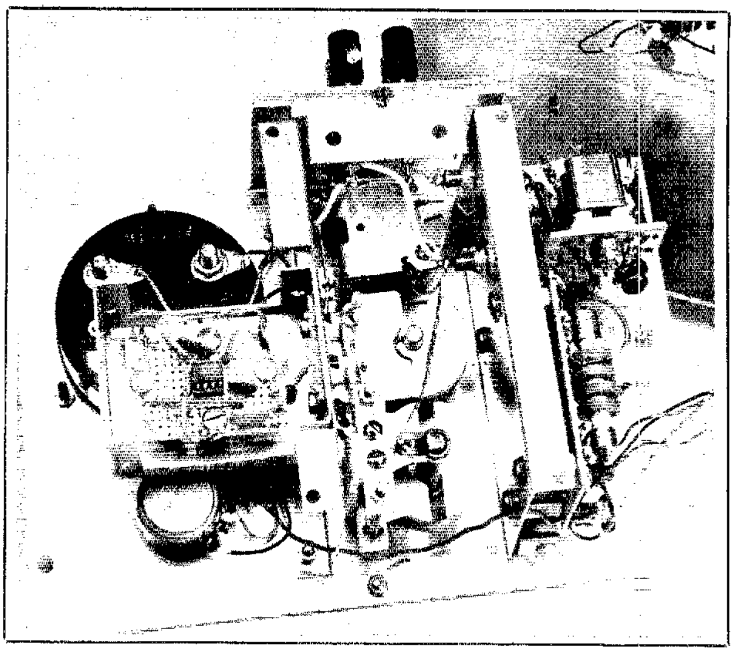
Buffer Q2 is another JFET with an RF choke serving as an untuned output transformer. The three-turn secondary provides a low output impedance suitable for driving the injection resistance. This choke should differ in value from that of the oscillator choke to discourage spurious oscillations. An unbypassed source resistor reduces waveform distortion.

The test circuit components are shielded from the oscillator so that coupling is restricted to the 0.042-ohm injection resistor. This resistor must be small in value compared to the smallest series resistance expected in the unknown coils; otherwise, it will degrade the coil Q. I use a straight piece of no. 36 wire about 1-3/16 inches long.[2] Its exact resistance does not matter, and long-term drift in its value will not affect the measurement accuracy. The variable capacitors are placed as close together as possible, and wired with the shortest and heaviest-gauge wire that is mechanically usable. This minimizes the residual inductance. More about that later.

The amplifier is thoroughly shielded and decoupled from the oscillator and the test circuit because any signal arriving from a source other than the hot side of the coil will produce errors. It is placed in its own shield box on the far side of the shield partition. The gate lead to the JFET source follower is short and has low capacitance to ground to minimize the capacitive load presented by the amplifier. A JFET is used in lieu of a MOSFET because it has lower input capacitance and nearly as high an input resistance. More importantly, it is not subject to gate failure created by the inevitable transients produced during testing. To maximize the input impedance, no gate resistor is used. The gate return is through the test coil. For this reason, power should be applied only when a coil is connected in the circuit.

The RF amplifier, U1, is an IC designed for AGC-controlled IF amplifiers. Its gain is adjustable over a wide range by means of a panel-mounted potentiometer. The meter is driven by a simple rectifier/filter using germanium diodes (silicon diodes are not as linear at low signal levels).

An IC-regulated, 12-V power supply is built on the inside of the back cover plate. It is controlled by a toggle switch on the front panel. An LED connected to the 12-V bus serves as an on/off indicator. The cabinet is of unfinished aluminum measuring 5 × 6 × 9 inches (HWD).



All shield covers have been removed for this photo. The meter amplifier is at the left, the calibrated tuning capacitors are in the center, and the oscillator section is on the right. Note that the meter amplifier is enclosed in a small aluminum box. A shield plate covers the rear of the variable capacitor compartment when the unit is assembled.

Calibration

The variable capacitors must be provided with dials having skirts that allow hand calibration. I made skirts by shearing 1½-inch holes in thin aluminum with a punch. The cutouts were flattened in a vise, and the edges were smoothed with a file. Manila folder paper is glued to the skirts, which are then epoxied to the knobs. Calibration is performed using a CMO operating on 160 meters.[3] A 10-pF capacitor is used to simulate the input capacitance of the source follower. The smaller capacitors are set at minimum capacitance and labeled zero at the proper location. Their minimum capacitance is charged against the main capacitor; their calibration is in added capacitance. Calibration marks are made directly on the manila-covered skirts, then transferred to typewriter paper. These second scales may then be labeled and glued in position on the skirts. The index marks are placed on the left side because the dials are stacked closely in the vertical direction. Such placement provides more room for labeling.

Operation

For all measurements, a coil is connected to the binding posts *before* the instrument is energized, and removed *after* it is turned off. This is because the source-follower gate return is through the coil. Meter transients will occur if power is applied before the coil is connected.

For inductance measurements, the RANGE switch is set for the estimated inductance. The INJECT control and the amplifier GAIN are set at midrange, and the coil is resonated using the largest capacitor. The INJECT and GAIN controls are adjusted to keep the meter on scale. Exact peaking is done more easily with one of the smaller capacitors, depending on the inductance and Q of the coil. The inductance in μH is equal to the RANGE switch reading divided by the sum of the capacitance readings in pF.

For Q measurement, the meter reading is maximized by using the variable capacitors, then set to full scale by the INJECT and GAIN controls. (The amplifier must be linear; for this reason, it is wise to keep the injection level low.) The circuit is then detuned to 70.7% of the response on the high-C side of resonance, and the total capacitance, C2, is noted. Then, the

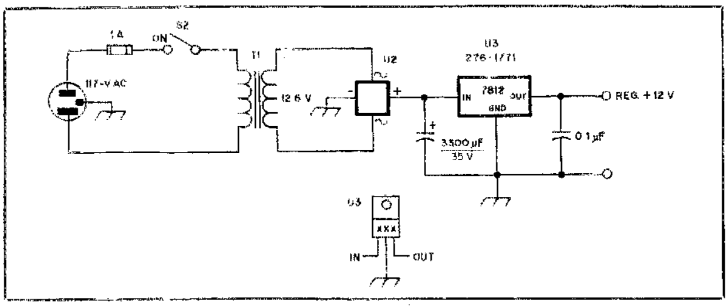


Fig. 3 — Schematic diagram of the built-in, IC-regulated 12-V supply. Power transformer T1 has a 117-V primary and a 12.6-V/300-mA secondary (273-1385). U2 is a 1.4-A/100 PIV bridge rectifier (276-1152), and U3 is a 7812 regulator IC (276-1771). Part numbers in parentheses are Radio Shack. The input and output capacitors for the regulator should be placed as close as possible to the IC using minimum lead lengths.

circuit is detuned to the 70.7% point on the low-C side, and the total capacitance, C1, is recorded. The Q is the ratio of the sum to the difference of the values as shown in Fig. 1. Capacitance is measured by the substitution method explained earlier.

Accuracy

Measurement accuracy depends on the tolerance of the capacitance standards employed. I used 100-pF, 5-% silver-mica capacitors for reference. As explained in note 1, apparent L (which, for reasonably good coils, is close to true L) is measured. Corrections may be made if better accuracy is desired. The same is true for Q. In the case of very good coils, the Q measurement will not be highly accurate because C2 – C1 may be less than 1 pF, which is difficult to interpolate. A fourth variable capacitor with a range of 0.4 pF might be used to cover such situations.

In the 100 RANGE position, a correction for residual inductance should be made. In my unit, the residual inductance measures 0.114 µH. This is simply subtracted from the value obtained with the Q meter. The residual inductance will vary with the components and wiring used, so it must be measured. To do this, shunt the L terminals with the shortest possible piece of no. 14 wire and add external capacitance to the C terminals. These capacitors should have the shortest leads possible, and the leads should be of heavy gauge wire to minimize inductance. When resonance is achieved, the residual inductance (in µH) is found by dividing 100 by the sum of the capacitance (in pF).

Discussion

Coil Q determines the maximum selectivity of any passive tuned circuit in which the coil is used. Thus:

$$B = \frac{f_o}{Q} \qquad \text{(Eq. 2)}$$

where

B = the half-power bandwidth

f_o = the resonant frequency.

Q also enters into the expression for the equivalent parallel resistance of a parallel resonant circuit since

$$R_p = Q\,\omega_o L = \frac{Q}{\omega_o C} = QX \qquad \text{(Eq. 3)}$$

In many cases, the desired operating Q may be lower than the unloaded Q of the coil. The operating Q may be lowered by adding resistors in series, or in parallel, with the coil. Knowledge of the coil Q is necessary to calculate the values of these resistors, however. Since the operating Q may never exceed the coil Q, high-Q coils are desired for flexibility.

As a practical matter, the Q in many cases need not be known to great accuracy, but its general order of magnitude is required. The problem arises frequently where a "junk box" coil with a slug or toroidal core is considered for use at a particular frequency. The Q meter will determine the inductance easily and accurately. If the Q is 30 or more, the coil will be suitable for most purposes. The Q meter is also an accurate and easily used capacitance meter for values below 400 pF.

There you have it. This simple instrument will measure Q, L and C over the range of values commonly used at frequencies from 160 to 10 meters. It is easy to build and use, and should prove to be a reliable instrument. No bench should be without one. I'd like to thank Dick Schellenbach, W1JF, for many helpful discussions throughout the course of this project.

Notes

[1] Terman and Pettit, *Electronic Measurements*, 2nd ed. (New York: McGraw-Hill, 1952), p. 96.

[2] mm = in × 25.4.

[3] F. Noble, "CMO — A Capacitance Measuring Oscillator," *QST*, Aug. 1979, p. 38; Sept. 1979, p. 23.

[4] A pie (or pi) is one of several pie-shaped coils spaced along a single core or form and connected in series to form a larger inductor. QST

Strays

QEX: THE ARRL EXPERIMENTERS' EXCHANGE

☐ Wonder what you've been missing by not subscribing to *QEX*, the ARRL newsletter for experimenters? Among the features in the April issue were:

- "A Wide-Band Instrument Amplifier," by Clint Bowman, W9GLW
- "A Practical Digital Control Unit for the ICOM 720A," by Bob Young, VK4BRY (a *RADCOM* reprint)
- "AMTOR in Australia," by S. E. Molen, VK2SG

QEX is edited by Paul Rinaldo, W4RI, and is published monthly. The special subscription rate for ARRL members is $6 for 12 issues; for nonmembers, $12. There are additional postage surcharges for mailing outside the U.S.; write to Headquarters for details.

CALL FOR *QST* TECHNICAL ARTICLES

☐ Optical fibers are being put to ever-increasing application daily. What do you know about fiber optics? Have you used them in an Amateur Radio-related area? If so, share your experiences and expertise with other readers of *QST*. We're always looking for good technical articles. Your ideas and work in such areas of experimentation are of interest.

Submit a short summary or outline to Paul Rinaldo, W4RI, Manager, Technical Department, ARRL, 225 Main St., Newington, CT 06111. — *Paul K. Pagel, N1FB, Assistant Technical Editor*

I would like to get in touch with...

☐ anyone who has service manuals for the Yaesu FL-101 transmitter and the FR-101S receiver. John J. Slaveter, KA2TFA, 1681 Blue Jay La., Cherry Hill, NJ 08003.

Next Month in QST

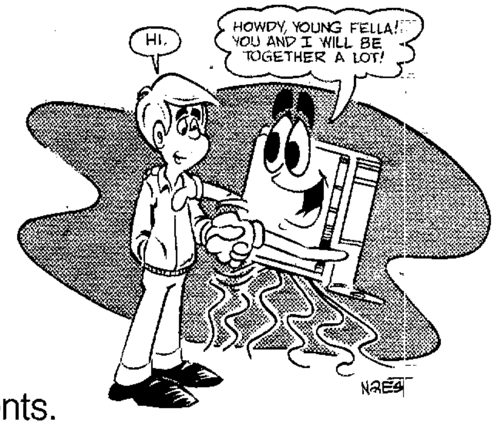
There's always lots to do in June: make final adjustments to the antenna system replacing the one that blew down during that March storm, get ready for Field Day and the VHF QSO Party, and enjoying those long, warm days.

One way to enjoy yourself, in a hammock or elsewhere, is to absorb the contents of *QST*, which will include:

- tips on operating from overseas
- an easy-to-build 20-meter antenna project that's just the ticket for Field Day
- a simple computer-interface project for the IC-720
- results of the latest Simulated Emergency Test

• *First Steps In Radio*

An Introduction to Coils and Transformers



Part 5: This time, we'll take a look at two useful and common components. Coils are simply turns of wire wrapped around a form, while transformers change (transform) a voltage. What could be simpler?

By Doug DeMaw,* W1FB

Can we get by without coils and transformers in our Amateur Radio pastime? If we worked only with logic circuits and audio amplifiers, the answer might be "yes." But receivers, transmitters, antenna systems and most power supplies require some type of transformer and/or coil. Let's look at how coils and transformers fit into the overall scheme of things.

Meet the Coil

A fancier name for a coil is *inductor*. Each coil, depending on its diameter and the number of conductor turns it uses, has a property known as inductance. Inductance is defined as the "property of an electric circuit by virtue of which a varying current induces an electromotive force in that circuit or in a neighboring circuit."

The basic unit of inductance is the henry, abbreviated H. Our radio math can be carried out much more conveniently if we work with small fractions of the henry, such as the millihenry (mH) or microhenry (μH). A mH is 1/1000 of a henry, or 10^{-3} henry. A μH is 10^{-6} henry and a nanohenry (nH) is 10^{-9} henry. Inductance values of 1 H or greater are common only in audio and power-supply circuits. It is important to familiarize yourself with these various expressions of the henry, since you will encounter them often.

Types of Coils

Most of the large coils are wound on insulating cylindrical forms. Some are self-supporting, or "air wound." Generally, the conductor is large-diameter copper wire, but some very large coils are fashioned from copper tubing. Large conductors are needed to create a self-supporting coil. Other large coils are semi air wound; that is, they have high-grade insulating material in the form of ribs that are spaced 90 degrees apart, parallel to the axis of the coil. The coil turns are essentially air wound between the four ribs (see Fig. 1). Two

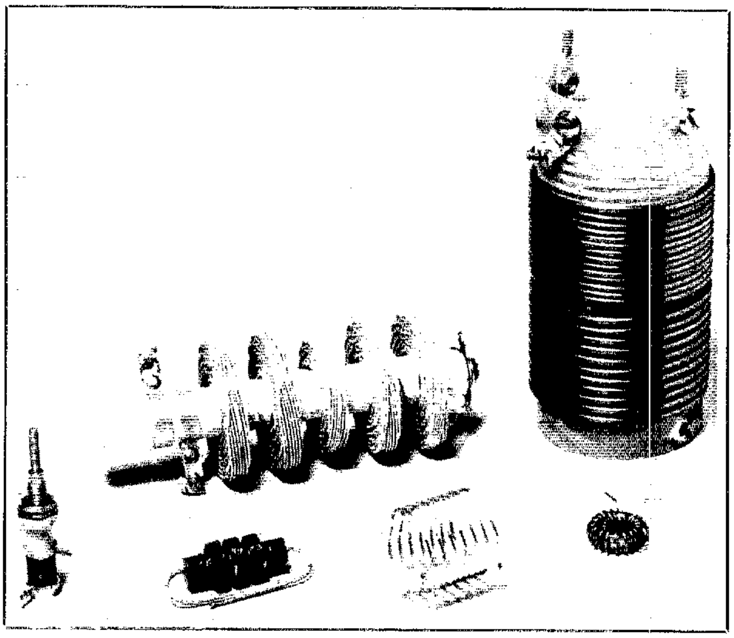


Fig. 1 — A variety of coils. Clockwise, from the left, are: a slug-tuned coil with the adjustment screw visible at its top, a high-power RF choke for transmitters, a homemade coil wound on a cylindrical insulating form, a small toroidal coil, an air-wound Miniductor coil and a small RF choke.

*ARRL Contributing Editor, P.O. Box 250, Luther, MI 49656

firms make coils of this type (Barker & Williamson Miniductors® and Poly Coils Co.).

Most of the smaller coils we will use are wound on some type of insulating form, and the wire gauge is small — usually no. 20 to, say, no. 40 gauge. Small coils are suitable in low-power circuits, but large air-wound inductors are the rule when working with high power. Today's miniature coils are wound on high-quality plastic, ceramic or phenolic forms. The coils may have only a single layer (solenoidal) of wire, or many layers may be stacked atop one another to obtain high values of inductance. The wire used in these little coils must be insulated to prevent the turns from shorting to the adjacent ones. Most large air-wound coils use bare wire for the conductors.

Another common style of inductor is the toroid. The coil is wound on a toroidal core, which is doughnut-shaped. Fig. 1 shows such a coil. The toroidal core may be made from ferrite or powdered-iron material. The exact nature of the particular core (there are many types) will determine the final inductance value for a given number of turns. This magnetic core material will always yield a higher-inductance coil than we would obtain when using an equal number of turns on a standard insulating form, or if our coil happened to be an air-wound type.

Similarly, many small coils contain a movable iron or ferrite core (slug). The slug provides a range of inductance for a specified number of turns of wire. These slug-tuned inductors are very convenient when we need to adjust the inductance for a critical value in our circuits. You will often hear an amateur say that he or she "tweaked" a circuit for correct performance. Generally, this means that the ham adjusted the slug in a coil, or perhaps adjusted a trimmer capacitor.

Some adjustable coils contain brass slugs. These are used chiefly at very high frequencies (VHF). The brass core has the opposite effect of powdered iron or ferrite: it *decreases* the inductance of a coil.

We should be aware that there is also a style of coil contained within an enclosure made from ferrite material. The coil is wound on an insulating form or bobbin, and the halves of the core material are bolted together (or cemented) over the bobbin. These units are called *cup cores* or *pot cores* (see Fig. 2). The core halves increase the coil inductance, just as an iron or ferrite slug does in a slug-tuned coil. The advantage of the pot-core inductor (or transformer) is that the outer shell provides a shield, just as would be true if a plain coil was mounted within a metal enclosure. The shielding is helpful when we want to isolate our coil from adjacent circuit elements.

No matter what form a single inductor has, it is a coil. You will hear about radio-frequency (RF) chokes. They are simply coils used for a specific purpose. You may also hear of coils being called *reactors*. In essence, these terms indicate that we're using the "same players in different games."

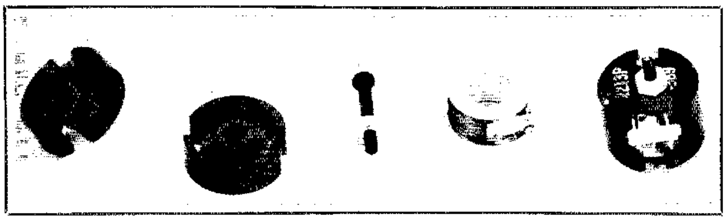


Fig. 2 — A pot-core or cup-core assembly. To the left is a break-down view of the core halves and the insulating bobbin that contains the coil winding. The unit at the right is a completed pot-core coil with the core halves bolted together.

Some Common Coil Applications

First, let's look at the coil symbols we are going to find in schematic diagrams. Memorize these, for you will be using them many times. The common designations are given in Fig. 3.

Thus far we've talked a lot about coils, but haven't shown examples of their use. Let's contrive an imaginary circuit for the purpose of illustration. Fig. 4 shows a suitable example in schematic form. Here we have a two-stage transistorized code transmitter. Q1 is the oscillator, and it creates our signal when the telegraph key is closed at J1. Y1 is the quartz crystal that determines our transmitter frequency. In the collector circuit of Q1, we find an RF choke (a coil) labeled RFC1. All coils are for use in alternating-current (ac) circuits: Remember that radio-frequency (RF) energy is also a form of ac. There is no such thing as a direct-current (dc) transformer. So, RFC1 is used in Fig. 4 to permit the flow of dc to the collector of Q1 while preventing, or choking, the flow of RF energy back into the +12-V voltage line. The RF choke has a value of 1 mH.

If we look to the right in Fig. 4, we will note another coil, L1. It is used to tune the output of the crystal-oscillator stage to the frequency of the crystal — 3.7 MHz. C1 is used with L1 to achieve this requirement. When the combination of C1 and L1 is tuned to 3.7 MHz, we have what is known as a *resonant* circuit, or we might say the circuit is tuned to *resonance*. We can see

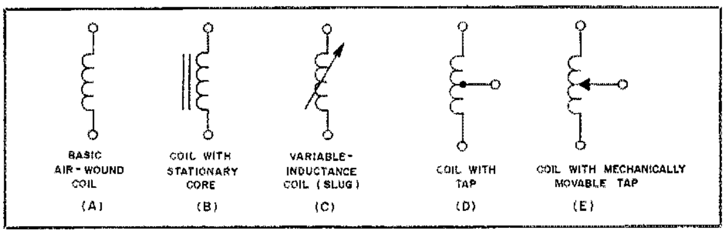


Fig. 3 — Various common symbols for coils. The example at E is for a coil with manual taps such as terminals and clip leads, or a coil with a movable contact, such as a roller inductor has.

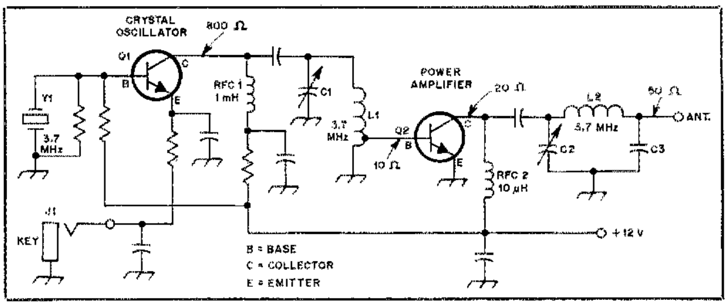


Fig. 4 — Circuit example of a transmitter that uses four styles of coil. See text for details.

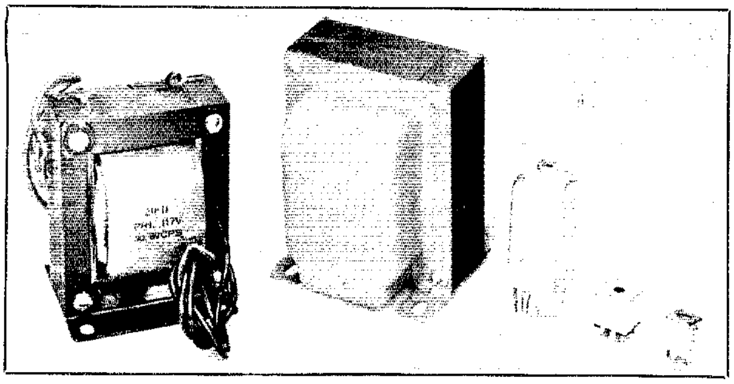


Fig. 5 — Various transformers. The one at the left is called an "open frame" or unshielded type. Next is a shielded power transformer, which is enclosed in a metal shell or case. To the right of this transformer are three styles of shielded RF transformers for use in transmitters or receivers.

that L1 serves a different purpose than does RFC1, but both are coils. L1 must have a specific value of inductance, and C1 must be set for a particular capacitance value in order to tune the circuit to 3.7 MHz. Not just any coil and capacitor combination can provide the desired resonance.

Moving to the right of our diagram once more, observe the placement of RFC2. It functions in a like manner to RFC1 — keeping the RF energy where we want it to be while permitting dc to reach the collector of Q2. In this example, we have an RF choke in the microhenry (μH) range. The reason for RFC2 having much less inductance than RFC1 is not important now. Later in our beginner's course we will learn more about such matters. You will recall that 10 μH is 1/100th of a millihenry (mH).

At the far right in Fig. 4 we have L2. It is a coil also, but in this application it serves two purposes: It is tuned to resonance by means of C2 while acting as an impedance-matching network. Our circuit example shows that the collector of Q2 looks like 20 ohms to the circuit that follows it. But, the antenna presents a 50-ohm impedance. If we are to have maximum power transfer from Q2 to the antenna, we must match the impedances of the two devices. By selecting the proper values for C2, C3 and L2 we can reach this goal.

So, we have seen three important uses for coils in Fig. 4. I should mention also that the tap on L1 (near ground) is selected to provide another impedance match. This time, we are matching the 800-ohm collector of Q1 to the 10-ohm base of Q2. The coil, L1, actually functions as a transformer under such a condition. The impedances presented by the various elements of a transistor are determined for the most part by the operating voltage and current common to the transistor. The values listed in Fig. 4 are by no means specific.

Enter the World of Transformers

From a physical point of view, a transformer is simply two or more coils wound on a magnetic core. The word "transformer" means the component can be used to transform one ac voltage to another (higher or lower than the source voltage). It also is used to transform one impedance to another, or to match unlike impedances.

A specific definition of a transformer is "a device consisting of a winding with tap or taps, or two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits." Transformers that have no magnetic core material are used at radio frequencies, but many RF transformers do contain core material. Conversely, coreless transformers are not suitable for use at audio frequencies and lower. Fig. 5 shows a variety of transformers as assembled units. The larger the size, the greater the power-handling ability of the device.

Transformer Applications

I'm sure you are aware of the large transformers found on utility-company poles throughout your area. These "pole pigs," as some amateurs call them, are used to reduce the potential on the power line before it is routed to the consumer. The power lines that crisscross the country carry thousands of volts. It would be unsafe and impractical to route so high a potential into our homes. Therefore, the existing power-line voltage is dropped to 234 V for entry into our homes.

You will also find power transformers in your TV set, hi-fi gear and ham radio equipment. These are used in the equipment power supplies to change the 117-V ac-line level to some higher or lower voltage. The voltage chosen depends on the requirements of your equipment. After the voltage is lowered or raised by the transformer, it is converted to dc voltage by means of *rectifiers* (usually semiconductor diodes). Then, the not-so-pure dc voltage is filtered to remove any ac energy that may still be present after rectification.

Various types of transformers are shown schematically in Fig. 6. Illustration A shows the basic arrangement for a transformer that has two windings — a primary and a secondary, as we call them. The two parallel lines between the windings signify that a magnetic core exists. It might be made of iron, powdered iron or ferrite material, depending on the application. Voltage is specified in Fig. 6 as E, and it can be of any frequency in the ac range. The proper core material must be used for the frequency of operation if the transformer is to function correctly, however.

Next, let's consider the transformer of Fig. 6B. It is similar to the one shown at A, except that it steps down the voltage we might apply to the primary winding. The ratio of the turns of the windings determines what the transformer output voltage will be. The smaller the number of secondary turns, the lower the output voltage.

Fig. 6C shows a transformer with a number of taps on the secondary winding. Under this arrangement, we may have a variety of secondary voltages available. The location of the tap, respective to the number of turns for both windings, will determine the output voltage. Fig. 6E shows a unit that can achieve the same results, except that separate windings are used to obtain the different output voltages.

At Fig. 6D we have a tuned transformer. This is a common type that we will encounter in working with RF circuits. Because the transformer primary winding and capacitor C form a resonant circuit at a desired frequency, we are actually dealing with what is called a *narrow-band* transformer. Untuned transformers respond to a broad range of frequencies, so they are known as *broadband transformers*. The core material in the transformer of Fig. 6D is adjustable within the coil winding. This slug enables us to tune the transformer precisely to the operating frequency. For RF work, the core will be made of powdered iron or ferrite.

Finally, we see an audio transformer at Fig. 6F. It is similar to the transformers shown at A and B, except that we have a center tap in the primary winding. This allows us to provide what is known as "push-pull" operation for the two output tubes or transistors in the audio amplifier. In other words, we will achieve a desired balanced condition for the amplifier devices.

Audio transformers are used also to ensure an impedance match between the amplifier output and the load, which in our example is an 8-ohm speaker. The impedance transformation is related to the turns ratio of the windings. It is the square of the turns ratio. Hence, a turns ratio of 3:1 will yield an impedance ratio of 9:1. Conversely, a 12:1 impedance ratio will be

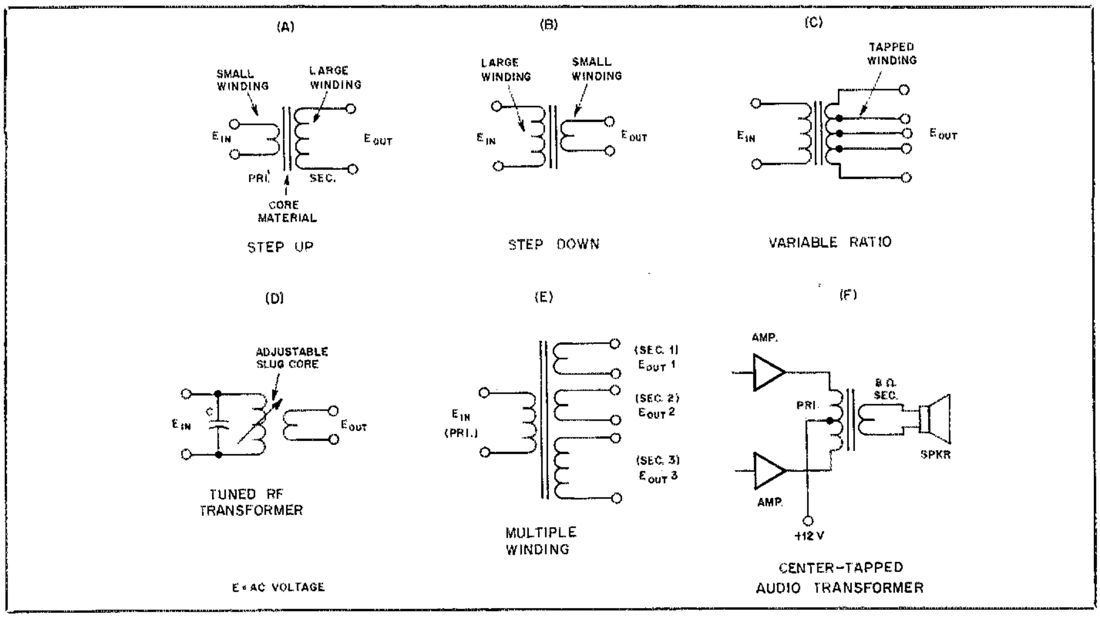


Fig. 6 — Schematic representations of a number of common transformers. These are discussed in the text.

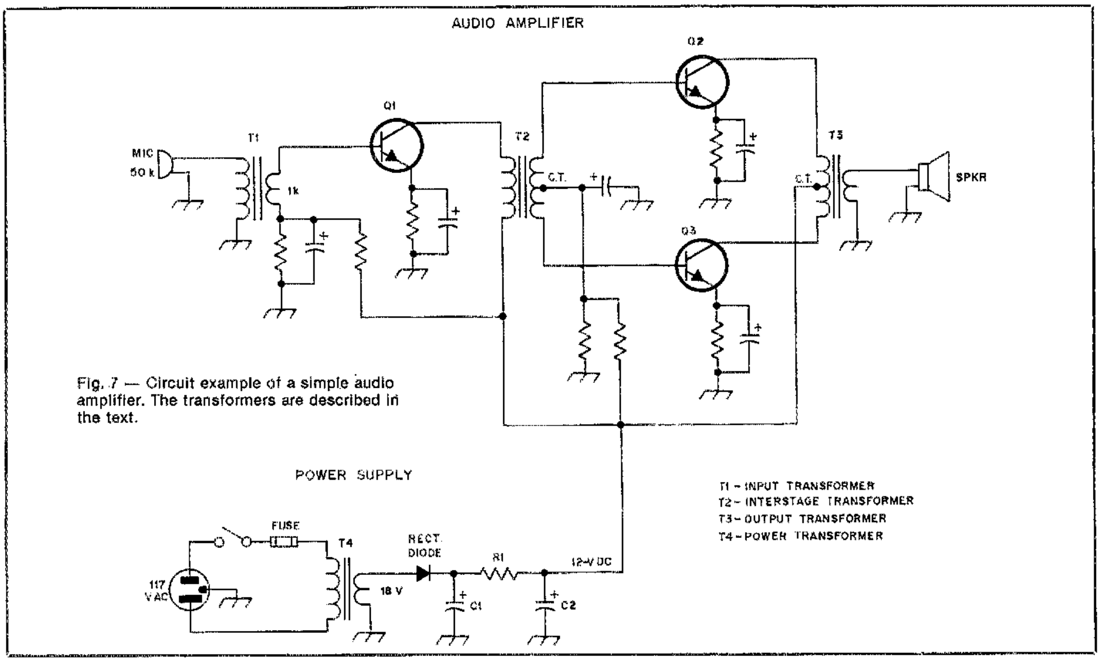


Fig. 7 — Circuit example of a simple audio amplifier. The transformers are described in the text.

had when the turns ratio is 3.46:1. The transformer voltage ratio, however, is the same as the turns ratio. Memorize these facts for later use.

Fig. 7 shows a hypothetical audio-amplifier circuit in which some transformers are used. You will note that we have a power supply in our circuit. It also uses a transformer, T4. It steps the voltage down from 117 to a more manageable 18. The diode rectifier converts the ac voltage to dc voltage. The remaining unwanted ac energy is filtered out of the +12-V line by means of C1, C2 and R1. T4 also isolates us from the 117-V wall *outlet, helping* to prevent shock hazards.

Transformer T1 is used to match the high impedance of our microphone to the low impedance of the Q1 transistor input. So, we can think of T1 as a matching transformer, or an input matching transformer. T2, on the other hand, is an interstage transformer with a center-tapped secondary winding. The split winding enables us to supply audio energy in push-pull (balanced) to the push-pull output transistors. It can be used also to match the output impedance of Q1 to the input impedance of Q2 and Q3 if the proper turns ratio is chosen.

The output transformer, T3, functions as does the example of Fig. 6F, which we have already discussed. We have not assigned parts values to any of the circuit components, since this is purely an imaginary circuit. In reality, most modern audio amplifiers that use transistors do not employ audio transformers, but they were standard fare in the vacuum-tube days and during the early days of transistors.

Glossary

henry — basic unit of inductance. Abbreviations are H: henry; mH: millihenry; μH: microhenry; nH: nanohenry.
inductance — a property of an electric circuit by which voltage is induced in it by varying current in the circuit itself or a neighboring circuit.
inductor — a coil or transformer winding, with or without a magnetic core, for introducing inductance into an electric circuit.
magnetic core — one of various materials, such as iron, brass, powdered iron or ferrite, contained within a coil or transformer winding to increase the inductance over that which would exist with no core material. It concentrates an induced magnetic field in a transformer or coil.
potential — the relative voltage or voltage level in an electric circuit.
reactor — a device used for introducing reactance in a circuit. An inductive reactor, or inductance. Coils and transformer windings exhibit reactance, hence can be referred to as reactors.
rectifier — a device used to convert ac to dc. Semiconductor or tube types of diodes are used for this purpose.
resonance — a point at which a coil and capacitor combination are set for the same or zero reactance at a chosen frequency. A condition under which the coil and capacitor are adjusted so as to be tuned to a specific, chosen frequency. The circuit is then said to be "resonant."
shielding — the use of metal or other conductive material to prevent magnetic or capacitive coupling between circuit elements. A shield is an electrical barrier for ac energy.
signal — ac or dc current varied according to the information it carries.
quartz crystal — a mineral that resonates at a precise frequency according to how it is cut.
toroid — doughnut-shaped device, such as a toroidal core for coils and transformers.

Coil and Transformer Power Capability

The greater the power a transformer must accommodate (watts = E multiplied by I, where E is voltage and I is current), the larger the wire size and the greater the core area. The core material plays an important role in the power rating too, as some materials are more efficient than others. The large wire is needed to reduce the resistance (and heating) of the windings. Also, the greater the winding resistance, the higher the transformer losses. An ideal transformer would be cool to the touch after many hours of operation, but this is seldom the case. Most transformers in power supplies are warm or quite warm to the touch after they have been on for a period of time. This heat causes wasted power and reduced efficiency.

Coils that must handle RF power also can become warm. To reduce resistive losses, it is wise to use large-diameter wire for such coils. High-quality insulation should always be used in coils and transformers to prevent arcing between the windings, and to minimize losses.

Let's Summarize

What have we learned? First, that coils can take many shapes. They can be built for fixed values of inductance, or they can be made variable by using a movable slug inside them. They are used in all manner of radio circuits and at many power levels. Coils are also known as inductors, and they may be wound on magnetic cores or can be built as "air-wound" units with no core.

Transformers are used from the power-line frequencies (50 or 60 Hz), through audio frequencies, and into the high RF range. They can be narrow band or broadband, and they may also have cores or no cores. They are used not only to step up or step down a specific voltage level, but may serve as impedance-matching devices between components of unlike characteristics. The impedance ratio of transformers is the square of the voltage or turns ratio and vice versa.

Coils and transformers are among the common radio parts we will be working with during our amateur careers. Detailed information about them can be found in the *Radio Amateur's Handbook* and other ARRL books.

Next, we'll take a look at still another electronics component. See you then.

New Books

ELECTRONIC PROTOTYPE CONSTRUCTION
by Stephen D. Kasten

Published by Howard W. Sams and Co., Inc., Indianapolis, IN. First edition, 1983. Soft-bound, 5-3/8 × 8-1/2 inches, 398 pp. including appendixes and index, $17.95.

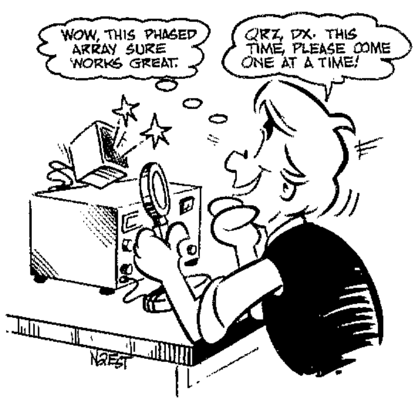
A bit of the author's background may help explain what to expect from this book. Steve Kasten is a professional chemist who is experienced in the use of computers in laboratory automation. He's presently working on the development and application of computer models for various chemical processes. His interests include certain computer systems and their interface circuits.

This text clearly shows Steve is no stranger to a workbench. The 11 chapters of this book are packed with illustrated information covering wire-wrapping; printed-circuit technology; PC-board design, layout and artwork; photography; photo-resist techniques and PC-board etching. Other subjects include electroplating and coating, screen printing, PC-board machining, soldering and assembly, the construction of high-density PC boards, and electronic systems packaging. The author covers each subject in good detail. No matter how much you know about any of the various subjects, you're bound to learn something.

Construction projects include a D/A converter (it will plug into an Apple® II computer), an air-bubble PC-board etching tank (it's made from a plastic ice chest and uses a small laboratory pump, fish-tank aerator or vacuum-cleaner exhaust), a PC-board tab-plating tank and a simple screen-printing frame. There's even a description of the construction of a double-sided PC board from two thin, single-layered PC boards. (That's a method I'd not heard of before.)

If you do any electronic circuit construction at all, you should take a look at this book. Reading it may provide the impetus to get you started on that project you've "been meaning to build, some day." — *Paul K. Pagel, N1FB*

40 Meters with a Phased Delta Loop



Large 40-meter Yagis can set you back a week's salary and take a month to install. A bidirectional, 2-element Delta Loop array provides a better way to snare some DX at modest cost.

By Edward Peter Swynar,* VE3CUI

A station in the U.K. was heard to say, "Forty DX separates the men from the boys." In line with this, it is fortunate for the home-construction crowd that 7 MHz is an area where the mind must often rule over matter! In pursuit of 40-meter DX, some amateurs have embraced the costly "consumer approach." Others have resigned themselves to the likes of the simple and relatively ineffective inverted-V antenna — coupled to the omnipresent kilowatt amplifier. There *is* a better way!

With moderate property dimensions, some trees (perhaps), wire, coaxial cable and a bit of patience, it is possible to build an excellent gain type of array. It can be switched to either of two directions. It is inexpensive and effective for working long-haul DX. I will refer to it as the "2-element, 90-degree-phased Delta Loop."

The Case for Phased Loops

Literature abounds regarding the cardiodal pattern of 2-element 90-degree-phased vertical antennas with 0.25-wavelength spacing. A gain of 3 dB is available over a single 0.25-wavelength vertical element.[1] But, since such an element has a *minus* gain of 1.8 dB over a dipole, one can realize a 1.2-dB gain over a dipole when using two verticals that are phased. The major advantage of the vertical 2-element array is, therefore, the low radiation angle and the directivity (at the expense of many buried copper radials).

With 90°-phased dipoles there is, relatively speaking, more gain and less wire. Again, each dipole element by itself has no gain (using dBd as a reference). Also, this type of array must be fairly high above ground to be an effective DX antenna on 40 meters.

Now, consider the phased Delta Loop arrangement of Fig. 1. By virtue of the feed points on each element, the array is vertically polarized and produces a low angle of radiation, as with the phased vertical system. Furthermore, each loop (by itself) offers a 2-dB gain over a dipole (3.8 dB over a single 0.25-wavelength vertical). Imagine the benefits of two such gain-style loops, positioned properly and driven in combination to enhance the already-existing gain of a single loop element.

Construction

Your specific situation will dictate the precise shape of your loop. Nevertheless, the length of the wire for each element should be taken from the standard loop equation — $L(ft) = 1005/f(MHz)$.[2] I like to add approximately 2 feet of additional wire to facilitate final adjustment for lowest

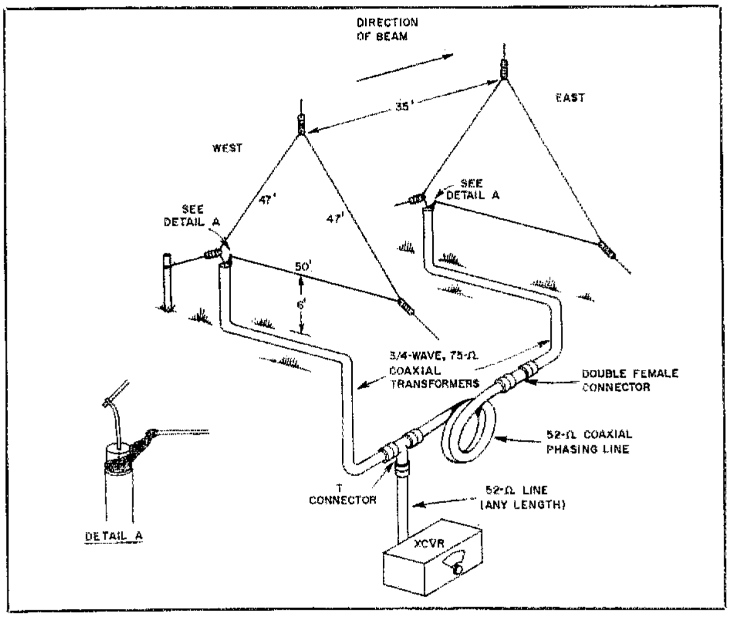


Fig. 1 — Illustration of the final arrangement chosen at VE3CUI for the phased 2-element Delta Loop array. Corner feed, apex up (as shown) yields vertical polarization and a low radiation angle.

[1]Notes appear on page 21.

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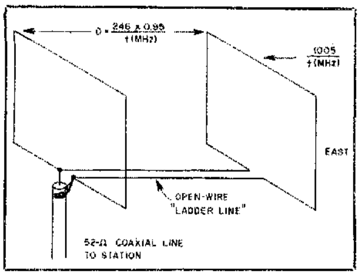


Fig. 2 — Arrangement for the unidirectional loop array that was used first at VE3CUI.

SWR. The element spacing (based on free-space conditions) is obtained from L(ft) = 246/f(MHz).

I first used the feed method seen in Fig. 2. This system has the advantage that use of costly coaxial line is restricted to a single run of 52-ohm cable from the antenna to the ham shack. Also, the balanced phasing line helps to preserve the symmetry of the array. I'm sure this could be improved further by inserting a 1:1 balun transformer at the feed point. The disadvantage of this method is seen when trying to reverse the directivity of the antenna: I must go outside the shack, remove the coaxial feeder from one loop and connect it to the other loop. This is no fun whatsoever when the band is open to two directions at once during a cold January morning!

My present feed system is that of Fig. 1. It is an odd-multiple expansion of the conventional ¼-wave matching transformer, the type used for matching to single loops that are fed with 50-ohm line. I tripled the length of the 75-ohm line section to ¾ wavelength. This was a convenience because of the distance between the shack and the most distant loop. Two equal lengths of 75-ohm coaxial cable are used as transformers (one per loop). The line length is determined by

$$L\ (\text{feet}) = 0.66\left[\frac{246}{f(\text{MHz})}\right] \times 3 \quad (\text{Eq. } 1)$$

when the coaxial cable has solid dielectric rather than foam material. In this case, the velocity factor of the line is 0.66. This factor will be different if you do not use solid-dielectric polyethylene line.

Adjustment

The loops should be adjusted separately for resonance. Attach a 3/4-wavelength transformer to one loop, then connect the free end of the transformer to a random length of 52-ohm line (through an SWR indicator). Attach the remaining end of the 52-ohm cable to your transmitter. While using the least power possible to obtain an SWR-meter indication, adjust the loop length for a 1:1 SWR. *[Safety first! Do not touch a "hot" antenna. Take the rig to the antenna site, or have a friend switch it on and off for you during the tests. — Ed.]*

On completion of this procedure, repeat it with the remaining loop. I do not recommend that you "stagger-tune" the loops in the hope of obtaining increased bandwidth; one loop should be the electrical twin of the other one. I have found, also, that both loops should be the same shape and height above ground, and as perfectly spaced apart as possible. This suggestion may seem extreme, but best results will be had later on if some pains are taken during installation and adjustment.

With the loops installed in their final positions, it is time to add the 52-ohm coaxial phasing section. The length is determined by Eq. 1, but do not multiply by 3, as in the equation, since the line will be an electrical quarter wavelength rather than 0.75 wavelength. This phasing line can be rolled up and taped so that it won't occupy a lot of space in the ham station. This phasing line should be placed in series with the feeder that connects to the loop element that will serve as the *forward* radiator, since it will be the element that will require the 90° lag. The remaining end of the phasing section is connected (by means of a coaxial T connector) to the end of the feeder that goes to the other loop element. The third port of the T connector is used to mate the feed system to the transmitter and receiver via a short run of 52-ohm coaxial cable. Switching of the directivity is done manually in the shack by transposing the ends of the T connector that go to the feed system. Faster switching can be had by using a coaxial relay or manual switching method. For my needs, it was easy to grow used to reversing the two PL-259 plugs by hand.

The layout of my 50- × 80-foot lot is such that the directivity of the array is NNE or SSW. This has been good for DX from Europe and the South Pacific. One loop is held aloft by means of a tall tree. The other loop is supported by my 48-foot tower, and it is spaced 10 feet away from the tower.

The SWR curves differ between "beaming east" and "beaming west." See Fig. 3. I feel that the problem is caused by the aluminum siding on the house, which is close to one of the loops. Despite this annoyance, the system is flat across the part of the band that interests me — the DX segment.

Results

The bulk of my DXing is done at a power level of 500-W dc input. The exception was my first QSO with the antenna, during which I was using 50 W: I received an RST 559 report from 3B8CF on Mauritius Island, despite the pileup bedlam.

The front-to-back ratio of the array appears to be roughly three S units (18 dB) over long DX paths. Over short paths (interstate or interprovince), do not expect much by way of F/B ratio. Close-in contacts will be more satisfactory with a high-angle radiator, such as a single loop from this array, or a dipole, can provide.

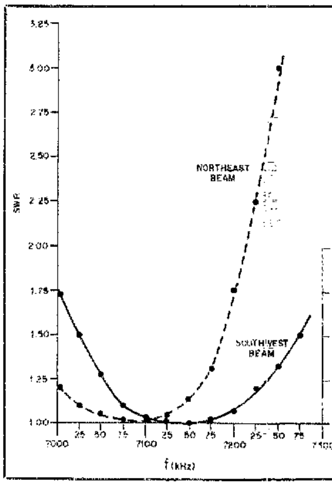


Fig. 3 — SWR curves developed at VE3CUI for the 2-element loop array. Note that the curves show a disparity. This may be the result of one loop being in proximity to the aluminum-sided house.

The phased loops certainly "hear" the signals better than other antennas I have used. Also, I seem to receive longer band openings than with other types of antennas I have used. I have been gratified a number of times by comments such as, "Best signal from North America, OM." I have not made performance comparisons against a reference dipole, but I received the substantially stronger signal report during a four-way DX QSO that included two local hams. One was using an inverted V, and the other had a single Delta Loop. One fellow had a report of "inaudible" (inverted V at 40 feet), and the ham with the Delta Loop was barely discernible in the noise. My report was 5 × 8.

Conclusion

Despite the low antenna height and cramped space, the 2-element phased loop array is a superlative budget-saving performer. I hope some of you will investigate the DX potential of this simple antenna. Certainly, you will experience the same kinds of pleasures I have while chasing DX on 40 meters!

Notes

[1]Gain figures are unproven and are theoretical.
[2]m = ft × 0.3048.

E. P. Swynar, 31, was licensed in 1971. His first ham station was homemade from circuits in the ARRL literature. He has had two antenna articles published in CQ. His major interests in radio are homemade gear and homemade antennas. He has a BA in history and economics, and works as a supervisor in the quality control section of General Motors of Canada, Limited.

Eliminate TVI With Common-Mode Current Controls

Are your TVI-related problems caused by errant common-mode currents? Here's how to keep them in line.

By Richard J. Buchan,* WØTJF

High-frequency currents caused by the switching of electromechanical devices have a devastating effect on other electronic equipment operation unless the currents are properly filtered and controlled. Line-to-line transients are handled easily. Common-mode currents, however, prove to be the real culprits and the most difficult to tame. In this article, I'll show you common-mode control techniques I have learned and successfully applied to eliminate TVI.

I live in a TV-fringe area, 75 miles from the nearest station.[1] The apex of my inverted V antenna is 4 feet from the TV antenna, which is mounted atop the common supporting mast. My TV set is 4 feet from my Amateur Radio station transmitter. Even under these conditions, I have interference-free TV reception while operating my amateur station.

Common-Mode Currents

Common-mode currents can be defined as currents resulting from the difference in magnitude between the outgoing and return currents in a transmission line. In a perfectly balanced line the currents are equal, resulting in total field cancellation and no radiation from the line as indicated by currents A of Fig. 1. Extensive tests with a high-frequency signal generator and a current-probe recorder show that, in virtually every case, an unwanted signal generated on a signal, control, ground or power line results in the major part of the signal becoming common mode in nature. The return path consists of many paths throughout the surrounding area: building wiring, plumbing, heating ducts, telephone lines, etc., shown as currents B of Fig. 1.

Common-mode currents can be described as having these characteristics: (1) They flow in the same direction through all conductors in a cable or transmission line; (2) they can assume many return paths through the universal reference return path; (3) if a wide gap exists between the conductors and the return path, little field cancellation takes place and the line can act as an almost perfect radiator.

The Universal Reference

A universal reference can consist of: (1) a metallic building structure; (2) plumbing and/or drainage systems; (3) earth ground; (4) concrete floors and reinforcements; (5) station ground; (6) signal-control cables; (7) telephone lines; (8) a combination of all of these.

Tests show that evidence of these return paths could be found on almost any metallic piece in a building that the aperture of the probe could be made to surround. It was enlightening (and discouraging) to see and record high-frequency current bursts peaking in the 10-A range with the probe encircling what was considered to be an almost perfect ground conductor! These bursts were usually found to be generated by the turning on and off of electromechanical devices within the building.

Station Ground

A station ground conductor, if of any appreciable length (inches, at the VHF TV channels), *cannot* act as an infinite sink to dissipate unwanted harmonic and parasitic currents. Unless designed as a low-impedance lossy type of conductor, the ground conductor can act almost like a perfect radiator for these currents. A system ground can be analyzed by considering it as a conductor whose termination is a ground, or as a universal return with a very low impedance path approaching zero. Under these conditions, it can be analyzed as a shorted transmission line. The input impedance (Z_s) can be shown as

$$Z_s = Z_0 \cot(\theta K) \qquad \text{(Eq. 1)}$$

where

Z_0 is the characteristic impedance $\sqrt{L/C}$
K is equal to the loss factor
θ is the electrical length of the line

With a line length of ¼ λ or a multiple thereof, and a lossless line (air), the cotangent becomes infinite and the loss factor zero. Under these conditions, a ground conductor can have an input impedance approaching infinity. Not likely? At the upper TV channel (7-13) frequencies, a ¼-λ line is 2½ feet or less. Furthermore, a 0.1-λ cable (approximately 1 foot at the upper channels) can be an efficient radiator. The

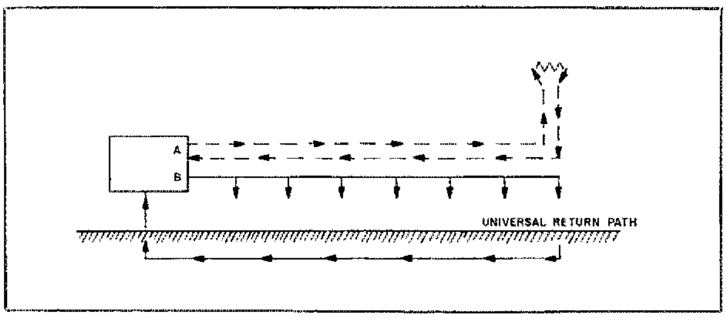


Fig. 1 — Currents A are balanced and exhibit total field cancellation. Currents B are unbalanced (common mode), with respect to a universal return path, and exhibit little field cancellation.

[1]km = mi × 1.609; m = ft × 0.3048; mm = in × 25.4.

*4695 Dodd Rd., St. Paul, MN 55123

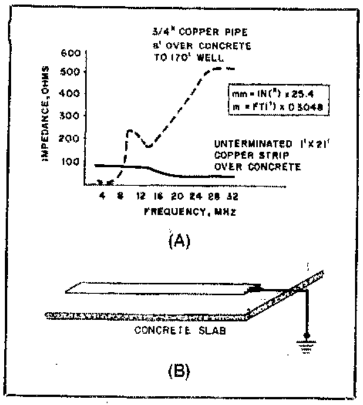


Fig. 2 — At A, a chart showing the high-frequency impedance of ground systems. Terminating the copper strip in an earth ground would improve the low-frequency performance. An example of a strip-line ground is shown at B. A 3-foot-wide conductive strip terminated in a good earth ground will provide an approximate 10-ohm infinite-sink ground from dc through the VHF range. The effectiveness of this copper strip concept is pointed out in "Facility Planning," by David A. Reismah, published in *Datamation*, Nov. 1974.

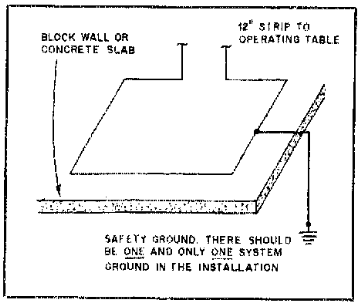


Fig. 3 — A 15-square-foot metallic sheet placed over a lossy dielectric will produce an approximately 10-ohm capacitive shunt to unwanted high-frequency signals.

experimental plot of two ground systems is shown in Fig. 2A. As Eq. 1 shows, if L can be made very low, C very high and K very lossy (high), an almost perfect ground termination can be had. Tests have shown that a 3-foot-wide metallic strip over a concrete base (see Fig. 2B) produces a virtually perfect ground and acts as an infinite sink line with *no* reflections, all unwanted signals being dissipated in the lossy dielectric.

Where a continuous length of copper strip cannot be used, a similar dissipative ground sink can be made with the use of flat copper sheet over a lossy dielectric. The dissipative element is, in fact, a large capacitor using the floor, wall or some other lossy dielectric separating the copper plate from the universal reference (see Fig. 3).

The Low-Pass Filter

Perusing low-pass filter specifications will show that a high degree of attenuation can be obtained over a wide frequency range. You must realize, however, that these figures are a result of laboratory testing under ideal conditions: a matched termination (rarely obtained at the high-frequency ham-band harmonics), and with the filter case mounted on a table with a near-perfect ground sheet. The fundamental design of most (if not all) such filters depends on the ability of high-Q passive elements to shunt the unwanted signals to a dissipative mass in such a manner that practically nothing leaks through. From a line-to-line standpoint, this can be accomplished with a reasonably good installation. With an inadequate or high-Q ground system, however, the common-mode component can flow easily through the return frame and back to the outer coaxial conductor, resulting in the entire transmission line acting as a long-wire radiator (see Fig. 4A). The solution to this problem is to use a large dissipative mass and a routing system that results in a transmission line with a low Z_0 along its entire length as shown in Fig. 4B.

Transmission-Line Radiator

Radiation from an unbalanced line is a function of the height above ground and the line length. If we consider the coaxial line as one conductor and the ground return as the other, and assume under these conditions that it is a two-wire nonresonant line, the radiation from it can be expressed as

$$\frac{\text{Radiated power}}{I^2} = 160\left(\frac{\pi D}{\lambda}\right)^2 \quad \text{(Eq. 2)}$$

where
radiated power = watts
D = spacing in wavelengths
I = RMS line current in amperes

As Eq. 2 shows, large amounts of radiation can take place with a spacing of a fraction of a wavelength, and an almost perfect radiator exists for the common-mode component at ¼ and ½ wavelengths, as shown in Fig. 5. This applies to all conductors, such as power lines, telephone cables, ground conductors and control lines. It also demonstrates why all conductors subject to common-mode pickup *must* be coupled tightly to a lossy mass of some sort so as to minimize the radiation from this loop. This fact also explains why the electronic-packaging engineer will route cables or wires tightly in cabinet corners or close to a ground plane so as to minimize radiation and coupling from the cable.

The Common-Mode Choke

Ferrite cores have made possible the construction of common-mode chokes to control the flow of unbalanced currents. A

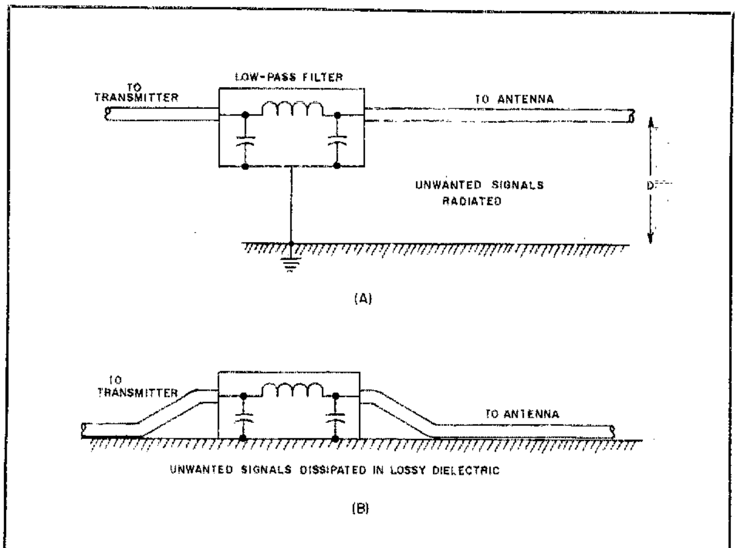


Fig. 4 — At A, lacking a direct dissipative mass, the shunted high-frequency currents will flow along the outer cable and back through the universal reference. With D greater than 0.1 λ, almost perfect radiation will take place. With the case of the filter directly coupled to a large dissipative mass as at B, the unwanted signals are absorbed. Virtually no unwanted radiation takes place.

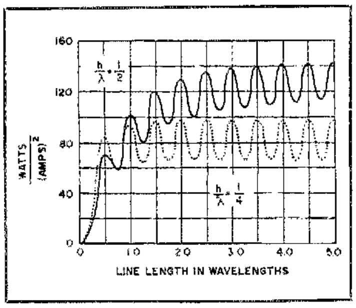


Fig. 5 — Unbalanced currents are much more effective in producing radiation than the normal balanced currents because of the considerable distance between the two sides of the circuit through which the unbalanced currents flow. The amount of radiation depends both on the height of the line above ground and on the line length. The order of magnitude of the factors involved can be estimated using this chart. (Reproduced from *Radio Engineer's Handbook*, by F. E. Terman, first edition, courtesy of McGraw-Hill Book Co.)

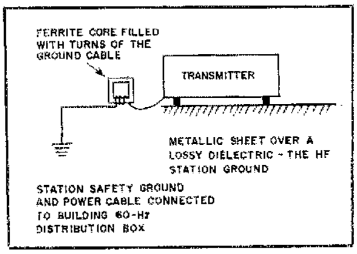


Fig. 6 — The common-mode choke presents a high impedance to high-frequency currents, thus forcing them to be dissipated in the metallic mass and lossy dielectric.

number of cable turns threaded on the core exhibits no attenuation to balanced currents because complete field cancellation takes place. To the unbalanced (common-mode) current, however, a high impedance exists because no field cancellation takes place. This is true because the return current is through the universal reference, which can be far removed from the core.

A typical application is shown in Fig. 6, where the core has been wound with the safety ground conductor to force the dissipation of unwanted currents into the lossy ground mass. These common-mode chokes can be used effectively with speaker leads on audio equipment (see Fig. 7), and power cables used with solid-state devices such as electronic organs, antenna transmission lines and telephone cables. Flyback transformer cores from junked TV sets may be used to wind these chokes.

Current Loops

Current loops can have a devastating effect on TVI control. The most common offender is the use of two ground returns in a system — a safety ground consisting of a third wire in the power cable back to the ac-line entrance box, and a station ground to a water pipe or a metal stake in the ground. The difference in potential between the two grounds, plus the large radiation loop between the two paths, can spell disaster to the best of installations. The solution to this problem is to have the system ground consist of a large dissipative sink for the station ground with *no* current path back to the safety ground.

In cases where interconnecting cables between cabinets are shielded, loops will exist unless the shield is grounded at one end only, which is highly unlikely. The impact of this can be minimized by maintaining a low Z_0 between the shield and the ground mass as shown in Fig. 8. Fig. 9 illustrates a loop that contains a high-Z_0 loop that can radiate, and is the way *not* to do it.

In cases where a ground conductor is contained in a cable to the equipment, this ground must be removed and the case grounded directly to the copper sheet. The metallic sheet, in turn, is connected to the safety ground at the ac-line outlet. Any cabinet in which the safety ground has been disconnected should carry a warning to alert the user that other steps must be taken to assure that the enclosure has a low-impedance metallic circuit to the building ground.

Putting It All Together

To reach the goal of a TVI-free Amateur Radio station, one fact must be recognized: *All* unwanted signals must be dissipated in a manner such that *no* radiation of these signals takes place. This can be accomplished by

1) establishing a lossy ground reference;
2) coupling all equipment directly to this mass;
3) adding a low-pass filter directly coupled to this mass;
4) using a dedicated, filtered ac line;
5) routing all wires to achieve a low Z_0 to a lossy universal reference;
6) having *no* current loops in the system;
7) offering *no* compromises. A few inches of wire can act as a nearly perfect radiator and negate all the techniques applied.

The Lossy Ground Reference

This can be made by covering the operating table top, sides and back with 1-oz copper sheet as shown in Fig. 10. The sheet extends about 12 inches up the back of the table so that it can be folded over the interconnecting wires and cables.

Coupling to the Mass

Copper strips are looped over the four legs of the transmitter. This results in four virtually zero-impedance couplings to the copper sheet. The power supply and other cabinets have no legs, so their metallic bottoms sit directly on the copper sheet. If there is *any* doubt as to safety, solder a safety wire to the sheet.

Adding a Low-Pass Filter

In the example shown, the filter is coupled directly to the copper sheet so as to shunt high-frequency currents into the lossy ground reference. Ideally, this connection should be as close as possible to the transmitter and with the coaxial line input tightly coupled to the ground plane. Common practice is to mount the filter on the back of the transmitter. This approach is acceptable, but there is some risk in shunting the currents back into the device and thus causing a feedback loop. The risk is a function of the equipment design and the filter mounting method employed. This was demonstrated to me when a filter was added to a computer peripheral to prevent its conducted EMI from faulting the system. The equipment faulted under certain operations because of reflected EMI currents.

The Dedicated, Filtered AC Line

This approach has many advantages:

1) It eliminates the common coupling to other circuits in the building.
2) It can be routed so as to achieve a low impedance to the universal reference.
3) It can (and should) include the safety

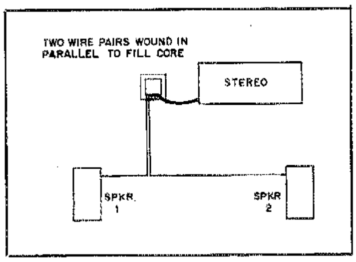


Fig. 7 — The high-impedance common-mode choke prevents high-frequency currents from entering the stereo chassis, thus forcing them to be reradiated or dissipated in the speakers.

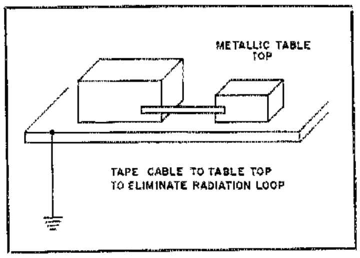


Fig. 8 — Use of a metallic sheet, a single safety ground connection and a loop length confined to inches ensures that little unwanted radiation can take place.

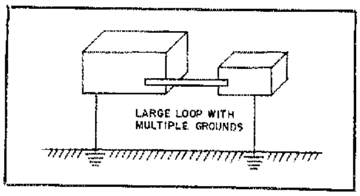


Fig. 9 — Long ground leads combined with high-impedance loops can spell disaster to TVI control.

ground conductor (an electrical code requirement).

A Low Z_0

All wires should be coupled as closely as possible to the lossy reference. Fig. 11 depicts the methods I use. A similar approach is applied to the ac line power and ground conductor, which lies on the ground under my mobile home.

No Current Loops

I use the dual isolated-ground system. The safety ground is the ground conductor in the ac cable; system ground is the lossy copper sheet. There are *no* interconnections between the two systems. Any compromise to this — such as a grounded neutral connection to a box — can create havoc with the TVI control system. On the operating table, current loops will exist as a result of the direct coupling to the copper sheet and the grounded, shielded interconnecting cables. By confining the loop to a low Z_0 (taping the cables to the cabinet wall or the sheet), the radiation loop can be virtually eliminated.

No Compromises

Mobile operation has demonstrated to me that even a small antenna can serve as an efficient radiator. If there ever was a place for Murphy to demonstrate the validity of his famous law, EMI suppression is the place! In my station, several feet of coaxial cable hang in free space. This does not prove to be a problem for a couple of assumed reasons: (1) The filter and low Z_0 up to this point provide sufficient suppression; (2) the several feet exposed are in an area surrounded by lossy material — earth, building wall and floor. There are probably thousands of antenna transmission lines hanging in free space between houses and masts. Hopefully, these stations are in a primary signal area, and the common-mode component is dissipated before it reaches a point where it may become a problem.

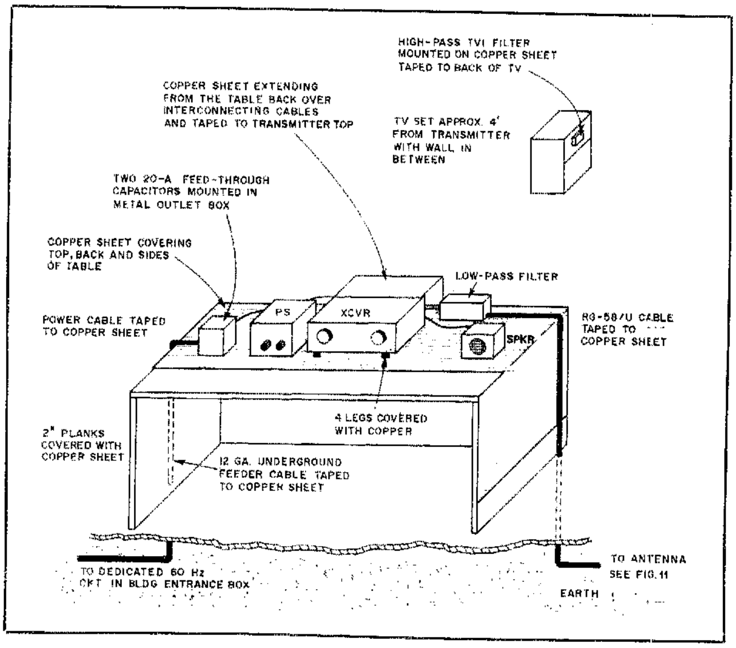


Fig. 10 — A station layout showing the measures taken to dissipate and eliminate radiation from common-mode currents.

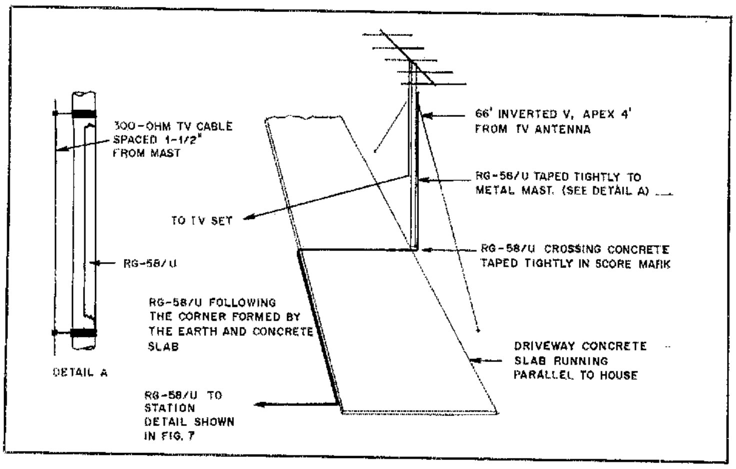


Fig. 11 — With the inverted V serving as guy wires and the coaxial cable taped tightly to the metal mast, the entire setup appears as nothing more than a normal TV antenna installation.

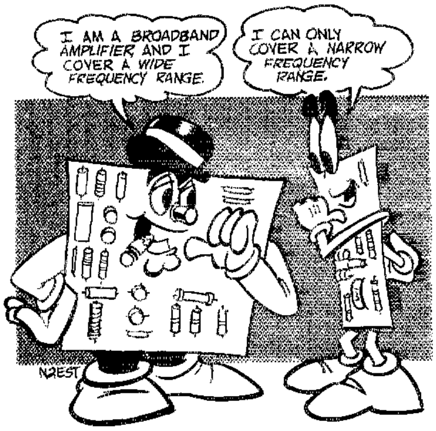
Summary

The TVI-free station depicted here is a result of a challenge — one that resulted from buying a winter residence in a densely populated mobile-home community located in a TV fringe area. This private community is particularly sensitive to any type of radio transmission, and has a population firmly convinced that any type of radio transmission could only result in TVI.

My antenna is camouflaged by using two of the TV-mast guy wires as an inverted V. The station is hidden in a bedroom closet next to the den, where the TV set is located. For several years, an SB-200 amplifier was used. Not a single TVI complaint from neighbors was received; a small amount of interference was noted on the home set, however. During the past several years, the station has been operated without the amplifier. It is indeed rewarding to demonstrate how interference-free television reception can be had while operating on the 40- and 15-meter amateur bands. QST

BEGINNER'S BENCH

Broadband and Narrow-Band Amplifiers



Narrow-band amplifiers have been around for many years, and most hams know how to design them. But, the broadband RF amplifier did not become popular until the semiconductor world bloomed. This article covers some practical aspects of both types.

By Doug DeMaw,* W1FB

Have you wondered what the difference may be between a narrow-band amplifier and a broadband one? Are all broadband amplifiers linear? Must they be linear? These are natural questions in the minds of most beginners to electronics, so we will try to provide simple answers.

If you work with transistors and RF circuits, it is likely that you will need to know something about how a broadband amplifier is designed, what to expect from it and how to build one for the job you have in mind. For the most part, these amplifiers are less prone to self-oscillation than are tuned, narrow-band styles of amplifier. The fundamental thought to keep in mind however, is that we must always trade some overall gain for increased bandwidth. If we can accept that trade-off, the major barrier will have been abolished.

Narrow-Band versus Broadband

The narrow-band amplifiers we use from day to day in our VFOs, receivers, converters and transmitters are *tuned* to some particular operating frequency. The tuned circuits are usually designed to yield a fairly high loaded Q (Q_L). The greater the circuit Q, the narrower the frequency response of the amplifier. Many applications require high Q and the attendant narrow bandwidth. Examples are VFOs, receiver front ends, transmitter tank circuits and filter circuits that contain an amplifier.

The narrow bandwidth is needed to reject unwanted signals above and below the desired operating frequency, and to prevent spurious energy from leaving the transmitter and reaching the antenna system. When broadband amplifiers are used in some of these more critical circuits, a filter of some kind must be used to obtain the desired spectral purity. By way of simple explanation, a broadband amplifier that has no filtering elements is merely an *untuned* amplifier. It will respond to a broad range of frequencies and, if designed well, should have relatively constant gain across that frequency range. An audio amplifier is but one example of a broadband amplifier.

Another advantage of the narrow-band circuit over the broadband type is that some circuits require minimum noise — as in the case of a receiver oscillator strip — and the high-Q tuned circuits greatly reduce the inherent noise output of the oscillator. High-performance receivers require "quiet" local oscillators in order to minimize "reciprocal mixing" in the mixer stage. Transmitter local oscillators should be similarly clean if we are to avoid broadcasting prohibitive amounts of broadband noise along with the desired signal output. Some commercial early-day solid-state transmitters were very offensive in terms of transmitted wideband noise.

Fig. 1 shows examples of narrow-band and broadband amplifiers in some simplified circuits. Illustration A shows a conventional small-signal RF amplifier with tuned circuits at the input and output. This is typical of what we may find at the input of a receiver. The high-Q tuned circuits or resonators restrict the frequency response for a given setting of C1 and C2. For this reason we will call our circuit a narrow-band amplifier.

Although the circuit at B of Fig. 1 is an oscillator, it is in reality a form of amplifier. For an oscillator to work as such it must be designed as an amplifier. Some of the output energy is fed back to the input terminal to cause oscillation. Again we have a high-Q tuned circuit (C3, C4 and L1), which restricts the bandwidth of the circuit in accordance with the particular setting of C3. Owing to our use of some of the output power as feedback, this type of amplifier is not as efficient as is the circuit in Fig. 1A.

Fig. 1C contains an example of a broadband amplifier for RF use. It operates linearly because it is biased for class A. T1 is a broadband transformer that can be used to match the amplifier impedance to that of the load by virtue of the transformer turns ratio. Note that T1 is untuned; hence the bandwidth.

A class-A linear broadband amplifier

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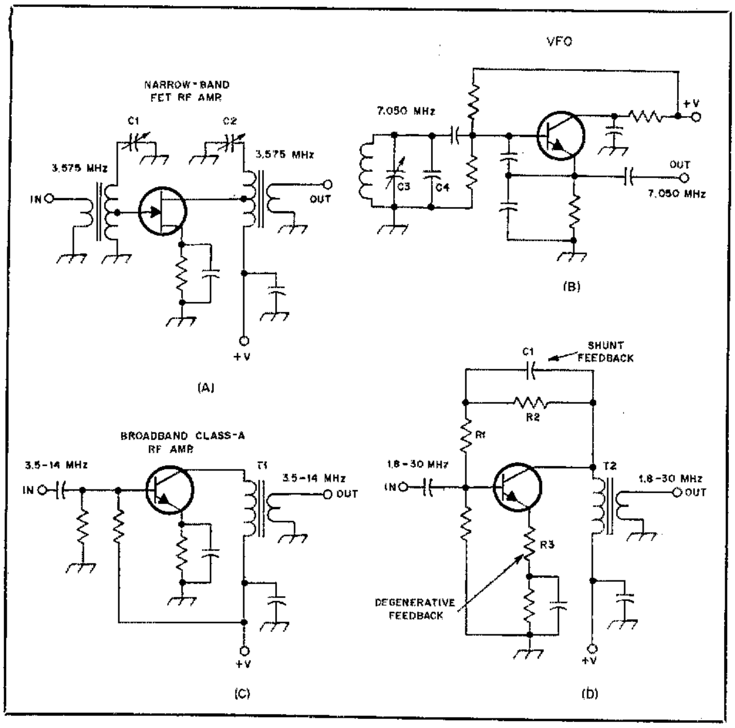


Fig. 1 — The diagrams at A and B illustrate narrow-band amplifiers. The VFO circuit is still a form of amplifier, since its output power (in part) is fed back to the input for the purpose of causing oscillation. A simple Class-A broadband amplifier without feedback is seen at C. A fed-back Class-A broadband amplifier is shown at D. It uses a combination of shunt and degenerative feedback (see text).

with feedback is shown at D of Fig. 1. Here, we have intentionally introduced feedback by means of resistive divider R1/R2 and C1. Degenerative feedback is provided by means of the unbypassed emitter resistor, R3. This type of amplifier has considerable bandwidth. The shunt feedback stabilizes the current gain of the stage while decreasing the input and output resistance of the amplifier. The emitter degeneration helps stabilize the transistor voltage gain, and it increases the input impedance of the transistor. The increase is approximately proportional to the transistor beta. A specific treatment of feedback applied to broadband amplifiers is contained in *Solid State Design for the Radio Amateur*, available from ARRL.

Amplifiers with feedback are used not only for low-power circuits, but are practically the order of the day for high-power solid-state RF amplifiers. A circuit for a broadband, fed-back linear amplifier is provided in Fig. 2. Since this diagram is purely for illustrative purposes, no component values are assigned.

Assume that the circuit is capable of delivering 100 W of output from 1.8 to 29.9 MHz. Shunt feedback is made possible by the networks that contain R1, R2, R3, R4, C1 and C2. Here, we are applying negative feedback between the collectors and bases. Were we to use positive feedback, as in the case of oscillators, the amplifier would "take off" in a spasm of self-oscillation. *Positive* feedback is of the same phase as the input energy, whereas *negative* feedback is approximately 180 degrees out of phase with the input signal. This relationship is important to remember. An absolute 180-degree phase shift is difficult to realize when working with transistors, owing to some inherent phase shift as the signal current passes through the semiconductor material.

T1 and T2 of Fig. 2 are broadband transformers whose frequency response, if they are designed well, is reasonably flat across the 1.8-30 MHz range. Generally, ferrite core material of 800 to 950 effective permeability (μ_e) is used for high-frequency broadband amplifiers. This is a no. 43 material when ordering from Amidon Associates or Fair-Rite Corp.[1] Palomar Engineers and RadioKit also supply cores of the no. 43 variety. Core permeabilities of 125 and 40 are commonly used for VHF broadband transformers.

Broadband transformers work like this: As the operating frequency is increased, the core material becomes less and less effec-

[1]Notes appear on page 30.

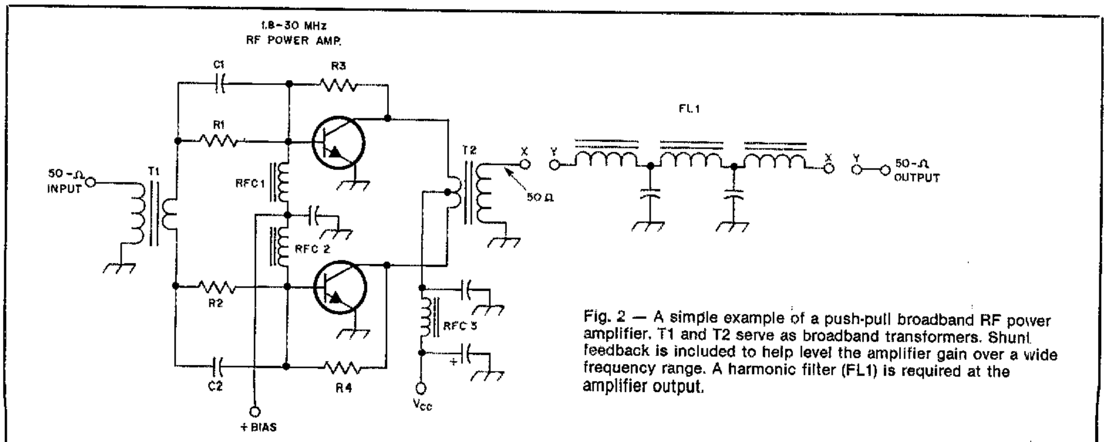


Fig. 2 — A simple example of a push-pull broadband RF power amplifier. T1 and T2 serve as broadband transformers. Shunt feedback is included to help level the amplifier gain over a wide frequency range. A harmonic filter (FL1) is required at the amplifier output.

tive in the circuit. At the low-frequency end of our transformer range, the core does its job and increases the inductance of the windings (necessary). At the high end of the transformer performance range, the core becomes essentially "not there" as far as the windings are concerned. This enables us to obtain a substantial bandwidth that would be impossible with coreless transformers. A suitable rule of thumb for transformer design is to make the inductive reactance of the smallest winding approximately four times the load impedance. Hence, if the base of a transistor amplifier exhibited a 10-ohm impedance, the broadband-transformer winding that we connect to the base should have sufficient inductance to have a reactance of 40 ohms or slightly greater. If not, the low impedance of the winding would shunt part of the driving power to ground and could cause an SWR condition.

Let's assume that our amplifier is operating at 7.1 MHz. The base impedance of the transistor with drive applied is 12 ohms. How much winding inductance would we need for the transformer secondary? The standard equation for inductance would be used:

$$L(\mu H) = \frac{X_L}{2\pi f(MHz)} \qquad \text{(Eq. 1)}$$

So, with an X_L of 4 times 12, we would obtain the following answer:

$$L(\mu H) = \frac{48}{6.28 \times 7.1} = 1.07 \qquad \text{(Eq. 2)}$$

The required number of turns can be calculated from

$$\text{Turns} = 100\sqrt{L(\mu H)/A_L} \qquad \text{(Eq. 3)}$$

where A_L is the number provided for each type of core by the vendor or manufacturer. Each core, relative to its cross-sectional area and the core material, has a specific A_L factor. The Amidon Associates catalog contains such data, as does a book concerning magnetic cores.[2]

I don't want to mislead you into thinking that broadband amplifier design is a snap. There are many subtleties involved, and considerable study of the pertinent literature is important before launching one's own project from scratch. Motorola Semiconductor Company has a wealth of useful data in its book on power semiconductors, inclusive of application notes on transformer and broadband amplifier design.[3]

But, let's return to Fig. 2 and learn a bit more about what's going on. T2, the output transformer, serves also as an impedance-matching device. The inductances in the transformer windings are based also on a ×4 rule, respective to the collector impedance. This impedance can be calculated closely from $Z = V_{cc}^2/2\,P_o$ ohms. Eq. 1 is then applied. FL1 is a harmonic filter, and is a low-pass type. A

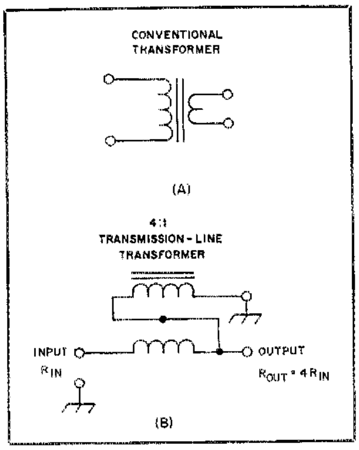


Fig. 3 — Examples of conventional and transmission-line transformers. See text for additional information.

switch can be inserted at points X and Y to permit band switching of the low-pass filters. This is standard procedure in commercial equipment. For single-band use, a jumper can be placed across X and Y.

It is important in all broadband amplifiers to minimize the stray capacitive and inductive reactances. These parasitic quantities of L and C have a marked effect on the amplifier performance as the operating frequency is increased. In other words, unwanted capacitive and inductive reactance will limit the upper frequency response of the circuit. An improperly designed broadband transformer will degrade the performance in a like manner.

If we are to minimize the presence of stray reactance, we must use large or very short circuit-board strips. This will reduce the effective inductance of the PC-board foils. These copper strips should also be as direct as possible. Similarly, the connecting leads of resistors and capacitors must be held to a minimum length. Many amplifiers contain chip resistors and capacitors to keep stray inductance and capacitance to a minimum. These components are supplied without leads or "pigtails." They are soldered directly to the PC-board foils. They are practically a requisite at the upper end of the HF range and higher, but they are more costly than are silver-mica or disc-ceramic capacitors.

Conventional or Transmission-Line Transformers?

I'm sure you've heard designers speak of "conventional" and "transmission-line" transformers. The so-called conventional transformer is built along the lines of an audio or power transformer. That is, it has a core and separate windings, as in Fig. 3A. The transmission-line transformer, on the other hand, has bifilar, trifilar or quadrifilar windings that are placed on the core in parallel, or they may be twisted together beforehand. In this case, each winding conductor is the same length. The windings function as short lengths of transmission line, and the impedance is generally 25 ohms. Either style of transformer can be used in a broadband amplifier, or as a matching transformer in other types of circuits, such as antennas.

The conventional transformer is considered less efficient than the other type, but it enables us to obtain nearly any turns ratio we desire. The transmission-line transformer (Fig. 3B) yields only specific integers of transformation, such as 4:1, 9:1, etc. Furthermore, we can find ourselves rather frustrated when trying to hook up a multiwire transmission-line transformer, especially if the same size and color of wire is used for the windings. Many engineers use enameled wire of various colors to avoid this problem. Green, red and brown wire is often used. You can solve the problem by dipping the wires in different colors of paint before using them. I have had good results by spraying the wires with fast-drying paint.

A Handy Broadband Amplifier

Many times we find ourselves in need of a little extra "push" when working with a scope or frequency counter. Perhaps the sampling point in the circuit has insufficient signal voltage to trigger our frequency counter or cause ample deflection on the face of the scope tube. A broadband amplifier is useful at such times to give that weak signal the needed boost.

Our workshop project this month is shown schematically in Fig. 4. It is patterned along the lines of a broadband amplifier designed by Hayward, W7ZOI. His design did not use transformers and there was no high-level stage at the tail end of the amplifier strip, but the feedback networks are similar to his. The particulars of the general design are given in the text of *Solid State Design for the Radio Amateur*, referenced earlier in this article.

CATV transistors are used to ensure good bandwidth (1.2 GHz f_T) and linearity. Each stage is biased for linear Class-A operation. A combination of shunt and degenerative feedback is used throughout the circuit. The input of each amplifier is roughly 50 ohms, and each output is approximately 200 ohms with the values given. Amplifier stability is excellent, even when there is no termination at the input and output ports. Circuit boards and parts kits for this circuit are available.[4]

The bandwidth is flat from 400 kHz to 34 MHz (within 1 dB). I measured the overall gain as 41 dB. The maximum acceptable output, in terms of distortion, is 0.25 W. The circuit draws 90 mA of current with a supply voltage of +13.

Owing to the linearity and bandwidth of the circuit in Fig. 4, it is ideal as a drop-in

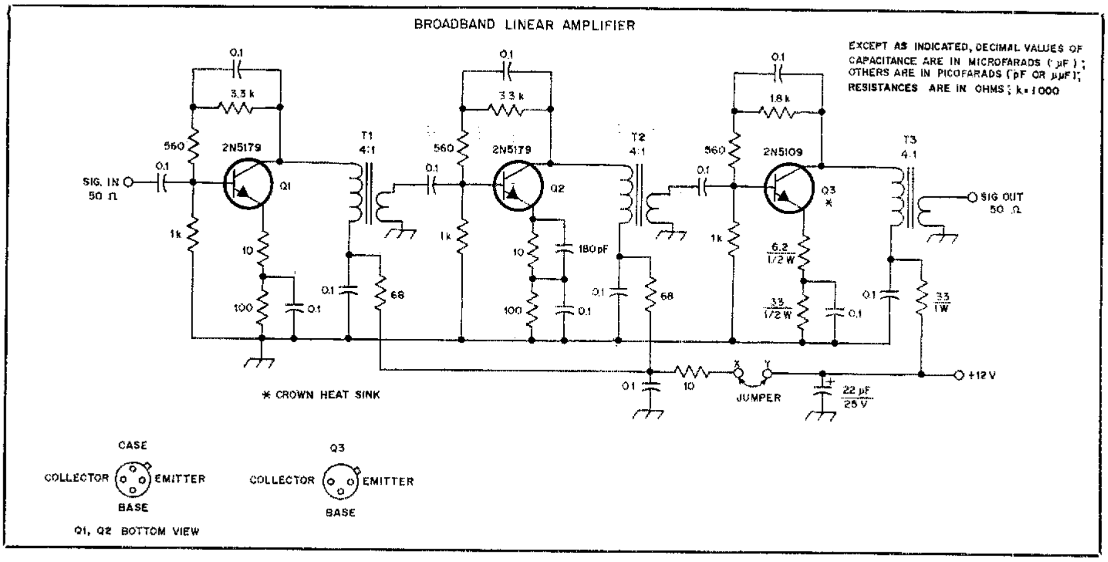


Fig. 4 — A practical circuit for a broadband linear-amplifier strip. This can be used as an instrument amplifier, a low-level RF strip in a transmitter or as part of a receiving-loop preamplifier. Resistors are ¼-W carbon-composition unless otherwise noted. The polarized capacitor is tantalum or electrolytic. All others are chip-style or disc-ceramic with short leads. T1 and T2 contain 15 primary turns of no. 28 enameled wire on an Amidon FT37-43 toroid core. The secondary windings consist of seven turns of no. 28 enameled wire. T3 uses an Amidon FT50-43 toroid core with 12 primary turns of no. 26 enameled wire. The secondary of T3 contains six turns of no. 26 wire.

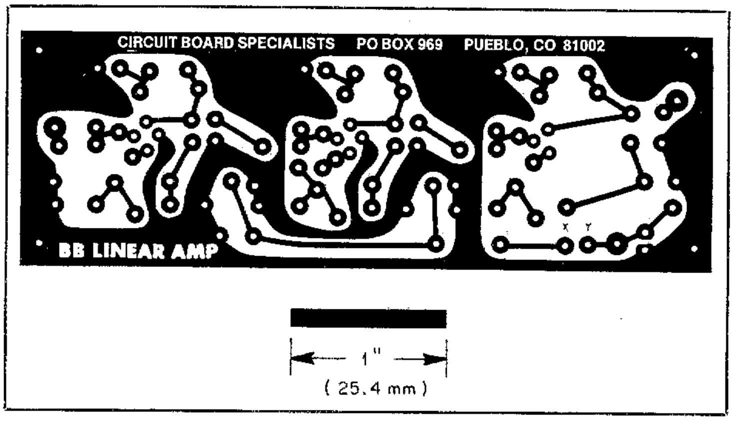


Fig. 5 — Circuit-board etching pattern for the broadband amplifier of Fig. 4. The pattern is shown full size from the foil side of the board. Black areas represent unetched copper foil.

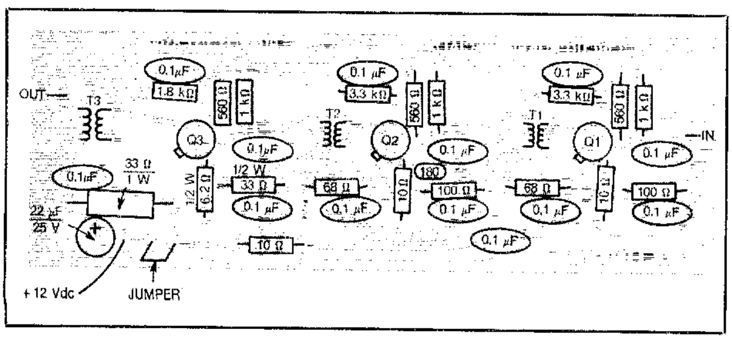


Fig. 6 — Parts-placement guide for the broadband amplifier of Fig. 4.

unit for an HF-band CW or SSB transmitter. It can be used as the low-level section of such a transmitter. I wish to caution you, however, that it should not be used for QRP operation unless a suitable harmonic filter is placed between the amplifier output and the antenna. A half-wave style of filter should be suitable if you want to try your hand at low-power operation.

Terminals X and Y on the circuit board are available for use as a standby point, or for CW keying. If a keying line is attached at X and Y, be sure to include a shaping network so that your signal won't sound clicky.

This amplifier can be used also as a preamplifier for loop antennas. A step attenuator can be inserted at the output of the amplifier to control the gain. If you choose to use this circuit in such a manner, a low-noise preamplifier should precede Q1 of Fig. 4. I find that a JFET stage is suitable for this purpose. Owing to the small signal that a receiving loop provides, the preamplifier (even at 1.8 MHz) must be a low-noise type. If not, you will enjoy listening to "pop-corn" noise along with the DX signals! Q1 does not have a low enough noise figure for satisfactory weak-signal reception.

Construction

If you choose to make your own PC board for this project, try to keep all stages in a straight line. Keep the PC-board foils short and direct. Minimize the lead length of each capacitor and resistor. Make sure the transistors are seated close to the PC board in order to keep their leads as short

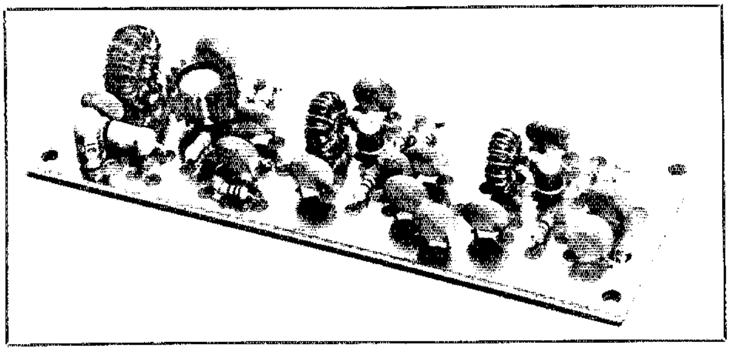


Fig. 7 — The assembled broadband amplifier. Note that in-line layout is used.

as possible. A crown heat sink is needed on Q3, the 2N5109. A coating of silicone grease should be applied to the transistor cap before installing the heat sink. Double-sided PC board is recommended in the interest of stability. Fig. 6 shows the parts placement for the circuit board, as seen from the component side. A scale template of the PC-board pattern is provided in Fig. 5. Fig. 7 is a photograph of the assembled amplifier.

Some Final Remarks

I hope you have learned the basics about narrow-band and broadband amplifiers. Certainly, we've only scratched the outer layer of the subject. A thorough treatment would require several *QST* installments. Our purpose this time is to explain the difference between amplifier types, and to provide a project that would enable you to try your hand at broadband amplifier construction and use.

A broadband amplifier can be built for Class A, B or C service, just as narrow-band amplifiers can. The advantage of broadband designs is, in retrospect, to obtain a wide frequency response with relatively flat gain. This helps us to design circuits that do not require band-switching provisions. In other words, it simplifies the design of a multiband transmitter. But, as an instrumentation amplifier, the circuit of Fig. 4 has a great many advantages around the workshop. Good luck with your project.

Notes

[1]Amidon Associates, 12033 Otsego St., N. Hollywood, CA 91607 (catalog available). Fair-Rite Products Corp., 1 Commercial Row, Walkill, NY 12589. See *QST* ads for Palomar and RadioKit.

[2]D. DeMaw, *Ferromagnetic Core Design & Applications Handbook*, no. 0-13-314088-1 (Englewood Cliffs, NJ: Prentice-Hall, Inc.).

[3]*Motorola RF Data Manual*, Motorola Semiconductor Products, Inc., P.O. Box 20912, Phoenix, AZ 85036.

[4]Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002, tel. 303-542-5083.

Strays

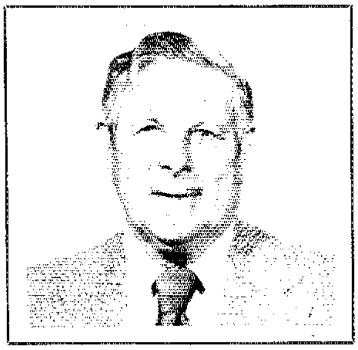
TA PROFILES

☐ It is our pleasure to introduce ARRL Technical Advisor Michael E. Hiehle, W6RZ. Since joining our official TA family on January 3, 1980, his professional advice as one of our antenna experts has been invaluable to radio amateurs. He is a Life Member of the ARRL, and has written articles for *QST*.

Mike received his first Amateur Radio license in 1929, while residing in Canada. He was issued the call W6RZ in 1930, and currently holds an Extra Class license. He is also the holder of a First Class Radiotelegraph Operators Certificate with endorsements and a radio Telephone Operator License, First Class.

After graduating from the California Institute of Technology with a BSEE degree, Mike was employed at General Electric Company. During his 10 years there, he was responsible for antenna radar design during World War II and subsequently on commercial antenna design. Mike now lives in Culver City, California, and is enjoying retirement after 31 years of service at Hughes Aircraft. He is presently working on a 5-band quad antenna.

For 20 years, Mike has been an active member of the National Ski Patrol (specializing in avalanche phenomena), and has worked with the Boy Scouts since 1943.



TA Mike Hiehle, W6RZ

His leisure time is spent backpacking/mountaineering (Mt. McKinley, 1964). — *Marian Anderson, WB1FSB*

ANTENNAS SUBJECT OF TRN TALK

☐ "Multiband, Broadband and Frequency Independent Antennas — An Overview" will be the subject of a talk by noted antenna expert John Belrose, VE2CV, on the North American Teleconference Radio Net on June 21 at 7:30 P.M. CDT. Belrose, director of radio communications at the DOC Research Center in Ottawa, Ontario, has written many articles on antenna design for *QST* and other publications.

Access to TRN is provided by more than 180 gateway stations, mostly VHF repeaters, linked together to cover virtually every metropolitan area in the U.S. and much of Canada. For information on linking your repeater into the net, send an s.a.s.e. to Net Manager Rick Whiting, WØTN, 4749 Diane Dr., Minnetonka, MN 55343.

ROANOKE DIVISION PLANNING SESSION THIS MONTH

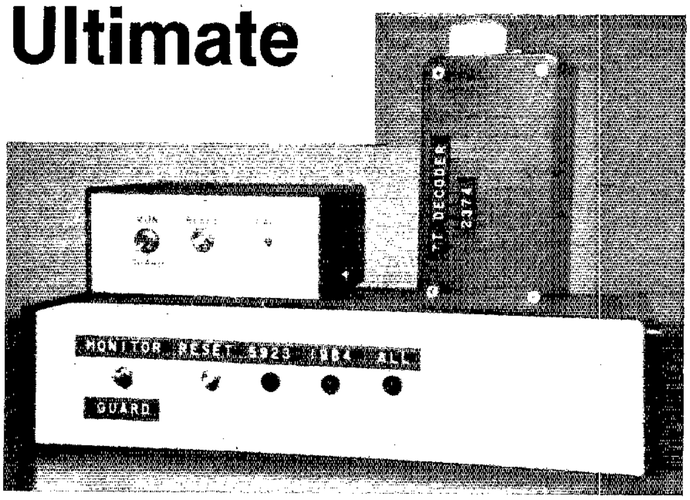
☐ This year's Roanoke Division League Planning Meeting will be held May 12-13 at the Ramada Inn, South Charleston, West Virginia. ARRL Communications Assistant Jim Clary, WB9IHH, will be among those attending. For more information, contact Albert Hix, W8AH, 860 Alta Rd., Charleston, WV 25314, tel. 304-344-1215.

QST congratulates...

☐ the following radio amateurs on 60 years as ARRL members:

- Robert Aldrich, WØJVM, of Minneapolis, Minnesota
- Frank A. Gunther, W2ALS, of Staten Island, New York
- John F. Longley, W2ANB, of Slingerlands, New York

The Nearly Ultimate Decoder



Need a simple project for your next club activity? Try this versatile paging system, a sequential DTMF decoder, for use with your favorite repeater.

By Paul Newland,* AD7I

Does your club need a system that will allow you to call other people on a repeater channel, just as you might ring their telephones? If you do, you might be interested in building the Nearly Ultimate Decoder, or NUD. NUD is capable of detecting either of two sequences of up to eight Touch-Tone® signals from a VHF-FM radio and then ringing a bell, buzzer or other alarm indicator when the proper sequence is received. It is also possible to link the two decoders to form a single 15-digit decoder. An all-call function is also supported for emergency use. If NUD hears any valid dual-tone, multifrequency (DTMF) signal on the channel for more than 5 seconds, it will trigger the alarm. If these features appeal to you, spend a weekend building this simple circuit.

Since 1976, I have been trying to devise a simple and reliable method of signaling individuals or groups using VHF hand-held radios. My first attempt used a four-tone selective-call sequence. Tone pads, either integrated into commercial VHF radios or added as accessories, were used to generate single tones by simultaneously pressing two buttons in the same row.

The decoder used an NE567 phase-locked loop (PLL) tone decoder. The desired frequency for the PLL was programmed by selection of an RC time constant. I used a CMOS counter driving a set of CMOS analog switches to select different resistance values, depending on which of the four tones was desired. When a tone was selected, the counter input was taken to the inactive edge. After the tone was removed and the PLL unlocked, the counter was advanced and the next resistance value was selected. If the next tone was correct, the counter advanced. When the counter reached four, a latch was set and an alarm sounded to tell the operator that a proper code had been received.

This system was unreliable for two reasons. First, ambient-temperature changes altered the RC-network time constant, which in turn changed the PLL detection frequency. Second, the NE567 PLL is sensitive to signal level. If the signal is too weak, the decoder never detects the signal. If the signal is too strong, the decoder responds to signals other than the desired one. Both problems proved to be too tough to overcome with the space and power that was available for hand-held portable operation.

My next attempt at a pager-like decoder was a system I called Not Just Another Decoder or NAD.[1] NAD was based on an IC encoder/decoder chip made by National Semiconductor. That chip was intended for use as part of a radio-controlled garage-door system. NAD's problem was that for reliable operation, the operator had to electrically couple it to the modulating circuitry of the radio for transmission. This was not a big problem, but it did require connecting and disconnecting NAD's transmitter to a radio microphone circuit; it was not convenient. After this experimentation, I decided that the only system of any real value to radio amateurs for pager-type operation must be based on the tone pad that has been incorporated into almost every VHF-FM Amateur Radio set manufactured since 1980.

The Next Generation

In late 1982, Silicon Systems, Inc., announced an 18-pin tone-decoder chip: the SSI 202-P.[2] This is a low-power CMOS device, ideal for battery powered operation. It uses an inexpensive TV color-burst crystal for timing, does not require any band-splitting filters, uses a +5-V supply, detects all 16 tone pairs, and has good speech immunity.

Because of the introduction of this IC (and other ICs with similar characteristics from other manufacturers), I believe the technology is available for a DTMF-based system for hand-held Amateur Radio use. Before these new ICs were available, such systems consumed too much power for battery operation, were unreliable (most systems used by amateurs employed 567 PLL decoders), or were too expensive. The 202-P chip, which forms the basis for NUD, overcomes all of these problems.

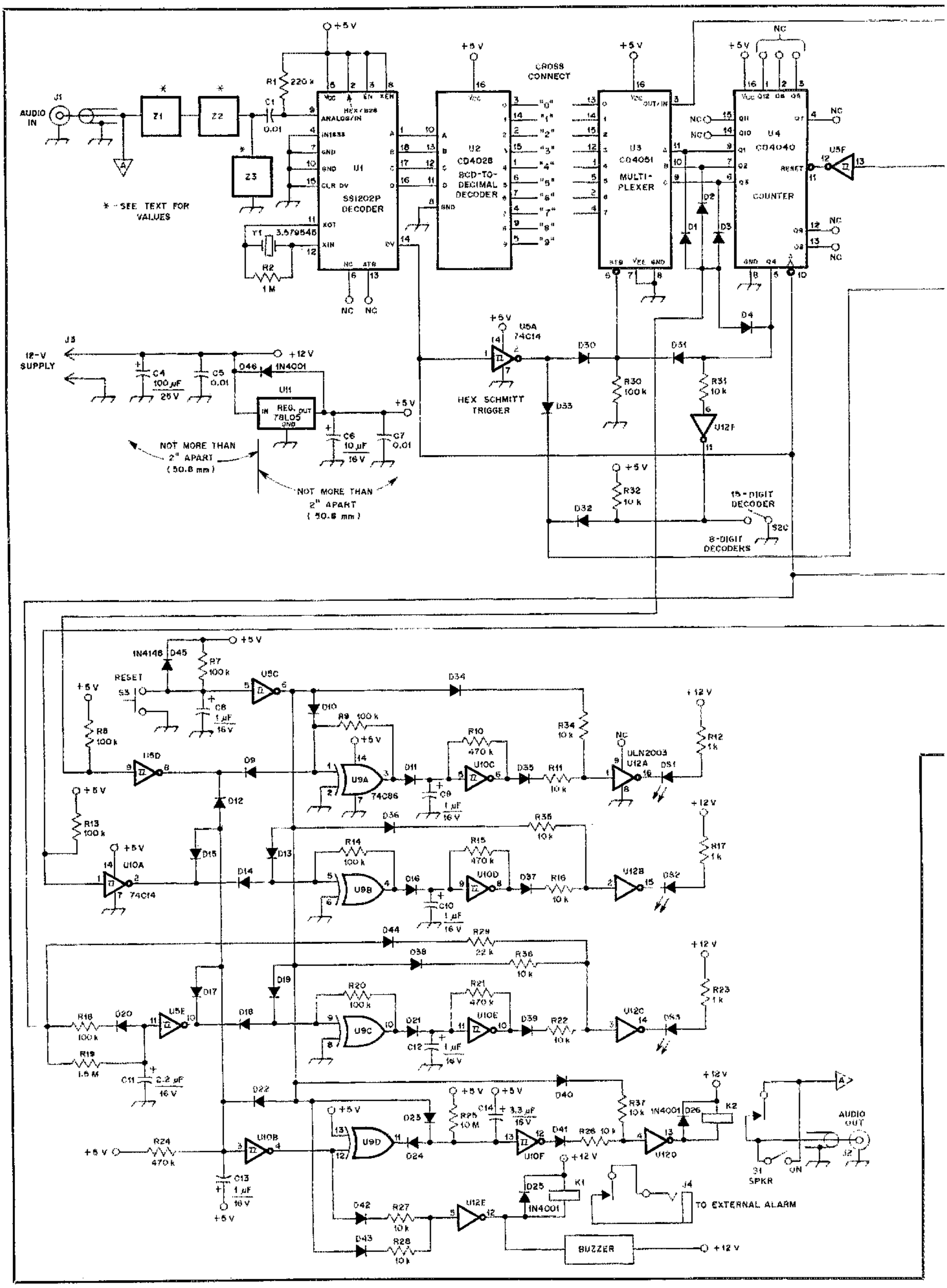
Circuit Description

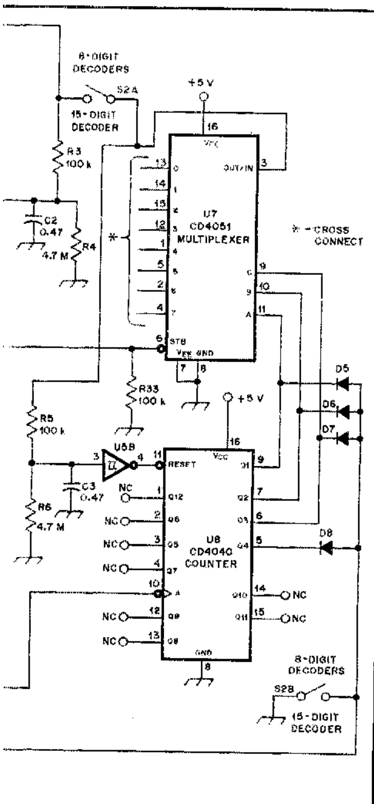
The lead photo shows three versions of NUD, and a complete schematic diagram is given in Fig. 1. The audio input is filtered by Z1, Z2 and Z3 to provide proper audio-frequency response for U1. The IC requires both tone-pair signals to be of equal amplitude. If there is a difference in levels, the lower-frequency signal should have the greater amplitude. The filter values depend on the audio characteristics of the radio receiver you are using. Table 1 lists the values of each component to be used with a given AF response. "High" refers to a radio that emphasizes the higher audio frequencies. "Low" refers to a radio that emphasizes the lower audio frequencies, and "flat" refers to a radio that reproduces all audio frequencies at the same level. Later, I'll discuss how you can determine what type of audio characteristics your radio has.

The DTMF decoder chip is biased by C1 and R1. A time base to enable the chip to detect DTMF signals is provided by Y1 and R2. Output signals from U1 include a binary coded-decimal (BCD) representation of the decoded signal and a data valid

*P.O. Box 205, Holmdel, NJ 07733-0205

[1]Notes appear on page 34.


AUDIO IN
J1
Z1
Z2
Z3
* - SEE TEXT FOR VALUES
R1 220 k
C1 0.01
+5 V
SS1202P DECODER
U1
Y1 3.579545
R2 1 M
NC
CD4028 BCD-TO-DECIMAL DECODER
U2
CROSS CONNECT
CD4051 MULTI-PLEXER
U3
CD4040 COUNTER
U4
U5F
D1
D2
D3
D4
J3
12-V SUPPLY
+12 V
C4 100 µF 25 V
C5 0.01
D46 1N4001
U11
REG. 78L05
C6 10 µF 16 V
C7 0.01
NOT MORE THAN 2" APART (50.8 mm)
U5A 74C14
HEX SCHMITT TRIGGER
D30
D31
D33
R30 100 k
R31 10 k
U12F
R32 10 k
D32
15-DIGIT DECODER
8-DIGIT DECODERS
S2C
1N4148 D45
R7 100 k
RESET
S3
C8 1 µF 16 V
U5C
D34
D10
R9 100 k
U9A 74C86
R10 470 k
U10C
C9 1 µF 16 V
D35
R11 10 k
R34 10 k
ULN2003 U12A
DS1
R12 1 k
R8 100 k
U5D
D9
D11
D12
R13 100 k
U10A 74C14
D15
D14
D13
D36
R35 10 k
R14 100 k
U9B
D16
C10 1 µF 16 V
R15 470 k
U10D
D37
R16 10 k
U12B
DS2
R17 1 k
D44
R29 22 k
D38
R36 10 k
D17
D19
R20 100 k
U9C
D21
C12 1 µF 16 V
R21 470 k
U10E
D39
R22 10 k
U12C
DS3
R23 1 k
R18 100 k
D20
U5E
D18
R19 1.5 M
C11 2.2 µF 16 V
D40
D22
D23
R25 10 M
C14 3.3 µF 16 V
R37 10 k
1N4001 D26
K2
AUDIO OUT
J2
S1 SPKR
ON
R24 470 k
U10B
U9D
D24
U10F
D41
R26 10 k
U12D
C13 1 µF 16 V
D25 1N4001
K1
J4
TO EXTERNAL ALARM
D42
R27 10 k
U12E
D43
R28 10 k
BUZZER



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (μF); OTHERS ARE IN PICOFARADS (pF OR μμF); RESISTANCES ARE IN OHMS; k = 1000, M = 1 000 000

Fig. 1 — Schematic diagram of NUD, a sequential DTMF decoder.
D1-D24, D30-D44 — 1N4148.
D25, D26 — 1N4001.
S1 — SPST switch.
S2 — 8-position DIP switch.
S3 — Momentary push button, normally open contacts.
K1, K2 — SPST 12-V relay.

Table 1
Filter Components

Receiver Audio Response	*Z1*	*Z2*	*Z3*
Low	6800 pF	0 ohms	10 kΩ
Flat	0 ohms	0 ohms	Open
High	0.1 μF	10 kΩ	0.022 μF

(DV) signal to show when the BCD output is valid. A significant deviation from what most would expect for a BCD output is that zero is encoded as 1010 (decimal 10) and the letter D is encoded as 0000 (decimal 0).

U2 is a 1-of-10 decoder, and converts the BCD input to a high logic level at one of its outputs. For example, if the BCD output from U1 is 0101 (5), then pin six (logic output five) of U2 is at +5 V and all other outputs are at 0 V. U3 is an analog multiplexer. You can think of it as a single-pole, eight-throw switch. Its position is selected by the BCD input on pins 11, 10 and 9. If the select inputs are in state 011 (3), input 3 (pin 12) can be considered connected to the output (pin 3). By cross connecting the outputs of U2 to the analog inputs of U3, NUD can be programmed to whatever sequence of tone digits is desired. The STROBE input to U3 (pin 6) can be thought of as an additional switch in series with the output. If the STROBE signal is at logic high, the switch is open; if it is at logic low, the switch is closed. U4, a binary counter, keeps track of how many digits in the sequence have been received correctly. The RESET pin on this chip is driven by the BCD-to-decimal decoder, U1, via the multiplexer, U3.

Now, let's see what happens when the unit detects a tone pair. This example will explain how the major portions of the circuit function. When a tone pair is detected by U1, its BCD outputs reflect the value of the tone pair received. Additionally, the DV signal will go high, telling the remainder of the circuit that the data on the BCD output lines of U1 are valid. U2 converts this value to a high signal level on only one of its outputs. Counter U4 would be in the 0 state because its reset pin is held high. (The input to U5F is low.)

With U4 at count 0, pins 3 and 13 of U3 can be considered connected together when the STROBE signal is low. With DV high, the STROBE signal is low, and if pin 13 of U3 is connected to the output of U2 that is high, C2 will charge to a high state. This will remove the reset signal from the counter. When U1 takes DV low (the tone pair has been removed from the input), U4 will advance its count by one and U3 will connect pin 14 to pin 3. If another tone pair is detected, and pin 14 of U3 is connected to the output of U2 that is high this time, the counter will advance again when the tone pair is removed. If the selected input of U3 is low (as would be the case if the wrong tone pair was received), C2 will discharge to a low state, resetting U4. If the gap between valid tone pairs is too long (more than 1.5 seconds), C2 will discharge to a low state through R4.

D1, D2, D3 and D4 form an AND gate to determine when the proper number of tone pairs have been received correctly. Table 2 shows which diodes must be installed for a given number of tones in the sequence.

When the proper count is reached, the input to U5D will go high, the latch formed by U9A will be set, and DS1 will flash on and off until the RESET button is pressed. Additionally, the output from U10B will go high for the time determined by R24 and C13 (about 3 seconds). This will cause the buzzer to sound by saturating U12E. The speaker will also be connected to the radio audio for about 30 seconds via U10F and U12D.

Table 2
End of Sequence Detection

No. of Tones	*D4*	*D3*	*D2*	*D1*
1	out	out	out	in
2	out	out	in	out
3	out	out	in	in
4	out	in	out	out
5	out	in	out	in
6	out	in	in	out
7	out	in	in	in
8	in	out	out	out
9	in	out	out	in
10	in	out	in	out
11	in	out	in	in
12	in	in	out	out
13	in	in	out	in
14	in	in	in	out
15	in	in	in	in

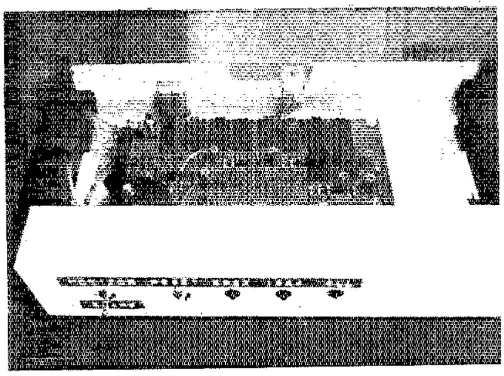
The second decoder, formed by U7 and U8, operates exactly the same as the first decoder. D30 to D33 and R30 to R33 allow the two decoders to be linked to form a 15-digit decoder. If two 8-digit decoders are desired, open switches S2A and S2B, and close switch S2C. If you want one 15-digit decoder, reverse the positions of these switches. With the 15-digit decoder, the first eight digits are programmed into U3 and the remaining seven digits are programmed into U7. Good design practice requires that any unused inputs of U3 and U7 should be grounded.

If the DV signal is high for more than 5 seconds, C11 will charge through R19 to more than 4 V and the output of U5E will go low. If the DV signal goes low before the capacitor is fully charged, it will quickly discharge through D20 and R18. When the output from U5E goes low, the alarm will sound and the speaker will be connected to the radio. This feature provides a simple all-call function for emergency operations. To disable this feature, simply short out C11. The time required for C11 to charge is proportional to its capacitance. To change the amount of time required to trigger the all-call feature, change the value of C11.

U5C and associated components form a power-on and manual reset/test circuit. When the reset button is pressed, all latches are cleared, the lamps light, the speaker becomes active, and the buzzer will sound. This provides a self-test feature, in addition to resetting the system.

Construction

Few construction details are given. You can choose any construction method you like. I prefer the wire-wrap technique because it makes circuit changes easier during the development stage. Fig. 2 shows the layout used for two decoders that I built. Power and audio-signal connectors can be any style available, but if everyone in your group uses the same convention, it will be



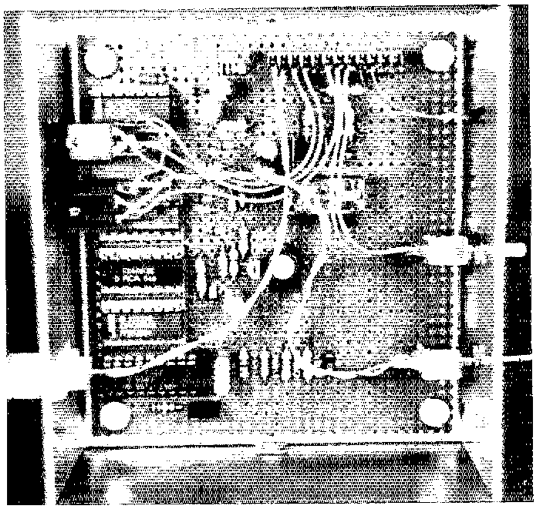


Fig. 2 — Parts placement for two versions of the decoder are shown. The unit shown above is a full-featured decoder. The power connector is located on the back panel and the audio input and output lines are on the left side. A buzzer is located at the front left corner of the perf board. At the right is a version of NUD that provides only a single-sequence decoder.

easier to use your decoder with someone else's radio.

Selective-Call Numbers

I have only a few comments about code selection. Each individual in a group should select or be assigned a number sequence to use as a selective call. Because U2, the BCD-to-decimal decoder, cannot detect a 1010 input, I recommend that the Touch-tone digit 0 not be used as part of a selective call. Instead, this digit should be reserved for resetting NUD to a known state. As an example, all selective calls could begin with 0 to reset the decoder. I don't recommend the use of a selective call that uses the same tone pair twice in a row. If a call for someone else fades out and then comes back during a tone that your decoder wants twice in a row, it might sound a "false alarm." A selective call of 023345 would not be desirable, but 023534 would be fine.

Programming

Programming NUD is a simple matter. The decoded outputs for the digits 1 through 9 are labeled on U2. Note that the 0 output will be active when the D button on a 16-button tone pad is pressed. This is because U1 encodes the D tone pair as 0000 (or just 0), and cannot be changed. Use of this output should be avoided because some stations may not have a 16-button tone pad. Connect pin 13 of U3 to the pin of U2 that represents the first tone pair you want to detect. Connect pin 14 of U3 to the pin of U2 that represents the second tone pair. Continue this process until you have programmed all the tone pairs in your sequence. If you are using fewer than eight digits connect the remaining U3 inputs to ground. Next, install D1, D2, D3 and/or D4 as required for the number of tone pairs in your sequence. Follow a similar procedure to program the second decoder. Remember that all unused inputs to U3 and U7 must be connected to ground.

Testing

With all ICs removed, apply power and check the voltage at the supply pin of each chip for +5 V. Turn off the power and install all of the chips. Re-apply power and key in the first tone-pair signal for your selective call. When the tone is detected, the DV output of U1 will go high and the proper output of U2 will also go high. DS3 will light when a tone-pair is detected. As each tone pair is detected in sequence, a high logic level can be measured at U3 pin 3. Failure to get these signals indicates a problem in the detection, decoding or selection circuitry. When the proper number of tone pairs have been detected, the diode AND gate will go high. This causes the lamp and buzzer to be activated.

Determining the Audio Characteristics of Your Radio

The audio-frequency response of all my radios favors the higher frequencies. In this instance, NUD requires a low-pass filter formed by Z1, Z2 and Z3 in Fig. 1. A simple way to determine the response of your radio is to have a friend transmit some tones. Connect a resistive load (100 ohms) across the audio output of your receiver. Wire a 1-V full-scale meter across the resistor. Have your friend send a single low-frequency tone by simultaneously pressing buttons 1 and 2. Record the voltmeter reading. Next, have him or her send a single high-frequency tone by pressing buttons 3 and 6 at the same time. Again note the voltage. Now, have your friend transmit the single tone that produced the largest reading. While this tone is being received, adjust the volume control on your radio to provide a full-scale reading. Then, have the other single tone sent and note the voltage.

If the weaker of the two tones measures more than 700 mV, your radio has a flat audio response. If the weaker tone is less than 700 mV and the high-frequency tone is the stronger of the two, your radio can be considered to have a high frequency response. If the low-frequency tone is the stronger one, your radio has a low frequency response. One note of caution for these tests: They are not exact, and you should probably try the measurements with several transmitting stations and average the results. Use your test results, along with Table 1, to determine the components to employ at Z1, Z2 and Z3 in your decoder.

The requirements of the DTMF decoder chip, U1, are such that it will detect signals properly only if the high-to-low-tone ratio is between −8 dB and +4 dB. So, if you must choose, it is better to have the high-frequency tone be weaker than the low-frequency one.

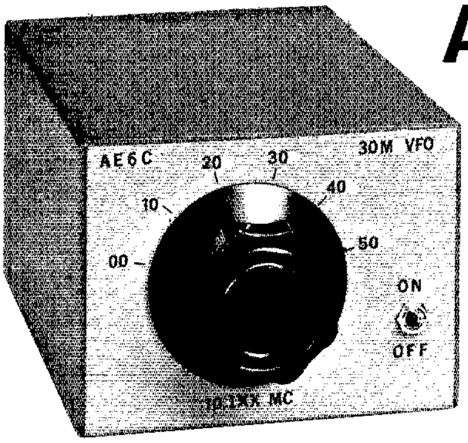
Conclusion

NUD provides many features that will prove useful for repeater clubs, ARES organizations and other groups of Amateur Radio operators. It may not be the *ultimate* DTMF decoder, especially in light of the rapidly advancing technology in this area, but the low cost and simplicity make it an attractive project.

Notes

[1]P. Newland, "Not Just Another Decoder (NAD)," *QST*, June 1982, pp. 25-27.

[2]Silicon Systems, Inc., 14351 Myford Rd., Tustin, CA 92680, tel. 714-731-7110.



A Battery-Powered 30-Meter VFO

Is your old tube CW rig collecting dust? Give it new life on 30 meters with this simple, stable VFO.

By Dennis Monticelli,* AE6C

The 30-meter band has generated a lot of interest, particularly among CW buffs. It is uncrowded, contest- and kilowatt-free, and open nearly around the clock to some point of the world. As the MUF declines, 30 meters will increase in value as an alternative to 20 meters. If your rig is new, you're only an antenna away from getting on the band; but if your rig is a few years or more old, you may be out of luck.[1]

While planning a "mod" attack on my Kenwood transceiver one weekend, I noticed my trusty old Johnson Viking II sulking in the recesses of my junk closet. It was proud once, but its time had passed . . . or had it? My mind was quickly made up! Work began immediately on designing a stable, self-contained VFO for use with the Viking. Receiving chores are handled by my Collins R-390A; others may want to try using a receiving converter.[2] I wanted the design to be simple and well isolated to encourage others to retrofit their old rigs, tube or transistor type. The VFO is suitable for use in a "homebrew" 30-meter rig, too.

Some Ground Rules

In working with VFOs, I've found that the choice of oscillator circuit is secondary to proper use of that circuit. This means paying attention to a long list of common sense rules. Failure to observe even one of these rules can result in less-than-satisfactory performance:

- Use the least amount of power necessary to drive the load.
- Use the least amount of feedback necessary to ensure quick starting and insensitivity to load changes.
- Shield the frequency-determining components.
- Use a regulated and well-filtered power supply (at least for the oscillator transistor).
- Keep supply lines isolated and/or decoupled from the transmitter RF field.
- Lightly couple the oscillator transistor output to the next stage, and/or employ a buffer stage with constant input impedance and a high degree of isolation.
- Choose a transistor (bipolar, JFET or MOSFET) whose frequency rating (f_T) is well in excess (>20 times) of the oscillating frequency.
- Stabilize the oscillation amplitude if possible.
- Choose low-temperature-coefficient, low-loss capacitors, such as NPO ceramic, silver-mica or polystyrene types.[3]
- Place capacitors in parallel to reduce self-heating. This is especially important when oscillator power is high and/or capacitors are physically small.
- Use mechanically stable, air-variable capacitors with a smooth turning action. Brass plates (often plated) and double end bearings are preferred, but not absolutely necessary.
- Use a mechanically stable, air-wound coil on a ceramic, glass or plastic form. Use "Q dope" on homemade coils. If a core is used, choose a low-temperature-coefficient iron-powder material and minimize core penetration into the coil.
- Keep air currents away from the frequency-determining components.
- Keep L and C strays to a minimum by using short lead lengths and a wide ground return path. Avoid the use of double-sided PC boards and their accompanying unstable stray capacitance.
- Reduce mechanical vibration by mounting all critical components securely and interconnecting them with heavy-gauge wire.

Circuit Description

The series-tuned Clapp oscillator was chosen for this VFO partly because it is able to use a larger inductor for a given frequency, thus reducing the effect of stray inductance. Fig. 1 shows that the VFO is battery powered. This is done for a number of reasons. First, it results in a high degree of isolation between the VFO and other components. The only wire leaving the VFO box carries the output signal. Second, the overall circuit is simplified, as there is no need to build and decouple a power supply. Third, to achieve long battery life, I was forced to come up with a low-power design.

The VFO runs at 5 MHz and depends on doubling in the transmitter to produce the desired output frequency. Sufficient output voltage (22-V P-P, unloaded) is produced by the VFO to drive most tube stages into frequency doubling.

I prefer to use JFETs or depletion-mode MOSFETs for oscillator service because their ability to self-bias eliminates the need for a stabilized and decoupled bias supply. Note that the output signal is taken from the drain of Q1, which is not the conventional in this type of oscillator. The drain-current signal is usually far from pure, but offers a way to couple maximum energy efficiently from Q1 to the next stage. In its direct-grounded, common-gate configuration, Q2 exhibits a high degree of isolation and consumes no additional current. Furthermore, it stabilizes the potential and im-

[1]Notes appear on page 37.

*48617 Tonopah Ct., Fremont, CA 94539

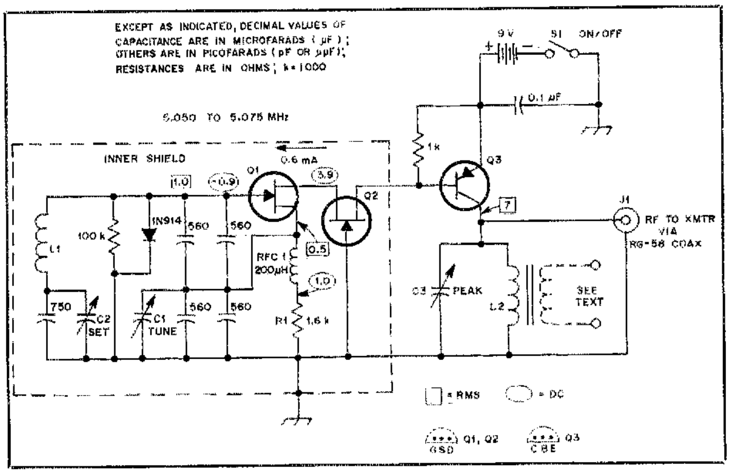


Fig. 1 — Schematic diagram of the battery-powered 30-meter VFO. The secondary winding on L2 is optional (see text). Fixed capacitors are silver-mica types. Resistors are 1/4-W carbon types. Refer to the text for additional information on certain parts.

C1 — 4-50 pF air variable (Hammarlund HFA-50B, Millen 22050 or Cardwell 167-3).[6]
C2 — 2-17 pF air trimmer (Johnson 189-0506-005 or equiv.).[6]
C3 — 180-pF mica compression trimmer (ARCO 463 or equiv.).[5]
J1 — Female BNC connector.
L1 — 2.9-µH air-wound coil, 1/2-in-dia, 2-in long with 16 tpi (Airdux 416T or Miniductor 3003).[5]
L2 — 5.0 µH, 32 turns of enameled wire on a T50-2 core.[5] (See text for explanation of secondary.)
Q1 — 2N5484 N-channel JFET with low V_p (see text).[4]
Q2 — 2N5486 N-channel JFET with high V_p (see text).[4]
Q3 — MPS3640 PNP switching transistor or equiv.[6]
RFC1 — 200-µH molded choke (J. W. Miller 9210-90 or equiv.).[4]
S1 — Subminiature SPST toggle.

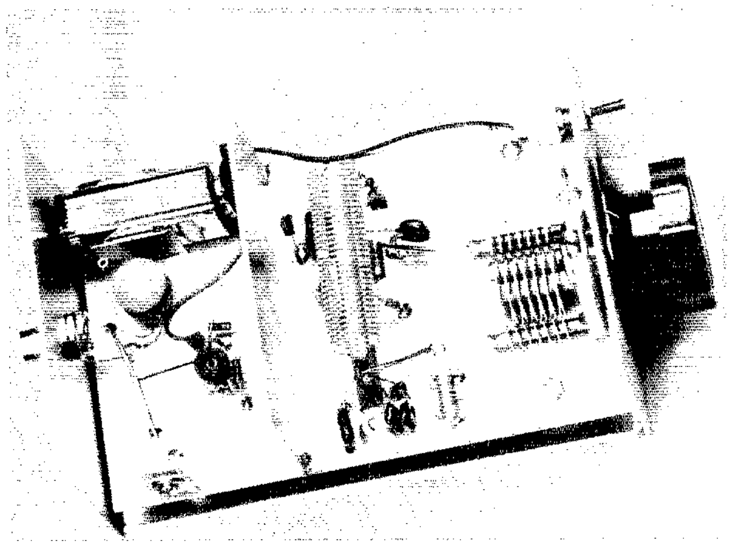


Fig. 2 — Inside view of the VFO showing the placement of parts.

pedance at the drain of Q1, doing away with the need for a power-hungry regulator or Zener diode at that point. The power consumption of Q1 is held to only 2.5 mW, which aids stability significantly.

The drain lead of Q2 passes through the shield wall and is dc coupled to Q3. Note that this lead is the *only* lead to exit the inner shield. It serves double duty as it carries battery power to Q1 and Q2, and carries out the signal to Q3. To reduce power consumption and clean up the oscillator signal, Q3 operates as a class-C amplifier with a high-Q tuned load. Power is furnished to the transmitter as needed by this stage. If the transmitter load is the grid of a tube, as it is in my case, the load is light and the total current consumption is only about 2 mA!

Construction

Although a PC board can be used for the VFO, I was lazy and used the "ugly" direct-wiring method of construction (see Fig. 2). Parts are wired over a ground plane of single-sided PC board. An eight-point insulated terminal strip holds Q1 and associated parts (including L1) rigidly. C1 and S1 are mounted on the front of the 3 × 4 × 6-in (HWD) LMB aluminum box.[4] J1 is mounted on the rear of the box. A PC-board partition shields Q1 and Q2 from the output stage energy. A small hole is drilled in the partition to allow the drain lead of Q2 to pass. Purists may want to place Q1, Q2 and the associated circuitry within a completely shielded enclosure, although that seems to be overkill for this design. On the other side of the partition, Q3 is mounted in a socket. L2 is sandwiched between two fiber washers and mounted above the ground plane by means of nylon hardware. C2 and C3 are soldered directly to the ground plane along one edge of the board and oriented such that a screwdriver can turn them while the box cover remains partially on.

Q2 should have a higher (at least 0.5 V higher) pinch-off voltage (V_p) than Q1 to obtain best performance. The transistor types listed virtually assure this condition, but using other transistor types, such as the 2N4416, 2N5485 or the popular MPF102, will require some testing. The simple V_p test described in Fig. 3 should be used regardless of transistor type(s) selected to

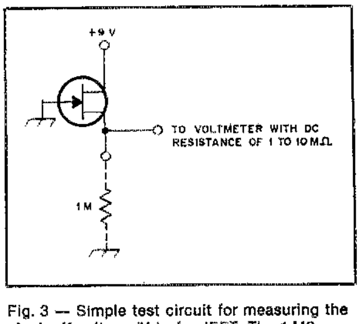


Fig. 3 — Simple test circuit for measuring the pinch-off voltage (V_p) of a JFET. The 1-MΩ resistor is needed only if your voltmeter has a dc input resistance greater than 10 MΩ. A low-impedance VOM (i.e., 20 kΩ/V) can also be used, but with reduced accuracy. The supply voltage should be greater than the highest anticipated V_p.

guarantee that the device with the higher V_p is used for Q2.

Power-Up and Adjustment

Connect 1 to 3 feet of RG-58 coaxial cable to J1. If a substantially greater length, or a higher-capacitance coax is used, you may have to reduce the inductance of L2 to establish resonance. Connect the coax to an oscilloscope if you have one, or just let it hang. Turn on the VFO power and check the voltages at the top of R1 and the drain of Q1 for values close to those indicated on the schematic diagram. Since the performance of JFETs varies quite a bit, the values you get may vary also. Tune your receiver to the VFO signal, or use an oscilloscope or dip meter to sense oscillation. If the VFO is not oscillating, the trouble could be caused by low gain at Q1; reduce R1 to induce oscillation. For best performance, the value of R1 should be as large as possible, consistent with quick starting. You may want to use a small trimmer potentiometer for R1 and change to a fixed resistor later on, or leave the trimmer in place.

Once the circuit is known to be oscillating, put the box cover part way down, leaving room to adjust C2 and C3. Connect a milliammeter across S1 (with the switch open) so as to monitor supply current. Using an accurately calibrated receiver or a frequency counter, adjust C2 for a frequency of 5.049 MHz with C1 fully meshed. With C2 unmeshed, the frequency should be slightly greater than 5.075 MHz. Now, adjust C3 for a sharp current dip (to about 2 mA), indicating resonance for L2. This current will vary from transistor to transistor. It will also depend on the unloaded Q of L2, and eventually on the load resistance presented by your rig. You can close the box now and check for frequency drift from a cold start.

The performance of my VFO is shown in Fig. 4, as measured in a fairly temperature-stable room. From a cold start, drift measured 19 Hz (38 Hz at 10 MHz) over the first 15 minutes of operation. Beyond the first several minutes, the drift was near the jitter and resolution capabilities of my frequency counter. This may explain a few of the erratic points on the graph.

An alkaline 9-V battery has a capacity of 550 mAh, giving the VFO a potential operating life of over 250 hours on one battery. A carbon-zinc battery can yield about 60 hours with its 125-mAh rating. NiCd batteries of the 7.2-V variety (80 mAh) have been used, also with good results. Unless you happen to get some JFETs with very high V_p (6 V), the unit will operate well down to the last gasp of the battery.

Applications

The VFO can be coupled to the oscillator or buffer stage of your rig by direct connection, through a dc-blocking capacitor, or via a secondary winding of your choice wound on L2 (shown as a dotted winding in Fig. 1). You will probably have to retweak C3 for a dip after connecting the VFO to your transmitter. There is sufficient output from Q3 to drive a tube into nonlinear conduction, thus creating the desired second harmonic. In some cases, the tube may have to be rebiased closer to cutoff to enhance nonlinear action. If you're fortunate enough to have a wide tuning range in your transmitter stages, as I have in the Viking II, then your rig will develop 10-MHz output and drive a 50-ohm load without the need for any modifications. I coupled the VFO through a 150-pF, 500-V capacitor to the grid of the oscillator tube with the band switch set to 20 meters. The 6AU6 oscillator stage operates straight through, and doubling takes place in the 6AU5 buffer stage. The dual 6146 final amplifiers load my inverted V easily through the wide-range pi-network output circuit.

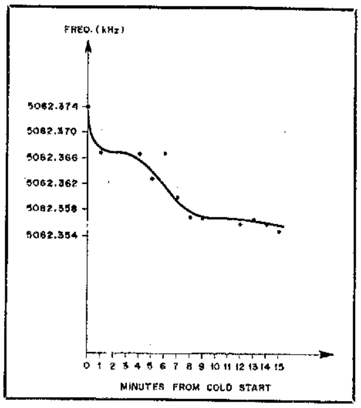


Fig. 4 — Measured frequency drift of the VFO over a 15-minute period beginning with a cold start. After 8 minutes, the drift approaches the resolution of the counter (1 Hz).

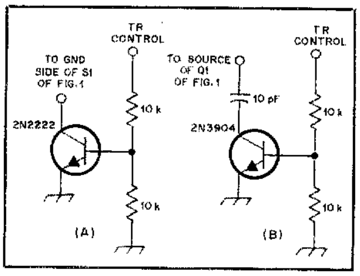


Fig. 5 — Suggested circuit additions to eliminate the possibility of hearing the continuously operating VFO during receiving periods. At A, the transistor shuts off the VFO during receive mode. With the circuit at B, the VFO frequency is "pulled" lower when receiving.

Normally the VFO runs continuously, but some rigs may allow sufficient key-up VFO leakage to mask weak-signal reception. You can turn off the VFO during receiving periods by connecting the simple transistor switch of Fig. 5A in series with the ground side of S1. Alternately, you can "pull" the VFO frequency during receiving periods by connecting the capacitor switch of Fig. 5B to the source of Q1.

This VFO is also at home with transistor rigs, homemade or commercial. Use a second winding on L2 to step the voltage and impedance down when driving transistors. Q3 is able to supply a surprising amount of power if called on to do so. Expect battery drain to increase and the output network Q to fall, allowing a higher harmonic content in the output. Of course, there will also be more heat generated within the box if you draw more power from the VFO.

Give the Rig a Second Chance

I hope this article has stirred your interest. Remember how well that old rig served you? Well, it deserves a second chance. Give it a purpose in life on 30 meters and discover the excitement of our newest band.

Notes

[1] D. DeMaw, "Building and Using 30-Meter Antennas," *QST*, Oct. 1983, p. 27.
[2] DeMaw, "A VXO CW Rig for 30 Meters," *QST*, Nov. 1983, p. 31.
[3] DeMaw has often cautioned readers about the potential unpredictable temperature coefficient of silver-mica capacitors. I have never experienced any trouble with them, however. Typical temperature coefficients for those units average about +50 ppm. The builder can always substitute NP0 ceramic or polystyrene types with good results.
[4] mm = in × 25.4.
[5] Available from Radiokit, Box 411, Greenville, NH 03048.
[6] Available from Circuit Specialists Inc., P.O. Box 3047, Scottsdale, AZ 85257.

Reference

Hayward, W. and D. DeMaw. *Solid State Design for the Radio Amateur*. Newington: ARRL, 1977.

Strays

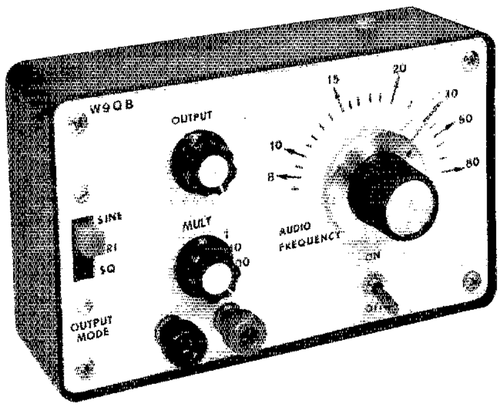
I would like to get in touch with...

☐ anyone with information on obtaining a TC9105P PLL synthesizer chip for a Motorola 550 AM/SSB 11-meter CB radio converted for amateur use. M. R. Viney, G6MRV, 8 Pine Close, Thornbury, Bristol BS12 1AS, Great Britain.

☐ anyone who can steer me to a wiring diagram for a Millen VFO, type/model 90700, vintage '40s. Joseph H. Kadlec, W9UIN, 1035 Asbury Ave., Evanston, IL 60202.

A Simple Function Generator

Are there gremlins in your audio? This inexpensive, home-built signal generator will help you track them down.



By Harry M. Neben,* W9QB

This function generator can produce a sine, square and triangular-wave output. It has relatively low distortion on the sine waveform, good linearity on the triangular waveform, a wide frequency range and relatively high output. It requires few components and is simple to build.

Signal Purity

The waveforms available from this oscillator are shown in Fig. 1. You can see that they are quite acceptable for most ham applications. I don't agree with those who demand a high degree of signal purity when it is not necessary. You purists can stop right now and go back to reading Grimm or Andersen. This is not a precision instrument, but one that will be useful in most ham shacks.

The Integrated Circuit . . .

The heart of this generator is the ICL8038 waveform generator (Radio Shack No. 276-2334). The ICL8038 is a monolithic integrated circuit, capable of producing sine, square and triangular waveforms with a minimum of external components. Signal frequency is controlled by a timing capacitor, a resistive divider and the voltage applied to the FM-sweep input. Thus, with the proper selection of timing components and a variable voltage connected to the sweep input, a wide-frequency-range function generator may be constructed.

. . . And How It Works

Operation of the 8038 is easily understood if you refer to Fig. 2. An external capacitor, C, is charged and discharged by current source no. 1, which is on continuously, and current source no. 2, which is switched on and off by a flip-flop. If you assume that current source no. 2 is off, and the capacitor is charged with a current *i*, the capacitor voltage rises at a constant rate with time. When this voltage approximates two-thirds of the supply voltage, comparator no. 1 triggers the flip-flop, which switches on current source no. 2. This current source supplies a current of $-2(i)$ and discharges the capacitor with a net current of *i*. Therefore, the capacitor discharges at the same constant rate as it is charged. When the capacitor discharges to one-third of the supply voltage, the flip-flop is triggered to the original state and the cycle repeats.

The equal charge and discharge rates produce a triangular waveform across the capacitor, while the flip-flop produces a

[1]Notes appear on page 39.

*1151 Fairway Dr., Dunedin, FL 33528

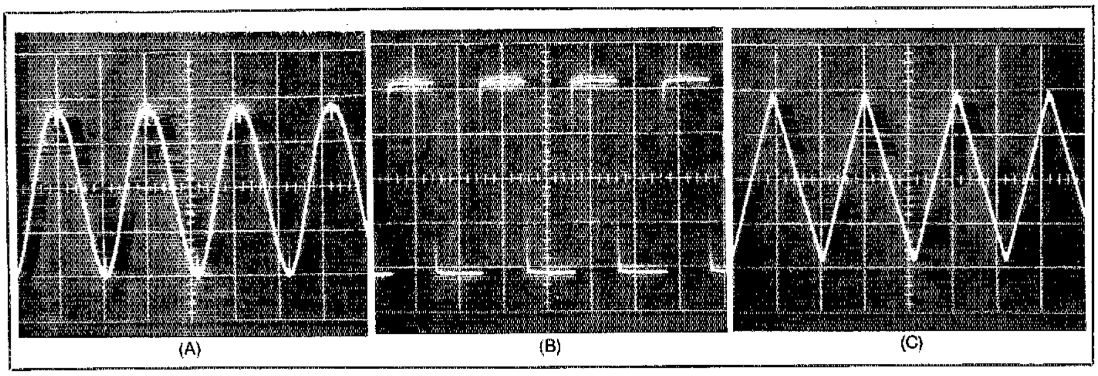


Fig. 1 — Output waveforms from the Simple Function Generator: sine (A), square (B) and triangular (C) waves.

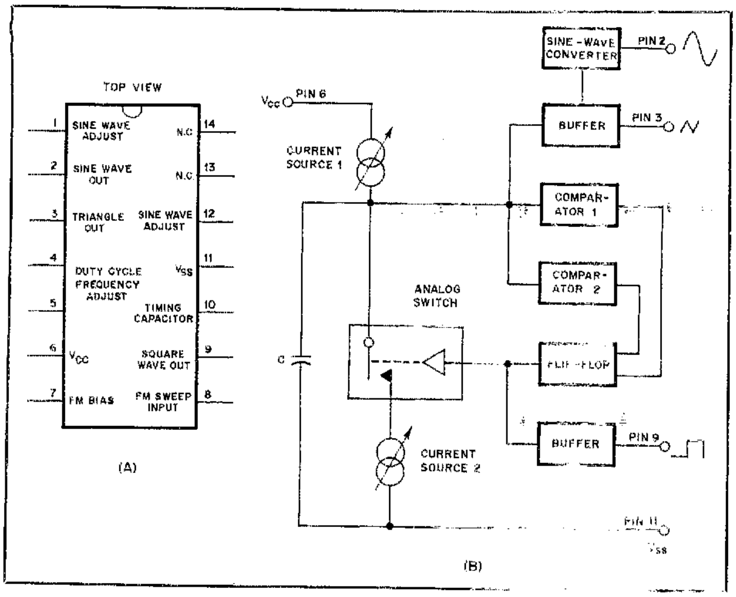


Fig. 2 — Pin-out (A) and block (B) diagrams for the ICL 8038 waveform generator.

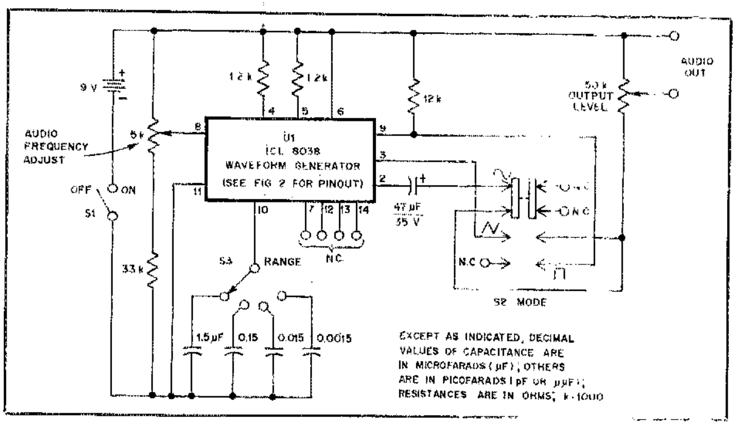


Fig. 3 — Schematic diagram of the Simple Function Generator. Capacitors are computer grade. Polarized capacitors are electrolytic.

S1 — SPST toggle switch.
S2 — 4P3T switch.
S3 — Four-position rotary switch.

U1 — ICL8038 (Intersil) waveform generator IC (RS 276-2334).

square wave. These waveforms pass through buffer stages and are available at pins 3 and 9, respectively.

Two external resistors can vary the levels of the current sources over a wide range. With the two currents set at different values, an asymmetrical sawtooth waveform appears at pin 3, and pulses with a variable (from 2% to 98%) duty cycle are available at pin 9. (This option is not implemented in the Simple Function Generator.)

A sine wave is formed by feeding the triangular wave into a sine-converter network. This network provides a decreasing shunt impedance as the potential of the triangular wave increases toward each of the two voltage extremes.

Construction

All components used in the function generator are readily available to most radio amateurs. The circuit is mounted in a 6 × 3 × 2-in box.[1] The IC, socket and most components are mounted on a pre-etched experimenter's printed-circuit board.

The frequency range is selected by a four-position rotary switch (labeled MULT). Frequency, within a range, is controlled by the AUDIO FREQUENCY potentiometer. An OUTPUT MODE switch selects the desired waveform. This is shown as a slide switch, but any two-pole, three-position switch may be used. The OUTPUT control varies the voltage available at the front panel binding posts. There is nothing sacred about the placement of these controls or the size of the case.

The "range" capacitors were selected by experimentation. Decade-related capacitors with 10% tolerance are available.[2] If you are satisfied with this accuracy, use them. I chose the 1.5-µF capacitor for the low range (8 to 80 Hz). Then I picked a 0.15-µF capacitor for the next range and "trimmed" it with a suitable fixed capacitor connected in parallel. With the audio frequency set to 20 Hz, I increased the range setting to 10 and found that only 500 pF is required to adjust the 0.15-µF capacitor for resonance at 200 Hz. This procedure was repeated for the 100 and 1K positions of the switch.

The oscillation frequency is controlled by a voltage supplied to pin 8 of the IC. This voltage is set by a resistive divider, comprised of a 5 kΩ potentiometer and 33-kΩ resistor. The maximum voltage is about 1.2 with a 9-V battery as a power source. Frequency calibration will change slightly as the battery ages. A Zener diode that would clamp the voltage across the resistive divider could be added to the circuit; however, as the scale of this unit is broad, I do not consider this refinement worth the cost and reduced battery life.

Operation

The oscillator output is fed to a three-position switch. This switch connects the selected waveform to a 50-kΩ potentiometer that controls output amplitude. This works fine for the sine-wave output, but I caution the user regarding the triangular and square waveforms. These waveforms will be satisfactory only if the circuit under test does not significantly load the function generator. One way to overcome this condition is always to set the OUTPUT control for maximum signal level. This should not be a great problem for the user, but a word of caution is in order.

The original battery in this project was a 9-V unit, as used in portable radios. Since the current drain is about 20 mA, I recommend the use of 6 AA batteries instead.

This oscillator has been in use at W9QB for about a year, and has given excellent service. It is stable and does not appear to be affected by stray RF in the shack. It certainly is simple to build, and the square waveform is very useful in audio amplifier repair and maintenance. Let the gremlins beware!

Notes

[1] mm = in × 25.4.
[2] One source for the timing capacitors is Mouser Electronics, 11433 Woodside Ave., Santee, CA 92071, tel. 619-449-2222.

Product Review

Conducted By Paul K. Pagel,* N1FB

Yaesu Electronics Corp. FT-726R VHF/UHF Transceiver

If you made a "wish list" of features you wanted in a rig for the bands at 6 meters and above, chances are good that Yaesu's newest multimode VHF/UHF offering would fulfill many of your desires. The FT-726R — a high-performance, multiband rig about the size of many modern HF transceivers — ushers in a new era for the serious VHFer.

Multiband Capability

One prime consideration on my wish list is multiband capability. Although multimode rigs for 50, 144 and 432 MHz abound, it would be great to have everything in one tidy package. The cost of separate rigs for each band really adds up at $400 to $900 a crack, and separate rigs (perhaps with outboard power supplies) take up a lot of table space. Besides, those HF guys get as many as nine bands in one box, so why not us?

The FT-726R operates on the three most popular VHF/UHF bands worldwide — 6 meters, 2 meters and 70 cm. Two-meter coverage comes standard with the rig (the exact coverage depends on which parts of the band are permitted for use in your part of the world). Optional modules for 6 meters and 70 cm are available for far less than the cost of separate rigs for those bands.

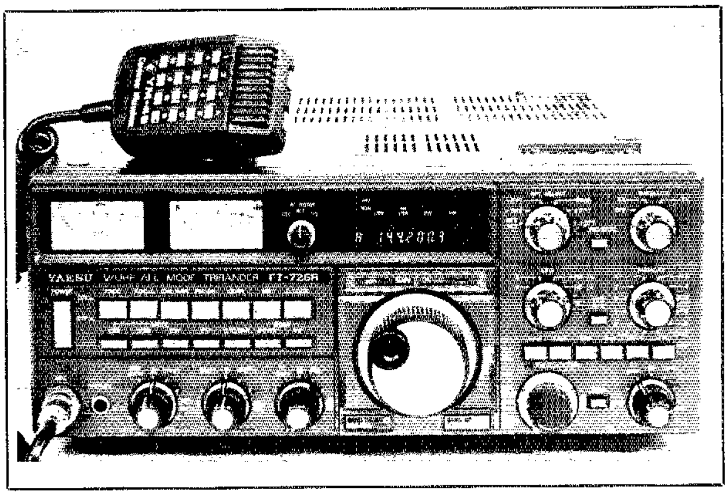
Basically, the '726 can be thought of as a 10-MHz IF unit with separate transverter modules for each band. The main unit houses the power supply, the VFO, the 10-MHz transmit and receive section, and the audio and display sections, which are common to all bands. Each band module contains the RF circuitry for that band, a PLL, a power amplifier and appropriate switching circuitry. An 8-bit microprocessor-based controller keeps everything running smoothly. With this arrangement, the FT-726 can conceivably be expanded to include other VHF/UHF bands.

The review transceiver was supplied with the 50-54 MHz and 430-440 MHz modules. Up to three modules may be installed in the FT-726 at any time. Module installation is a snap. Just remove the top and bottom covers, place the module in one of the vacant positions, and bolt it in place with five screws. Wiring is even easier — Yaesu provides three multiconductor ribbon cables that run from the back of each module to the audio board. Each cable has a different number of conductors, and the path they follow is short and straight, so there is little chance of a wiring error.

Features

Looking at the front panel, you might well think that the FT-726R is a state-of-the-art HF rig. Yaesu's VHF/UHF flagship includes IF SHIFT and WIDTH controls, separate AF GAIN and RF GAIN controls, selectable AGC, a CLARifier (RIT) knob, a noise blanker, a switch to place an optional 600-Hz CW filter in the 455-kHz IF, separate MIC GAIN (for SSB) and DRIVE (for CW

*Assistant Technical Editor



Yaesu Electronics Corp. FT-726R VHF/UHF Transceiver, Serial No. 3K070227

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency Coverage: 50-53.99998 MHz (optional); 144-147.99998 MHz; 430-439.99998 MHz (optional); 440-449.99998 MHz (optional).	50-53.99998 MHz; 143.5-148.499998 MHz and 430-439.99998 MHz (optional) modules installed in review unit.
Modes of operation: USB, LSB, FM, CW.	As specified.
kHz/turn of knob: 10 or 100, switchable.	As specified.
Frequency display: 7 digit.	Blue fluorescent, ¼-in-high digits.
Frequency resolution: 100 Hz.	As specified.
Backlash: Not specified.	Nil.
S-meter sensitivity (μV for S 9 reading): Not specified.	50 MHz: 19; 144 MHz: 18; 432 MHz: 2.7.
Transmitter power input: 20 W on 50 MHz; 30 W on 144 and 432 MHz. 10-W output on all bands.	Power output: 50 MHz, 12 W; 144 MHz, 11 W; 432 MHz, 12 W.
Harmonic suppression: Not specified.	Better than 70 dB.
Spurious suppression: Better than 60 dB.	Better than 70 dB.
Third-order IMD: Not specified.	−30 dB worst case.
Receiver sensitivity: CW/SSB — less than 0.15 μV for 10 dB S+N/N; FM — less than 0.25 μV for 12 dB SINAD.	Receiver dynamics measured with optional 600-Hz CW filter installed.

	6 m	*2 m*	*70 cm*
Noise floor (MDS) dBm:	−141	−140	−138
Blocking DR (dB):	121.5	116.5	107
Two-tone, 3rd-order IMD DR (dB):	86	90.5	80
Third-order intercept (dBm):	−12	−4.25	−18
Receiver quieting (μV for 12 dB SINAD).	0.16	0.18	0.14

Squelch sensitivity: Not specified.	Min. 0.053 μV; max. 0.55 μV
Receiver audio output @ 10% THD: 1.5 W min.	2.2 W.

Color: Two-tone gray.
Size (HWD): 5.1 × 13.1 × 12.4 in (129 × 334 × 315 mm).
Weight: 24 lb (11 kg) without optional modules.

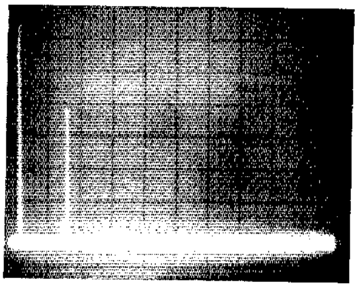


Fig. 1 — Worst-case spectral display of the Yaesu FT-726R. Vertical divisions are each 10 dB; horizontal divisions are each 100 MHz. Output power is approximately 10 W on 2 meters. The fundamental has been reduced in amplitude approximately 32 dB by means of notch cavities to prevent analyzer overload. All harmonics and spurious emissions are at least 70 dB below peak fundamental output. The FT-726R complies with current FCC spectral purity specifications.

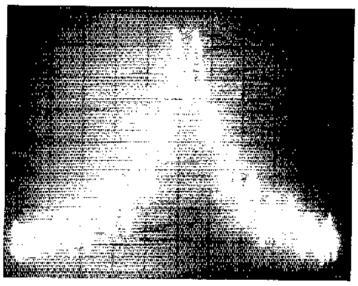


Fig. 2 — Spectral display of the FT-726R output during two-tone IMD testing. Third-order products are about 30 dB below PEP, and fifth-order products are approximately 42 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 2 kHz. The transceiver was being operated at rated output power on the 6-meter band.

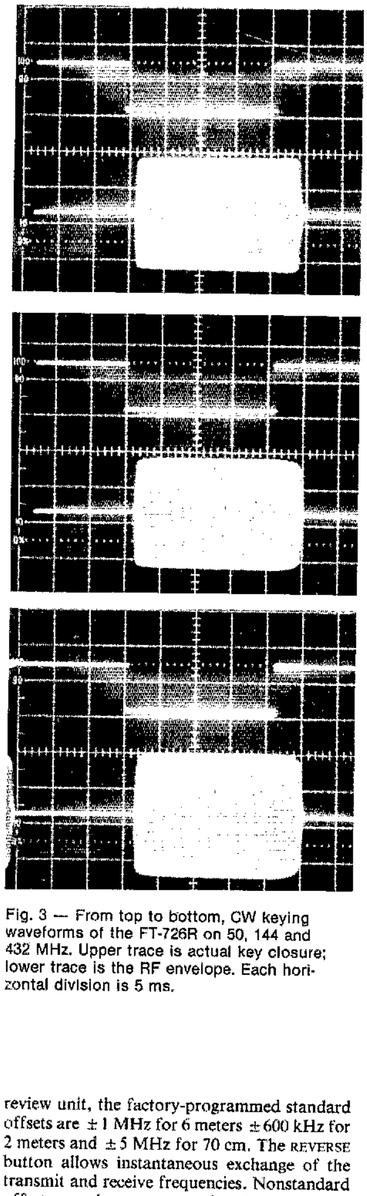


Fig. 3 — From top to bottom, CW keying waveforms of the FT-726R on 50, 144 and 432 MHz. Upper trace is actual key closure; lower trace is the RF envelope. Each horizontal division is 5 ms.

and FM) level controls, and a speech PROCESSOR switch.

For the low-end CW/SSB enthusiast, these features make the FT-726 a powerful tool. For example, the CW filter works very well. When the filter is used with the IF SHIFT and WIDTH controls, it is possible to dig a weak signal out of a pile of strong locals — a feature especially useful on the VHF bands where the locals are often orders of magnitude stronger than the DX. The noise blanker is effective against impulse noise from power lines and passing automobiles. The selectable AGC is useful, too. Many multimode VHF rigs have only one AGC setting with a very slow decay. For FM, this type of AGC is fine, but on CW and SSB it is very annoying when the AGC cannot track a rapidly fluttering signal, making for difficult copy.

As an FM transceiver, the '726 is a strong performer. In addition to SIMPLEX operation, standard plus and minus repeater offsets may be selected from the RPT SELECT switch. In the review unit, the factory-programmed standard offsets are ± 1 MHz for 6 meters ± 600 kHz for 2 meters and ± 5 MHz for 70 cm. The REVERSE button allows instantaneous exchange of the transmit and receive frequencies. Nonstandard offsets may be programmed and stored in the SFT SET position.

Another feature of interest to the FM operator is the FM-CH selector. When this control is activated in the FM mode, it allows the user to tune up and down the band in 10-kHz increments (switch-selectable to 5-kHz increments). This feature makes tuning around the FM portion of the bands a breeze. With the main VFO knob, it can be work zeroing in on the desired frequency, and at 10 kHz per knob revolution, it seems to take forever to get from channel to channel. With the FM-CH control, however, the channels flash past, and once the desired frequency is reached, there is no additional tuning required. It's just like having a channelized FM-only rig.

FM operators will probably appreciate the discriminator center-tuning meter and the standard tone-burst generator. A selectable continuous tone-coded squelch system (CTCSS) board is available as an option. The optional YM-48 hand-held microphone incorporates a tone pad.

The VFO and memory features on the '726 offer state-of-the-art flexibility. This rig contains two VFOs, which may be set up for in-band split-frequency operation or for crossband operation. When more than one band module is installed, the effect of having the VFOs set on different bands is like having two separate radios in one box. Eleven user-programmable memories are included. These memories store frequency and mode, and they may be used for a number of purposes. They can be used to store popular repeater frequencies, the calling frequencies for each band, or frequently used net or schedule frequencies. For example: MEMORY 1 might store 146.52-MHz FM; MEMORY 2 for 144.200-MHz SSB; MEMORY 3 for 432.100-MHz CW. Various controls allow switching among the memory channels, switching from memory to VFO and writing the frequency from the VFO into the memory.

Like many VHF rigs these days, the FT-726 has an elaborate scanning feature. It is possible to scan a band from top to bottom, a select portion of a band, or just the 11 preprogrammed memories. Through switches on the top panel, the scanning feature may be programmed to halt only on busy or clear channels, or when manually directed to halt by front-panel controls. In addition, the scanner may be set to halt momentarily (PAUSE), or to STOP.

Satellite Operation

Perhaps the most intriguing option available for the FT-726R is the satellite IF unit. With this option and two of the RF modules installed, the FT-726R may be used for full-duplex crossband operation. The satellite unit includes a complete additional IF system, so the result is really full duplex.

Despite initial misgivings about the ease of duplex operation with one radio, full-duplex satellite operation proved to be straightforward. To set the '726 up for satellite work, simply tune one of the VFOs to the desired transmit band and frequency. Set the RPT SELECT switch to SIMPLEX. Tune the other VFO to the receive band and frequency. The receive and transmit bands must be different. Then, set the VFO selector to the appropriate split operation setting (RA-TB to receive on VFO A and transmit on VFO B, or vice versa.) Next, switch the SATELLITE selector to the RX position. Set up like this, the FT-726 will transmit on the frequency for which it was initially set. Spotting is accomplished by tuning the main tuning knob, which now controls only the receive VFO, until the downlink signal is heard. Alternatively, the SATELLITE selector could be set to the TX position. In this position, the receive frequency stays put and the tuning knob controls the transmitter.

During actual operation, the FT-726 proved to be just as easy to use as two separate rigs. We set the radio up in the W1AW satellite operating position one lunchtime to try working through OSCAR 10. We set one VFO on the 435-MHz uplink and the other on the 145-MHz downlink, and hit the key. Our signal was perfectly copyable, even when using the FT-726R barefoot. During this time, we tried bringing the transmit frequency to stations calling CQ and bringing the receiver frequency to our CQing frequency. The FT-726 works like separate rigs.

There is no switching noise or desense; just smooth, quiet, full-duplex operation.

General Operation

The lab tests indicated that the receiver is "hot," and on-the-air operation confirmed that observation. Although not the equivalent of a system incorporating a high-performance receive converter with a GaAsFET front end and a good IF receiver using a clean crystal oscillator, the FT-726R is a step ahead of most other synthesized VHF multimode radios. Reciprocal mixing noise from the synthesizer is noticeable on stronger signals, but it is held to a tolerable level.

In addition to separate antenna connectors for each band module, Yaesu has thoughtfully provided separate amplifier key lines for each band as well. An operator active on more than one band can have separate amplifiers connected at all times without the hassle of external relays or relay switches.

The review '726 saw active duty during the ARRL 6- and 2-meter Fall Sprint contests, as well as during the ARRL January VHF Sweepstakes. Several operators used the rig; all commented that it is easy to use, the controls are in the right places and the receiver sounds good. Signal reports from other stations indicate that the audio quality is good and the CW signal is click free. Many of the operators who were asked for speech processor in/out comparison reports said that it added little, if anything, to the signal.

One glaring omission on the features list is VOX operation on SSB. The FT-726R incorporates semi-break-in operation on CW, however. There is also a rear-panel jack for an external PTT switch (e.g., a foot switch). My operating style does not require VOX operation on SSB, but it seems strange to find a rig with so many features that does not include this standard convenience.

Yaesu's newest VHF/UHF transceiver is certainly worth considering if you're in the market for a new rig. Even if you're only interested in 2 meters right now, the ability to add other bands at any time makes it an attractive box. If you like satellite operation, or would like to give it a try, take the time to see a '726 in action before spending those hard-earned dollars on separate radios.

Price class for the basic FT-726R with the 144-MHz module is $900. Price class for the options: XF-455MC CW filter, $60; 50-MHz-band module, $200; 430-MHz-band module, $300; satellite IF unit (SU), $100; 440-MHz unit, $250; HF module, $225; 144-MHz module (as a separate unit), $175; YM-48 hand-held microphone, $70. Manufacturer: Yaesu Electronics Corp., 6851 Walthall Way, Paramount, CA 90723. — *Mark Wilson, AA2Z*

HEATHKIT CANTENNA, MODEL HN-31A

☐ No Amateur Radio station is complete without a dummy antenna (also called a dummy load). Eventually, we all have a need to test a transmitter off the air. A dummy load makes leisurely testing possible while keeping signal radiation to a minimum. This will please the FCC and your fellow hams. A dummy load is also useful when testing receivers. It resembles an antenna electrically, but it does not pick up external noise and signals like an antenna; that's a desirable feature in some tests.

Electrically, a dummy load is a resistor. Not just any resistor, it must have certain

characteristics. The resistance must equal the characteristic impedance of the system in which it is used; for most systems that is 50 ohms. Ideally, it should have pure resistance; that is, there should be no reactance. In the real world, that is not possible; inductance and capacitance are always present. Further, for transmitter tests, the load resistor must be capable of safely dissipating the transmitter output.

The Heathkit HN-31 Cantenna has been around for a good many years. I have had one in my shack for about as long as I can remember. About a dozen years ago, an HN-31 was a fixture in the truck and at the bench I used in the two-way FM service business. For many of us, the name Cantenna is synonymous with dummy load.

A New Model

One immediately notices that the HN-31A is different. Gone is the small rectangular box with an SO-239 connector at one end and a phono jack at the other. The SO-239 is still there, now center-mounted and positioned vertically on the lid. The identification label is no longer painted on the can — a bright, three-color stick-on label is provided. Inside, the only noticeable change is the connector mounting. The result is that the connection between the SO-239 and the load resistor is more direct in the '31A.

There is one significant change in the electrical specifications. The '31A is rated for an SWR of less than 1.5 up to 450 MHz. (In the '31, the 1.5 SWR frequency is specified as 300 MHz, and for an SWR of 2, it is 400 MHz.) Fig. 4 shows SWR curves for an HN-31, an HN-31A and a Bird model 82 dummy load. Amateur bands between 50 and 450 MHz are identified so that you can

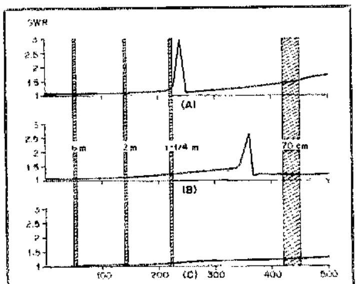


Fig. 4 — SWR curves for the Heath HN-31 shown at A, HN-31A at B and Bird model 82 at C.

make your own comparisons easily. As you can see, the models I tested in the ARRL lab readily surpassed their rated performance. There is a "bump" in the SWR curve for each of the Heath Cantennas. In the '31A, the bump is well removed from any amateur band and, for that reason, should not be a problem.

SWR below 30 MHz is better than 1.07 for the '31A. That compares to 1.1 or better for the '31, and better than 1.02 for the Bird '82. (At 1.8 MHz, the Bird '82 has an SWR of better than 1.006.) Certainly, the HN-31A is more than adequate for Amateur Radio use — at 450 MHz, the SWR was better for the '31A than for the Bird '82!

The '31 had a built-in peak RF voltage detector. The loss of that feature is a small price to pay for the improved SWR performance of the '31A. Chances are, most would never use that feature anyway, especially if there is a wattmeter in the shack.

The power-handling capability of the '31A remains the same as for the '31. When power is applied to the Cantenna, the 50-ohm resistor element absorbs the power and converts it into heat. The heat is dissipated into a liquid bath that surrounds the resistor element. If that liquid is transformer oil, the load can handle a kilowatt for up to 10 minutes of intermittent operation. [Some transformer oil contains PCBs, a suspected carcinogen. Handle all transformer oil carefully. — Ed.] Mineral oil may be easier for you to locate (Heath does not supply the liquid coolant); it will limit you to one minute at 1 kW, however. Below the 400-W level, mineral oil will work as well as transformer oil. You may be able to get transformer oil through your local power utility. Mineral oil is available at most drug stores. The Cantenna holds 1 gallon (3.79 liters) of coolant.

Final Words

I calculated SWR from return-loss measurements made in the ARRL lab while using a spectrum analyzer, tracking generator and a directional coupler rated to over 1 GHz. After making those measurements, I decided to replace the SO-239 with a type-N chassis connector. It didn't make any significant change in the SWR curve, but it does make it easier to use with my 70-cm station and its N connectors.

A dummy load should be part of every station. The HN-31A is available from Heath Company, Benton Harbor, MI 49022. Price class: $25. — *Chuck Hutchinson, K8CH*

Strays

I would like to get in touch with...

☐ other radio amateurs interested in exchanging RTTY/CW software and hardware ideas for the Timex-Sinclair T/S-1000 computer. John Dowlan, W3HU, 8341 Boyce St., Spring Hill, FL 33526.

☐ anyone who has developed an interface for a Timex Sinclair 1000 computer and Amateur Radio. Charles Hudson, KA2NWP, 44 Nelson Ave., Cooperstown, NY 13326.

☐ anyone who has successfully interfaced the Radio Shack Color Computer II with a Ten-Tec Argosy transceiver for RTTY and CW. Mark Callahan, KA1IGC, 8 Pondview Rd., Norfolk, MA 02056.

Hints and Kinks

Conducted By Larry D. Wolfgang,* WA3VIL

A HOMEMADE KEYER PADDLE

☐ While it may not be possible for the average ham to build a high-performance transceiver, most can construct high-performance station accessories. There is a certain feeling of pride and a sense of accomplishment that goes with using a piece of equipment you have built yourself. In this article, I will describe a keyer paddle that I made. With care and a workshop that is equipped with a drill press and a few other small tools, most amateurs should be able to duplicate the project. Fig. 1 shows my paddle.

The base for my keyer is made from a ¼-inch-thick block of black walnut wood.[1] Any hard wood or other sturdy insulating material should work fine. Fig. 2 shows the dimensions I used. You can vary the dimensions to suit your needs and the materials you have available. A few of the measurements have been purposely left off the drawing. Some of them are not critical, while others should be made as you assemble the paddle, to ensure proper alignment.

Make the hinge block next. Mine is made of ½-inch-thick aluminum, but brass, Plexiglas®, Bakelite® or even hard wood would be fine. Cut it to size, and drill and tap the mounting holes in the bottom. Then, mount it on the base.

Cut the two bars to the dimensions shown and make the stop plate to be soldered to the short bar, as shown in Fig. 2. Cut a piece of 1/16-inch-thick brass strip ¼-inch wide and 1¼-inches long. Form the hinge bracket around the end of the short bar from this piece. Using a high-wattage soldering iron or a soldering tip on a propane torch, tin the inside edge of the hinge bracket and the rear portion of the short bar. Lay the bar inside the bracket and carefully align the pieces, then, sweat them together with a propane torch. Similarly, attach the stop plate at the opposite end of the short bar. See the assembly detail in Fig. 2.

The inside back edge of the long bar must be rounded, to allow it to pivot against the short bar after they are pinned together. Clamp the bars together and secure them to your drill-press table. Then, drill the 1/16-inch hole through the hinge bracket and long bar. Drill through the top part of the hinge block, insert the bars in the opening, push the drill through the long bar, and drill into the base of the hinge block. You need not drill all the way through the hinge block. Drilling these holes is probably the most critical part of the project. Clamp everything in position before drilling, and be certain that the hole for the hinge pin does not go through the long bar at an angle.

Use the drill bit to align the hinge bracket and the long bar, and clamp the bars together. A number 38 drill (0.101 inch) is just right to tap the 5-40 hole in the long bar. A 3/32-inch bit is just a little smaller. Drill through both bars for all three holes shown. Tap the hole in the long bar where spring 1 mounts, and enlarge the other two holes with a 3/16-inch drill. Enlarge the mounting hole for spring 1 and the contact point in the short bar.

Almost any small compression spring will work for spring 1. I found the one in a crystal holder to be just about right. It is a good idea to grind the threads off the 5-40 bolt near the head where it extends through the short bar. This will prevent the spring from binding during operation. Spring 2 is fastened to the short bar by means of a loop of no. 21 copper wire soldered to the outside edge of the bar. The spring hooks onto this loop inside the bars.

To fabricate the contact points, place a piece of 3/16-inch brass rod into the drill-press chuck. Run this down against a file or piece of emery cloth to square the end. Cut a ¼-inch piece of the rod and place it in the contact-point hole of either bar. Keep the rod flush with the inside edge of the bar and flow solder around it. Follow the

[1]mm = in × 25.4.

*Assistant Technical Editor

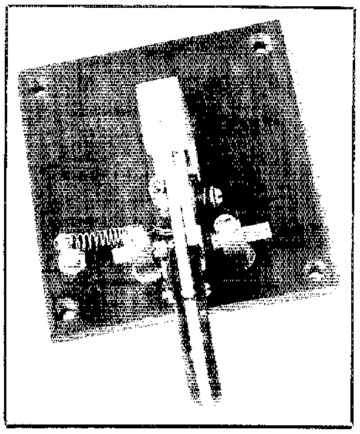


Fig. 1 — The final assembly details of a keyer paddle made by Arnold Harvey, W8OJN.

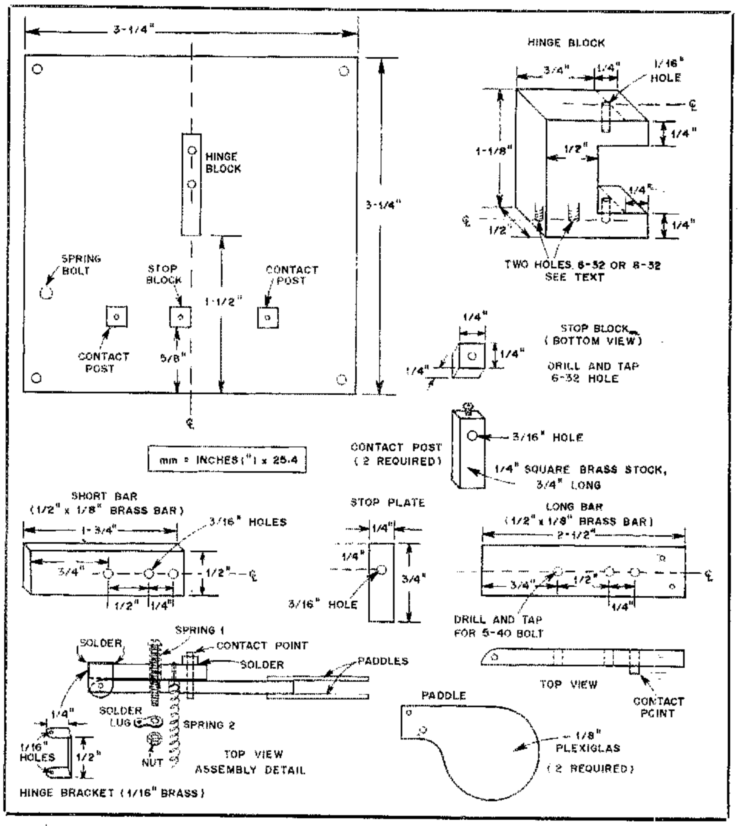


Fig. 2 — Dimensions and construction details are given for the keyer paddle built by W8OJN. See text for assembly instructions for parts where no dimensions are given.

same procedure to insert a contact point in the other bar. Then, file the inside edges so the bars will fit flush together.

Now you are ready for the final assembly steps. Slide the bar assembly into the hinge block and insert the pin. I used the shank from a broken 1/16-inch drill bit. Any portion that extends above the hinge block can be ground off after the assembly is complete.

Mount the stop block to the base so it will prevent the bar assembly from moving left of center. Stand the two contact posts next to the contacts, and mark the position of the contacts. Drill a 3/16-inch hole through each post at that height, and drill a 7/64-inch hole into the top of each post. Tap these top holes for 6-32 set screws. Drill and tap similar holes in the bottom of each post to fasten them to the base. Carefully mark the base holes, and drill 9/64-inch (or larger) holes to mount the contact posts. Use solder lugs on the bottom of the base.

Using the same technique as before, fabricate two 5/8-inch-long contact points. Slide the contacts through the posts, and adjust the spacing to suit your "fist." I insert one or more sheets of paper between the contacts to set the spacing. Then, tighten the set screws.

Cut two handles to a size and shape of your liking, and mount them on the end of the long bar. Wire the contacts as required by your keyer, for right- or left-handed operation.[1] You may want to use a router or other tool to cut grooves in the bottom side of the base for the wires. The base can be mounted on a weighted baseplate or fastened directly to your operating table.

I think you will find that this paddle operates smoothly and has a nice feel. There is very little lost motion. The paddles stay centered and don't flop around, ensuring that only the desired dots and dashes are sent. The stop block holds the assembly in position and prevents the short bar from moving to the left while you are sending a dash. Both bars move to the right to send dots. — *Arnold Harvey, W8OJN, Akron, Ohio*

KEYER-PADDLE CONSTRUCTION IDEAS

☐ Many of us are satisfied with a construction project as long as it works. So we stop with a breadboarded design or a mechanical assembly with lots of "rough edges." With a little thought about available materials and some patience and care in construction, any project can be "dressed up" for an appearance that rivals a commercial unit. It then becomes a source of pride, not just in the operation, but in the craftsmanship of the construction.

I would like to offer a few ideas about construction techniques using hand tools. A keyer paddle serves as an example. I have made several paddles using variations on the basic techniques.

My first consideration is the selection of a material for the base. Wood can be shaped and finished to add beauty to the project. But other materials can also be used. I prefer Masonite®, which is hard enough to withstand screw and nut pressure, yet can be shaped and drilled easily with hand tools, and can be smoothed with a sanding block. The base for the paddle shown in Fig. 3 is made from 3/8-inch Masonite.

One-inch brass angle brackets provide a nice way to mount the paddle blade and contact points. Holes in the brackets can be tapped for

[1]L. Wolfgang, "The 'CHIP' (Cheap, Homemade Iambic Paddle)," *QST*, Oct. 1982, pp. 33-35.

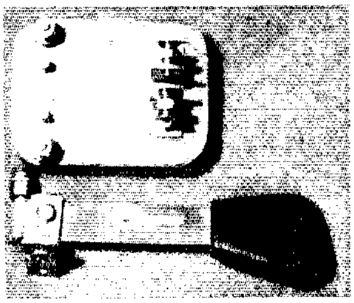


Fig. 3 — Photo showing a partially assembled keyer paddle made by W1HHF.

either 8- or 10-32 machine screws. If the corners are rounded slightly with a file, the appearance will be more professional.

The paddle blade can be a saw blade or other material that has some spring to it. The teeth should be ground or filed off, and the blade sanded clean. I have found that double-sided copper-clad PC board also works well. I solder a small brass contact strip to each side of the paddle blade to serve as contacts. If these are bowed away from the blade slightly, you can achieve a softer contact feel during operation.

A paddle handle can be made from a variety of materials. The important thing is to sand it smooth on all surfaces. It can be cemented to the blade with quick-setting epoxy.

Before mounting everything on the base, I countersink all of the holes for flat-head screws and cut grooves in the material for the wires. The top surface of the base material can be covered with wood-grain contact paper. Punch all holes through from the top using a scribe or awl. Reassemble the parts and securely tighten the hardware.

After assembly, I cut a piece of QSL card to serve as an insulator between the base and a piece of lead sheet used to add weight to the paddle. Take a little extra time to glue each piece to the base and allow it to dry. Contact cement works fine for this part. Trim all of the edges and sand them to produce a smooth surface. Finish the project with a strip of contact paper around the edge. If this is done with care, the base will look almost like a solid block of wood. — *Antonio G. O. Gelineau, W1HHF, Burlington, Vermont*

30-METER CONVERSION FOR THE HW-8

☐ The Heath HW-8 QRP transceiver can be modified easily to operate on 30 meters if you are willing to sacrifice one of the existing bands. I chose to give up the 80-meter band, since I have found it to be the most demanding one, in terms of antenna size, for QRP operation. Thirty meters seems to be an excellent band for QRP operation, and it offers the side benefit of WWV reception, which I use to calibrate my VFO dial.

Complete details of the modification are summarized in Table 1. The only expensive component is the crystal, which costs around $10. The other components can be found in your junk box or purchased from a variety of *QST* advertisers. Five of the original capacitors are reused in other locations.

Remove the control knobs and front panel; then, disconnect the loading capacitor from the front of the chassis. This will make it easier to

Table 1
HW-8 30-Meter Modifications†

Part No.	*New Value*	*Description*
Y1	18.895 MHz	Fundamental type, 15-pF load, HC-6/U holder. International Crystal Mfg. Co., P.O. Box 26330, Oklahoma City, OK 73126. Part no. 434112.
L1	1.8 μH	Secondary — 25 turns no. 24 enameled wire on T37-6 core (Amidon Associates, 12033 Otsego St., N. Hollywood, CA 91607). Primary — 2 turns no. 24 wire over C2 end of secondary (use original coil form).
L5	1.8 μH	25 turns no. 24 wire on a T37-6 core.
L13	4.0 μH	Remove 16 turns from original L13.
L22	2.7 μH	23 turns no. 22 wire on a T50-2 core.
L26, L27	3.2 μH	25 turns no. 22 wire on a T50-2 core.
C1	100 pF	Silver mica, 5% tolerance (use original C116).
C15, C96	100 pF	Silver mica, 5% tolerance.
C64	68 pF	Silver mica, 5% tolerance (use original C1).
C77	230 pF	Silver mica, 5% tolerance (use original C64).
C78	150 pF	Silver mica, 5% tolerance (use original C96).
C94	47 pF	Silver mica, 5% tolerance (use original C15).
C97	300 pF	Silver mica, 5% tolerance.
C116	30 pF	Silver mica, 5% tolerance.
C301A	—	Disconnect from L1.
R50	—	Remove.
R56	1 kΩ	½ W, 10% tolerance.

†Refer to HW-8 schematic diagram for part locations.

get at the components to be changed in the crowded area around SW1 (the 80-meter band switch). Remove the indicated components using a vacuum desoldering tool, solder wick or a piece of flattened braid from coaxial cable.

After the new components have been installed, the rig can be aligned according to the instructions in the HW-8 assembly manual. The only problem I encountered was that I had lost the small tuning tool used to adjust L17 in the heterodyne oscillator. I found that the larger tool or even an Allen wrench can be used. Carefully insert the tool through the top slug and tune the bottom slug for maximum output on 30 meters. Then, back the tool out and readjust the top slug (L18) for maximum output on 40 meters.

The transmitter dc power input should be about 3 W. The VFO will cover 10.0 to 10.25 MHz. Dial accuracy seems to be a problem with the HW-8, so it may be difficult to determine the band edges without a frequency counter. This is where WWV can assist you. Just be sure to stay within the legal segments (10.100-10.109 and 10.115-10.150 MHz). If in doubt, don't transmit. — *Wayne Burdick, N6KR, Santa Barbara, California*

Technical Correspondence

Conducted By
Bob Schetgen,* KU7G

The publishers of QST assume no responsibility for statements made herein by correspondents.

C 64 KEYBOARD

□ Dan Whipkey's program ("A Keyboard Keyer and Code-Practice System," Jan. 1984 *QST*) makes the VIC 20™ computer function as an excellent CW keyboard. Dan's program performs well because the Morse characters are generated in a compact machine-language routine. While the C 64 uses a 6510, rather than a 6502 microprocessor, the 6510 executes 6502 instructions; conversion of the program for the C 64 is not difficult. All changed lines and additional lines required for program operation on the C 64 are shown in Table 1.

The C 64 user-port location and memory map are different from those of the VIC. All references to the VIC user port (line 410) and Data Direction Register, DDR, (lines 310, 790, and 1340) must be changed for the C 64 user port and DDR (see Table 2). The user port is keyed in line 410 by writing a one to the port for "on," or a zero for "off." Memory locations zero and one, used by Whipkey's program for temporary storage (lines 190, 390, 420 and 1110), are used for memory control in the C 64; locations 251 through 254 are suitable substitutes.

A 6581 Sound Interface Device (SID) IC in the C 64 needs control statements that are not in the VIC program. All SID controls are set to zero in line 111. Line 112 sets Voice-One frequency (800 Hz), Attack/Decay, Sustain/Release and initial-volume parameters; Voice One is switched on by writing a 17 ($11) to the Voice-One control register (location S+4) for the audio-level adjustments. Lines 113 through 119 are an input loop that sets the audio level. Line 118 switches Voice One off by writing a zero to the control register. Voice One is keyed in lines 400 and 410 during keyboard and practice operation. — *Bob Schetgen, KU7G, ARRL Hq.*

Table 1

Changed and Added Lines for the C 64 Keyboard Program†

```
101 PRINT CHR$(147); CHR$(142): PRINT "MORSE CODE PROGRAM": PRINT
102 PRINT "C 64 VERSION BY BOB SCHETGEN, KU7G"
110 REM INITIALIZE "SID"
111 S=54272: V=8: FOR I=1 TO 24: POKE S+I, Ø: NEXT
112 POKE S+1, 52: POKE S, 110: POKE S+5, 16: POKE S+6, 240: POKE S+24,
  V: POKE S+4, 17
113 PRINT "PRESS (RVON)L(RVOF) FOR LOUDER, (RVON)S(RVOF) FOR SOFTER.":
  PRINT "PRESS (RVON)RETURN(RVOF) WHEN DONE.
114 GET A$: IF A$="" GOTO 114
115 IF A$ = "L" THEN V=V+1: IF V>15 THEN V=15
116 IF A$ = "S" THEN V=V-1: IF V<0 THEN V = Ø
117 POKE S+24, V
118 IF A$ = CHR$(13) THEN POKE S+4, Ø: GOTO 120
119 GOTO 114
190 POKE 252, T: TC = Ø
310 POKE 1019, ASC(B$): POKE 56579, 255
390 DATA C9,20,F0,67,C9,2C,90,4E,C9,5B,B0,4A,AA,BD,96,03,A0,08,84,FB,0A,C6,FB,90
400 DATA FB,85,02,A5,02,0A,85,02,A0,01,90,02,A0,03,A9,11,8D,04,D4,EA,EA,EA,EA,EA
410 DATA EA,EA,EA,EA,EA,EA,EA,EA,A9,01,8D,01,DD,20,A8,03,A9,00,8D,04,D4,8D,01,DD
420 DATA A0,01,20,A8,03,C6,FB,D0,CA,A0,02,20,A8,03,60,98,0A,0A,A8,A5,FC,A2,FA
790 POKE 1019, ASC(B$): POKE 56579, 255
1110 CS=225/CC: POKE 252, CS
1340 POKE 56579, 255
```

Note: The designations "(RVON)" and "(RVOF)" indicate a "CTRL 9" and "CTRL Ø" key combination, respectively.

†Characters in bold type are changed from the VIC 20™ keyboard program.

Table 2

Memory locations: VIC 20™ vs C 64

	VIC 20™	*C 64*
Temporary storage	0($0000)†	2($0002)
	1($0001)	251($00FB)
	2($0002)	252($00FC)
DDR	37138($9112)	56579($DD03)
User port	37136($9110)	56577($DD01)
Sound control	36875($900E)	54276($D404)

†$ indicates hexadecimal numbers.

*Technical Editorial Assistant

MODIFICATIONS TO 8P6 SPECIAL FOR 30 M

□ I would like to share some of my experiences with the 10-MHz Hamcation rig ("Putting the '8P6 Special Hamcation Rig' on 10 MHz," April 1983 *QST*). The keying characteristics of my rig were poor because of the time constants in the DC SWITCH circuit at Q6 (Fig. 2, p. 19, Nov. 1982 *QST*). My transmitter had key clicks and transmission continued long after the key was released. The 2.2-µF timing capacitor on the "key line" was charged through a low impedance when the key was down, but discharged through a relatively high impedance when the key was up. I improved this by placing the 2.2-µF capacitor in parallel with the 0.01-µF capacitor at the junction of the 1.2-kΩ resistors. The left 1.2-kΩ resistor was replaced with a 10-kΩ unit and the right with 750 Ω (Fig. 1A).

I noticed that there was some intermodulation distortion at night when a good antenna and the RF preamp were used. The situation can be improved by installing two back-to-back miniature 10.7-MHz IF transformers with a 1-pf capacitor for high-impedance coupling (Fig. 1B). (I used transformers from an old AM/FM radio; they had blue dots on the tops.) Install this assembly in series with the input to T4 (Q7 circuit, Fig. 3, p. 19, Nov. 1982 *QST*). The 10.7-MHz IF transformers have sufficient range to tune 10.15 MHz.

This project has given me the most fun of any project in years, and there is no commercial rig offered of the same size, weight and power. Also,

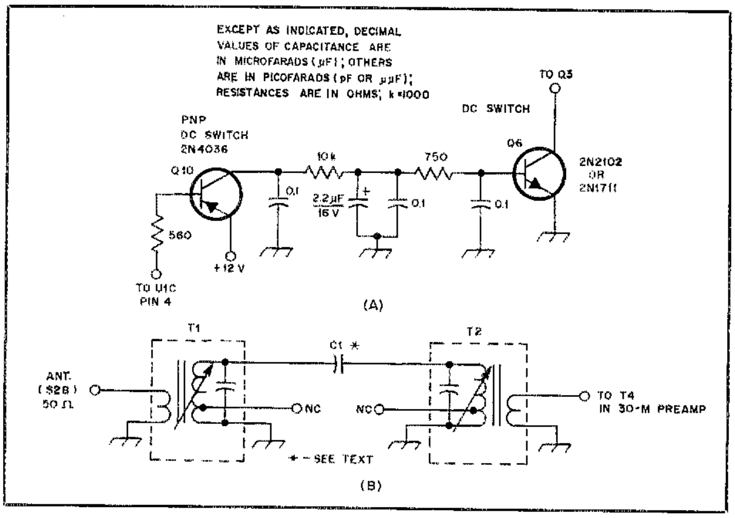


Fig. 1 — Modifications for the "8P6 Hamcation" rig. An improved keying circuit (A) and a band-pass filter to reduce intermodulation distortion (B) are shown.

the 10-MHz band is a good choice for portable CW operation with stateside and DX propagation. — *Jim Ford, N6JF, Costa Mesa, California*

REACTANCE AND Q OF ANTENNA TRAPS VS. BANDWIDTH AND LOADING

☐ From Ramo and Whinnery, the hot end of a very thin horizontal wire dipole is an essentially constant resistance of 3-kΩ and a reactance of less than ± 300 Ω over a bandwidth of 2%.[1] We make little error in assuming the antenna is a pure resistance over this frequency range. An equivalent circuit can be formed with the antenna resistance, 3 kΩ, in parallel with the trap resistance, R_T (both are subject to the same voltage).

The efficiency is:

$$\text{Eff.} = \frac{100}{1 + \frac{3}{R_T}} \qquad \text{(Eq. 1)}$$

where

Eff. = efficiency, as a percentage.
R_T = trap resistance, in kilohms.

Some values of trap resistance, and the associated trap-efficiency values are given in Table 3.

Leave this for a moment and consider trap reactance at resonance. It can be shown that, for frequencies well removed from resonance (as is the case for inactive traps), Q is unimportant in determining reactance.[2] So we can analyze the loss-free case, obtaining:

$$Z = X_o \frac{\gamma}{1 - \gamma^2} \qquad \text{(Eq. 2)}$$

where

Z = trap impedance.
X_o = reactance, in ohms.

$$\gamma = \frac{f}{f_o}$$

which is always less than one for traps as normally used.

Nothing can be done about γ, but we should minimize X_o to reduce loading effects. The trap at resonance is equivalent to a resistance:

$$R_T = Q_o X_o \qquad \text{(Eq. 3)}$$

where

Q_o = unloaded trap Q.

We see from Table 3 that for reasonable efficiency, R_T should be about 30 kΩ. So, a large Q_o is desirable because it allows for low values of X_o, hence smaller off-frequency loading effects, while achieving the necessary R_T.

To visualize the effect of trap Q, consider the system as the trap shunted by the antenna. The parallel combination of 3 kΩ and 30 kΩ (R_T) produces an effective system resistance of 2727 Ω. Since the trap resistance of a 90% efficient trap (30 kΩ) is large with respect to the system resistance (2727 Ω), unloaded trap Q has little effect on the system Q.

The system operating Q is:

$$Q = \frac{2727}{X_o} \qquad \text{(Eq. 4)}$$

[1]Ramo and Whinnery, *Fields and Waves in Modern Radio*, Wiley, 1945, pp. 490-491.
[2]Terman, *Radio Engineers' Handbook*, McGraw-Hill, 1943, pp. 144.

Table 3
Trap Resistance vs. Trap Efficiency

R_T (kilohms)	*Efficiency (%)*
3	50
6	66.7
12	80
24	88.9
48	94.1

Recall that the antenna is essentially a pure resistance over a 2% frequency range. Operating Q must be about 10 for the trap to be an essentially pure resistance over a 2% bandwidth.[3] Solving Eq. 4:

$$X_o = 273\ \Omega$$

This is the minimum X_o that maintains system Q requirements. Since R_T = 30 kΩ for 90% efficiency, we can solve Eq. 3 for Q_o.

For R_T = 30 kΩ, and X_o = 273 Ω, Q_o = 110.

The above values of X_o and Q_o are for traps of all frequencies. In the case of traps made from separate coils and capacitors, it is no problem to achieve these values, even though we may have to use resistive shunts to adjust the Q. But, for coaxial and bifilar traps, the reactance is not easily controlled; different types of cable or wire must be used for the various frequencies of operation. — *Frank Noble, W3MT, Bethesda, Maryland*

[3]Terman, p. 145.

QUADRAQUAD UPDATED

☐ Since building the first Quadraquad antenna ("The 'Quadraquad' — Circular Polarization the Easy Way," Robertson, April 1984 *QST*), I have developed a better feed system. The simultaneous occurrence of voltage and current antinodes makes voltage feeds an easy alternative to current feeds.

To implement a voltage feed, use a pair of quarter-wave transformers. These transformers are similar to the baluns described in the article except that they have a single center conductor instead of a coaxtube, and the delay line is tapped into them some distance from the shorted end. At the open ends, the inner conductors are attached to the driven element, which is now a continuous loop, and the outer conductors are left open. This is the same, electrically, as feeding a wire antenna at one end by means of a parallel-resonant tuned circuit.

The two advantages of voltage feeding are: (1) A slot in the outer conductor allows tap adjustment for impedance matching. (2) High-power can be used; with coaxtubes, conductor spacing it so small that arcing could occur.

Match each feed point to the main feeder independently. Once this is done, a delay line with the same characteristic impedance as the feeder is matched and the power divides evenly. Of course, this yields a 2:1 SWR on the main feeder unless a matching section is used.

It is best to make the transformers a little shorter than a quarter wavelength. Use a combination of tap-point adjustment and top capacitive loading to get a good match. For capacitive loading, use a short piece of wire attached to the open end of the transformer where it joins the antenna, and adjust with sidecutters. — *David S. Robertson, Stirling, Australia*

Feedback

☐ Joe Reisert, W1JR, has found an error in "A High-Quality UHF Source for Microwave Applications" (Feb. 1983 *QST*). The emitter of Q5 should be grounded, not connected to + V_{cc} as shown in the schematic on p. 29.

☐ Author Belrose has found several printing errors in his "Beverage Antennas for Amateur Communications" (Jan. 1983 *QST*). On page 25 under Eq. 1, the definition of "n" is misplaced, since "n" is a parameter of Eq. 5. On this same page, the numerical parameters associated with Eq. 4 are incorrect. For the Beverage wire, a = 0.0404 inches (0.1026 cm) and h = 3.707 feet (1.13 meters), so:

$$Z_o = 60\ ln \frac{2(3.707)\ (12)}{0.0404} = 462\ \Omega$$

On page 26, $\epsilon^{\Gamma l}$ in Eq. 5 should read $e^{\Gamma l}$ where *e* is Napier's natural logarithm base. Finally on the same page δ_g = conductivity of the earth, which is a parameter used in Eqs. 6 and 9, should be written as σ_g; while this is a printing error, these equations are correctly written, and the parameter δ_g is correctly defined.

☐ Frank Noble, W3MT, has found the following errors in his Mar. 1984 Technical Correspondence item about coax traps. The formulas for I_t and I_t', in the left-hand column of page 47, should read:

$$I_t = \frac{E}{\omega L} \qquad I_t' = \frac{E'}{\omega L}$$

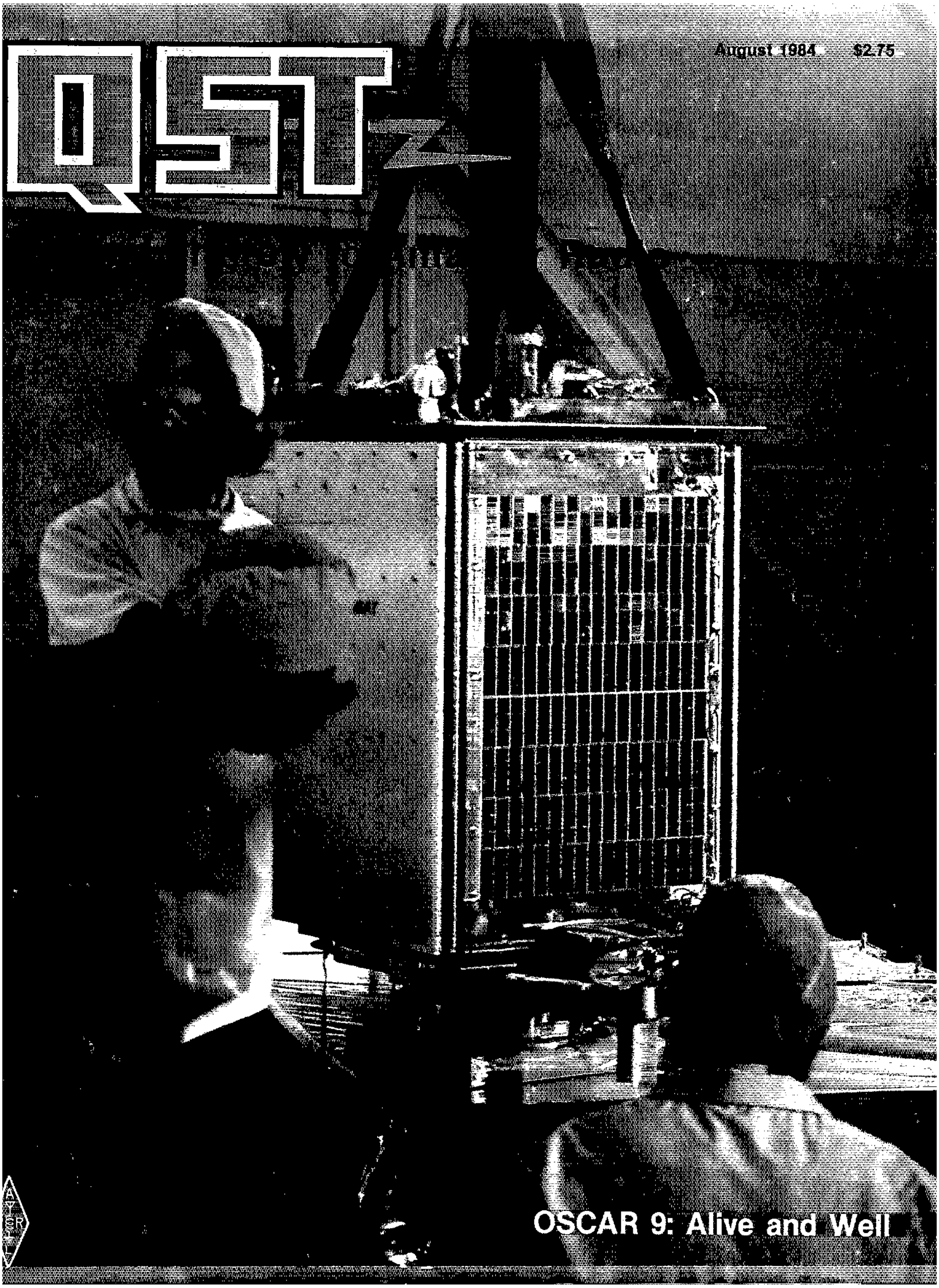
Also on p. 47, the value used for "d" in Eq. 5 is 1.695 inches (a 1½-inch diameter form with 0.195-inch diameter cable).[4]

☐ Two minor points in "The Perfect 10" (*QST*, March 1984, p. 17) could cause confusion. In Fig. 1, pins 2 and 3 of U1 are reversed. The pin numbers are shown correctly in Fig. 2. In Fig. 2, T1 is shown having an output voltage of 25 V, but 12.6 V is specified in the parts list; either voltage is suitable. The U1 input voltage is not critical: it must be at least 2 V greater than the U2 output voltage (10 + 2 = 12), and it must be less than the breakdown voltage of U1, 40 V. (Remember, in a power supply with a capacitor-input filter the available voltage is 1.414 times the transformer rating.) Of course, the higher the input voltage, the more power U2 must dissipate.

☐ The April 1984 Product Review of the AEA CP-1 Computer Patch Interface mistakenly refers to the VIC 20™/Commodore 64™ software as "HAMTEXT™." The AEA product is MBATEXT™; the former name belongs to a Kantronics product.

☐ That stray by W4RHZ about the Navy knob (Jan. 1984 *QST*, p. 25) excited some mail on the subject. One thing that all seem to agree on: The Navy knob came into being because it was a better knob with which to send code. Even today it is used and preferred by most operators simply because it feels better than the old-style landline telegraph knob.

[4]mm = in × 25.4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OSCAR 9: Alive and Well

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CONTENTS

OUR COVER
Both British amateur satellites, UoSAT-OSCAR 9 and U-O 11, are now healthy. Learn how you can copy U-O 9 telemetry by reading the article beginning on page 23. *(photo of G6BTU, G6APF and G3YJO, left to right, by W9KDR)*

TECHNICAL

BEGINNER'S BENCH

NEWS AND FEATURES

OPERATING

DEPARTMENTS

The Amateur Auxiliary for Volunteer Monitoring

The ARRL and the FCC's Field Operations Bureau have jointly organized the Amateur Auxiliary, thus maintaining over a half century of amateur self-regulation and insuring for its future.

By John F. Lindholm,* W1XX, and Robert J. Halprin,** K1XA

Originally conceived in 1926, the ARRL Official Observer (OO) program was created as a means of amateurs helping each other keep out of "trouble." One of the first published references to the OO corps appeared in September 1934 *QST*, in which the following objective was stated: "to help brother amateurs by calling attention to violations of good practice . . . in the right way . . . in bettering operating . . . and ham enjoyment." It is this spirit of cooperation, typified in The Amateur's Code (The Amateur is Considerate . . . He never knowingly uses the air in such a way as to lessen the pleasure of others), that has endured over the many years of the existence of the OO program. It's the same spirit of assistance to our brother and sister amateurs that must prevail in the further evolution of volunteer monitoring to meet the challenge of the '80s and the decades beyond.

Among the significant aspects of Public Law 97-259 (known as the Communications Amendments Act of 1982 before being signed into law in September 1982) is the one that authorizes the Federal Communications Commission (FCC) to formally enlist the use of amateur volunteers in monitoring the airwaves for rules discrepancies/violations (the same legislation paved the way for the new Volunteer Examiner program). This FCC/amateur cooperation is a crucial factor in maintaining the traditional high standards of conduct on the amateur bands.

The rationale for the enhanced amateur self-regulation posture was aptly addressed by the House-Senate Conference Committee, when P.L. 97-259 was being reconciled between the two legislative bodies:

> The Amateur Radio Service has been praised for being self-regulated. The Commission has reported that less time has been devoted to monitoring and regulating the Amateur Service than to any other service because of its self-policing and discipline. One primary purpose [of the law] is to allow the Amateur Radio Service to continue its tradition as the most self-regulated service in the United States, and to become to some extent self-administered . . .

The new law is a milestone in the history of the Amateur Radio Service, a catalyst for a modernized, dynamic service, enabling amateurs to play a much more integral role in their (our) own destiny. With respect to volunteer monitoring, P.L. 97-259 *exempts* Amateur Radio transmissions from the "secrecy of communications" provisions of Section 605 of the Communications Act, clearing the way for a more active role on the part of amateurs in monitoring functions.

The Amateur Auxiliary

As a preface to the implementation of volunteer monitoring, FCC's Field Operations Bureau (FOB) fully recognized the value of the organized and disciplined Amateur Radio community, through its membership organization, ARRL. FOB is also cognizant of the long history and tradition of the League's OO program and the ARRL Field Organization structure, specifically indicating that the volunteer-monitoring program should be compatible with the amateur organizational structure and avail itself of that structure.

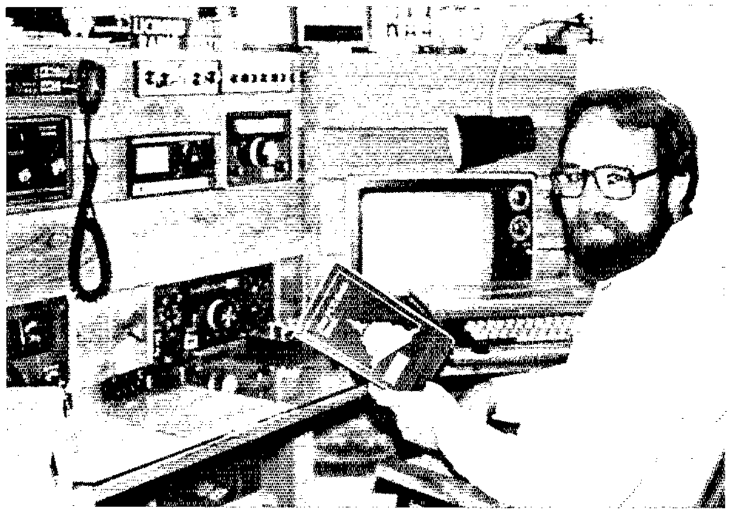
To achieve this, FOB is creating an Amateur Auxiliary (parallels in government can be found in the Civil Air Patrol and the Coast Guard Auxiliary). FOB and ARRL have entered into a formal agreement whereby the objectives and nature of the program are clearly delineated, with the League committed to administering the program. In essence, the Amateur Auxiliary/OO program will be administered by the League's Section Managers and OO/RFI Coordinators, with support from ARRL Hq.

In meeting its broad objectives, the Amateur Auxiliary will address both maintenance monitoring and amateur-to-amateur interference (the latter is sometimes misnamed malicious interference). Maintenance monitoring will be conducted through an enhanced OO program. Amateur-to-amateur interference includes inadvertent and careless interference as well as more serious harassment and malicious interference, which might be encountered on VHF repeaters. Such repeater problems will be within the purview of the Local Interference Committee, authorized by the ARRL Section Manager to enter into a local agreement with the local FCC engineer-in-charge or field supervisor. Logically, this is in harmony with a basic tenet of the Amateur Auxiliary that problems must be resolved

*Communications Manager, ARRL
**Deputy Communications Manager, ARRL

at the most-local level possible.

It must be emphasized that the Amateur Auxiliary serves as a forum for technical and operational advice to amateurs *who are receptive*. The task is not to find fault, but to identify cause and effect (often which is *not* based on technical but on behavioral or social issues) and to find ways to achieve solutions. It cannot be stated strongly enough that the mission of the Amateur Auxiliary is *not* direct enforcement. In fact, the law specifically *excludes* amateurs from enforcement activities. However, this does not preclude participation in disciplined evidence gathering at the direction of FCC. Indeed, the Auxiliary will be tasked and trained to do just that in those very few compelling cases that demand FCC attention.



The League's traditional leadership role in maintaining high standards of on-the-air decorum continues through dedicated volunteers such as Luck Hurder, WA4STO, ARRL OO/RFI Coordinator for Eastern Massachusetts. Luck's state-of-the-art listening (and operating) post is equipped for all bands and modes, including computer-generated RTTY.

Amateur Auxiliary Objectives

1) Foster a wider knowledge of and better compliance with laws, rules and regulations governing the Amateur Radio Service;

2) Extend the concepts of self-regulation and self-administration of the Service;

3) Enhance the opportunity for individual amateurs to contribute to the public welfare as outlined in the basis and purpose (Part 97.1) for the Amateur Radio Service;

4) Enable the FCC Field Operations Bureau to more efficiently and effectively utilize its manpower and resources.

A Multi-Level Approach

The Amateur Auxiliary structure consists of several levels to address operational problems of varying complexity. The vast majority of the activity will engender from OOs utilizing the friendly advisory report to advise of discrepancies. To further project the helping philosophy of the OO program, "Good Guy" reports will also be sent by OOs to those amateurs who exemplify the best in operating and technical on-the-air achievement. Likewise, Local Interference Committees will appropriately address repeater interference, whatever the nature. An OO/RFI Coordinator is delegated by the Section Manager to supervise Amateur Auxiliary activities in each ARRL Section.

There will be situations needing a higher level of expertise to bring about the proper resolution. Rather than immediately look to the overburdened FCC for "solutions," a second tier of the Amateur Auxiliary is reserved for more serious cases. This is where a new appointment, the Regional Monitoring Station (RMS), comes in. The RMS will cover a substantial geographical area, equivalent in scope to an FCC monitoring station. The potential RMS must have impeccable credentials to be considered for this appointment (which will be made by the ARRL President). It is anticipated that the number of qualified RMSs will be limited; only a small number of dedicated amateurs will have the time, maturity, experience and technical wherewithal to qualify for this important, specialized function. Inquiries regarding the RMS appointment should be directed to the Communications Manager at ARRL Hq.

The RMS will work closely with FCC personnel, where appropriate, in those cases requiring action beyond routine OO maintenance monitoring. The RMS will utilize a more compelling advisory notice, but again the thrust will be to bring about voluntary resolution by the individual(s) in potential violation. The RMS will also be a source of assistance to Local Interference Committees coping with difficult cases of true malicious interference. In some instances, the RMS may be manned by a dedicated group of highly qualified amateurs to provide more continuous coverage. In such an arrangement, a "chief" at the RMS facility will be designated.

The "court of last resort" is, of course, the FCC. In keeping with the intent of amateurs solving amateur problems (i.e., self-help), the FCC will be called in only by authorized individuals and then only after all avenues have been exhausted. In short, for volunteer monitoring to be effective, the amateur response through the Auxiliary must be capable of addressing the vast majority of discrepancies within the context of internal procedures. In this way, the FCC will be called upon for assistance only in matters of extreme seriousness, worthy of prosecution, if necessary. Only a well-defined administration of the Amateur Auxiliary can assure success — we must make the volunteer-monitoring program work for us *first* before the desired response from FCC can be obtained.

Training and Certification

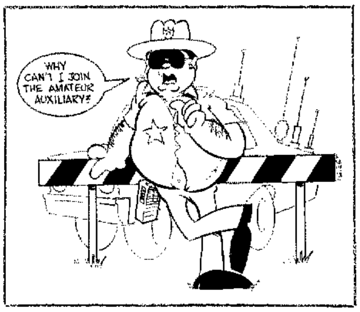
Amateur Auxiliary members must be properly trained to carry out their important role. The FCC believes such training is absolutely necessary. Potential Amateur Auxiliary members must not only be schooled in the rules and regulations, display technical competence and possess certain monitoring gear, but must be psychologically equipped to exercise the tact and discipline that the program requires. It takes a special kind of dedication to pass up working the DXpedition to rare Catalina Island to go look instead for Novice second harmonics. The potential Amateur Auxiliary member must also be well-versed in the administrative details of the program, particularly knowing whom to call in the chain of command for higher-level assistance. Certification of Amateur Auxiliary members will require the successful completion of a written examination, based on the Amateur Auxiliary *Training Guide* (which will be distributed to all candidates). The training/certification process must be preceded by a recommendation from the candidate's Section Manager and/or OO/RFI Coordinator.

Expectations

The Amateur Auxiliary has the potential for making the ham bands a better place for all to operate. The biggest obstacle to achieving "Ham Heaven" is unreasonable expectations. That is, the perception that Amateur Auxiliary personnel will be modeled after Boss Hogg or Sheriff Buford T. Justice or on the opposite extreme, Mary Poppins or other goody-two-shoes. None of these personality types possess a club or even a magic umbrella that can cure all of the on-the-air evils. The program must not have the slightest hint of enforcement; there must be a fundamental realization that this program will not be able to eliminate all of the woes of the amateur world. Such problems are often deeply rooted in the psychological inadequacies of our society as a whole. But the Amateur Auxiliary does provide the organized mechanism for addressing most matters pertaining to operating decorum.

Is It You?

Membership in the Amateur Auxiliary should prove to be extremely satisfying and fulfilling, but you must have what it takes to be of service to your fellow amateurs. Maturity, sophistication, competency — these qualities are needed. Don't look for rewards per se, because your efforts will



largely go unheralded. Moreover, you will *not* be authorized to dispense anything akin to Mr. T's brand of frontier justice by "knocking heads." The Amateur Auxiliary is based primarily on friendly persuasion and cooperation, values that allow amateur problems to be reasonably resolved within the amateur community in accordance with commonly accepted standards. This good-faith approach, a positive feature of the federal deregulatory environment, should prove effective and beneficial to all concerned. With this affirmative philosophy in mind, if the Amateur Auxiliary/OO program is right for you, go for it!

The foundation of this enhanced program of volunteer monitoring is the dedicated group of ARRL OOs. If you are already an appointed OO, you will be receiving a special mailing containing training materials to give you an opportunity to validate your appointment within the new framework. We also enthusiastically extend an invitation to qualified amateurs not presently OOs to step forward and volunteer. Your first point of contact is your ARRL Section Manager (see page 8 of *QST*).

A final note: According to *QST* archives, pioneer OOs stalked what was termed "prehistoric signals," reportedly a.c., broad r.a.c., chopper, etc. (June 1932 *QST*). There probably aren't many modern Amateur Radio equivalents to these relics of the past, but the basic objective, now and then, is the same: calling attention to discrepancies (whatever they might be) in the spirit of fellowship and friendship, and achieving creative solutions for the overall betterment and enjoyment of Amateur Radio.

Strays

A HOBBY SHARED

☐ Most of my married life has been involved with Ken's ham radio. WØMFR became a second name in no time. Little did I realize what this hobby would become when I first reviewed questions with him in preparation for his test, and the great pleasure he had in passing. He continued to be so pleased when he passed the test to be Extra a few years ago. I watched him plan teaching modules for classes in our area. How good he felt when his students passed and received call letters or advanced another level.

Ken *loved* ham radio and what it represented: a hobby with expectations for performance and knowledge. And it enlarged one's world with letters and meeting other hams while traveling. His radio "family" was large and a very special privilege in our life. As a wife, I encouraged his hobby and so enjoyed the friendships and excitement hearing from these friends we never met but knew so well.

When he retired in 1976 and we moved to our lake home, Ken could use all the varied bands and was free to explore at all hours the activity on the radio. He was far from lonesome.

But as his widow, I miss the *sound* of his hobby and the stimulation of an active ham schedule. Silent Key is truly descriptive. Code rhythm had a musical sound, and good code was almost a kind of musical symphony. A visit to a recent Field Day here made me aware of the beauty of the sounds I had heard for so many years.

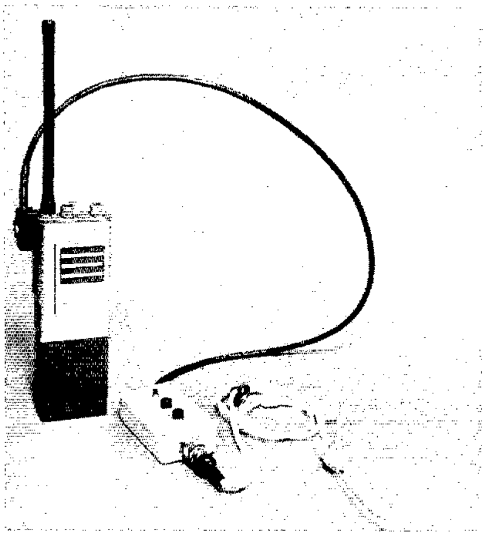
The mailman misses Ken, for WØMFR had the best mail on his route. Foreign stamps on beautiful QSL cards were fun to deliver.

Ken was so excited about others becoming part of his best hobby. He respected the organization, and it enriched our lives so much. Several foreign hams had not heard he had died, and I have received lovely cards and letters that must be answered. They were his friends.

I guess you could call this a tribute to a very fine activity that we enjoyed so much. I couldn't consider it finished until I said it. — *Emma Dahlmeier, XYL of WØMFR*

Shortly after becoming a Novice himself, at age 65, Mike Shepnew, KA2UGR (center), of Scotch Plains, New Jersey, decided to share his new hobby with this group of advanced-achievement students at Woodruff School in Berkeley Heights. One of their projects, quite appropriately, was a code-practice oscillator.

2AGQ (now W2AGQ) and 2AHK (now AE4X) congratulate each other on the 60th anniversary of their first QSO in 1924, which was also 2AHK's first QSO ever.



Amateur Radio's Hand-Held in Space

By Thomas McMullen, W1SL*; Jim Worsham, WA4KXY**; and Harold Sanderson, WB4TTA***

The 2-meter operation by Owen Garriott, W5LFL, on-board the space shuttle *Columbia* is now history. Many lucky amateurs made two-way contact with Dr. Garriott, and untold thousands listened to his signal from space. Having been in assorted hamshacks when contact was established, we can attest to the joyful bedlam that followed confirmation of contact. If such scenes were common in those stations that heard their call returned from space, there must have been a lot of extremely happy hams around the world!

Early phases of the program to put an Amateur Radio transceiver aboard *Columbia* have been documented in earlier *QST* articles, and need not be repeated here.[1] The effort to build the radio to be used on this flight was thoroughly enjoyed by all the members of the Motorola Amateur Radio Club of Fort Lauderdale who participated. Our task was to provide a hand-held 2-meter radio that could be connected to the standard NASA headset, which includes earphones and a microphone. The Project Manager was Jim Worsham, WA4KXY; Ron Alexander, KA4ZLS, served as NASA liaison for testing and qualification of the radio and battery for safety standards; Harold Sanderson, WB4TTA, assembled the radio, gave it a most exacting final test, and coordinated the frequency programming with NASA and W5LFL; John Ray, WB4BFS, designed and assembled the interface box; Bruce Burke, WB4YUC, provided test equipment and fixtures; and Tom McMullen, W1SL, provided documentation and circuit-board layout.

The Radio

The portable radio used by W5LFL on the *Columbia* is basically a standard Motorola MX300-S series, frequency-synthesized Handie-Talkie radio.[2] These radios are used by many law-enforcement officers, public-safety agencies, fire departments and commercial interests throughout the world.

The radio is microprocessor controlled, and of modular construction. It is capable of generating up to 96 separate frequencies (48 transmit and 48 receive) by reading control information encoded in a PROM (programmable, read-only memory). Frequencies are selected by means of switches on top of the radio. A "zone" switch selects one of four "zones," or groups of frequencies, and a frequency-select switch picks one of 12 frequencies for each zone.

Each major circuit is contained in a sealed module for ruggedness and protection against most environmental problems, and these modules plug into a four-layer circuit board that is held in place by rails in the Lexan frame. Controls and battery power are connected to the main circuit board by means of "flexes" that consist of metal conductors bonded between layers of tough, flexible plastic. This type of construction allows easy troubleshooting and servicing. A block diagram of the major circuits in the MX300-S is shown in Fig. 1. Fig. 2 shows an interior view.

The synthesizer reference frequency is provided by the 3.6-MHz crystal-controlled oscillator (reference oscillator, U10). Programmable frequency dividers in the controller/phase-detector assembly, A2, are controlled by the microprocessor, U11. The microprocessor obtains the transmit- and receive-frequency information from the PROM.

The controller provides voltage to the VCO, U14. In turn, it supplies an RF sample to the controller for frequency division and comparison with the product of the reference oscillator.

In the transmit mode, the VCO output is applied to a transmit PLL processor (U102) that locks the transmitter VCO (U103) to the programmed frequency. This VCO operates at the output frequency. Audio modulation is applied to the synthesizer VCO, which applies it to the transmitter VCO through the phase-detector and locking circuitry. FM output from the transmitter is amplified to a 5-W output level and filtered before being routed to the antenna relay and antenna.

During receive, synthesizer VCO output is applied to a multiplier that is part of the receiver preselector assembly, where the frequency is doubled to provide receiver injection for the first mixer. Incoming signals are amplified by U1 before being applied to the RF preselector and mixer. Mixer output is at 21.4 MHz. Filtering and two stages of IF amplification follow the mixer, and the signal is then applied to a crystal discriminator. Discriminator output is routed to audio-amplifier and squelch stages. Full audio output is 500 mW. Nor-

[1]Notes appear on page 17.

*4109 Waterway Dr., Lake Worth, FL 33461
**4300 Riverside Dr., Apt. 4, Coral Springs, FL 33065
***191 SW 79th Ave., Margate, FL 33068

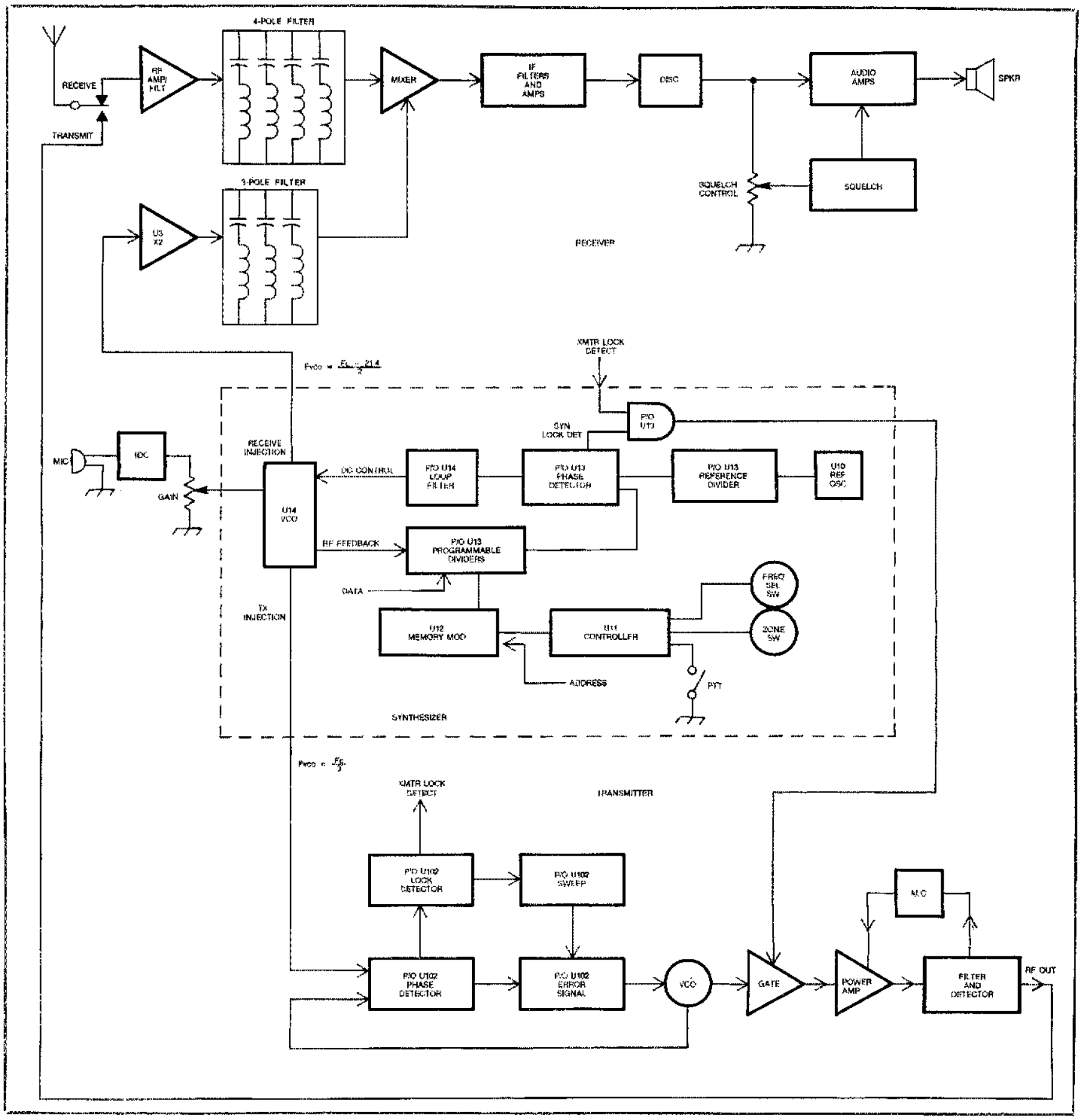


Fig. 1 — A block diagram of the Motorola MX300-S Handie-Talkie radio.

mally, a built-in speaker in the front of the case is used, but audio output is also available at an earphone jack on top of the radio and at an accessory connector on the side.

Audio for the interface box used in the *Columbia* was taken from the accessory connector. Similarly, a built-in microphone is normally used for transmitting but the NASA headset microphone was interfaced to the radio through the accessory connector. The push-to-talk (PTT) circuit and other internal circuits are also accessed through this connector. More about this in the description of the interface box.

Radio battery power is provided by a sealed, 7.5-V NiCd battery. Batteries are available in various sizes: four 2000 milliampere-hour batteries were provided to W5LFL. They proved to be quite adequate for the nine-day mission. Battery life is an important consideration, because no provisions were made to recharge them from the shuttle electrical system.

Modifications to the standard MX300-S radio were minimal: the agreed-upon frequencies were programmed into the PROM, and the transmitter power output was reduced to 4 watts to prolong battery life.

The Interface Box

Electrical and mechanical connections between the radio and the rest of the system are provided by the interface box. It matches the impedances and levels of the headset/microphone and the radio. Power for the headset microphone preamplifier comes through the interface box, and transmit and receive audio for a tape recorder are provided by the amplifier cir-

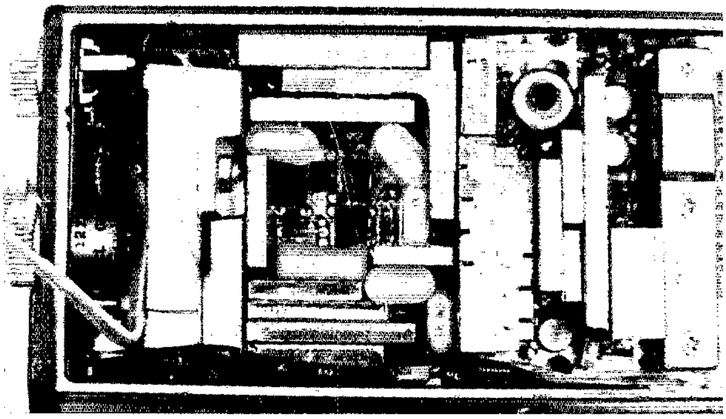


Fig. 2 — Interior view of the MX300-S Handie-Talkie radio with the front cover removed. Modules plug into a four-layer circuit board that is held in the frame by rails. *(photo by WB4YUC)*

cuitry in the box. Also, connections for the headset, tape recorder and radio are made through this interface. The title photograph shows the MX300-S radio with the interface-box cable attached to the accessory connector. Fig. 3 is a drawing of the box, connectors and cabling required. As an example of the details that had to be worked out, this drawing had to be supplied to NASA long before launch so they could provide secure storage space for the equipment!

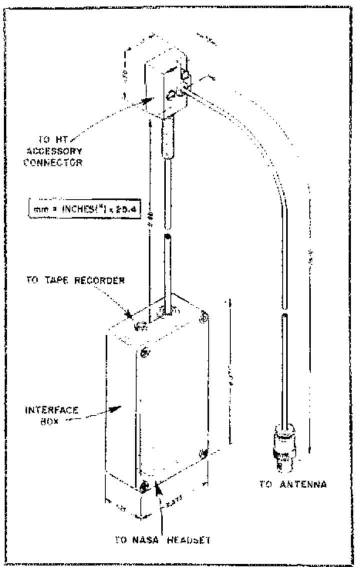


Fig. 3 — A scale drawing of the interface box and associated connectors.

Design

Three design constraints affected the mechanical and electrical configuration of the interface box. First, the total current drain had to be less than 1 mA. This is because the supply voltage from the radio, through the accessory connector, is fed through a 1-kΩ current-limiting resistor.

Second, all materials used had to be approved by NASA. This is necessary to ensure that everything has acceptable levels of resistance to flammability, toxicity and outgassing. (Outgassing is a tendency of plastics and other materials to emit gasses when heated, cooled or subjected to oxygen-rich atmospheres.) These considerations are extremely important when you cannot open the window and get some "fresh air"!

Finally, the box had to be as small as possible. A bulky, hard-to-manage system is difficult to use and reduces operator efficiency.

The Circuit

Interface-box circuitry consists of three parts: a voltage regulator, an audio amplifier and an audio mixer. The regulator handles the supply voltage from the accessory connector on the radio, removing any voltage variations caused by the 1-kΩ current-limiting resistor in the MX300-S radio. The regulated voltage is applied to the headset microphone preamplifier and to the amplifier/mixer in the interface box. One section of the op amp (U1) serves as this voltage regulator. See Fig. 4.

To minimize current drain, the audio amplifier uses the Siliconix L144CJ micropower, programmable, operational amplifier. This device works just like any other op-amp, except that you can "program" its current drain. The drawback to this is that the less current you let it have, the less bandwidth it will let you have! Since all the signals through the interface box are at audio frequencies, this bandwidth limitation is not a problem. The total interface-box current drain is approximately 0.5 mA.

Speaker audio from the MX300-S accessory connector is applied directly to the earphone. Microphone audio is amplified, and a proper impedance match is provided, before the signal is routed to the accessory connector. An audio mixer in the interface box combines receiver and microphone audio and routes it to a tape-recorder jack. The interface-box PTT switch keys the transmitter and turns off the audio amplifier in the receive mode. This prevents background noise from being applied to the recorder through the microphone circuit while the radio is in the receive mode.

To achieve a high degree of reliability, leadless (chip) components are used, as shown in Fig. 5. These chips are very small, and have low profiles. They are soldered directly to the etched circuit board. This minimizes the number of wire leads that can fail because of vibration. The box is cast aluminum with an anodized finish. Wire insulation and other plastic parts are either Teflon or nylon; the hardware is stainless steel; and the circuit board is glass-filled epoxy.

Fig. 5, a photo of the interface-box interior, shows two devices, and the title photo shows knobs labeled for VOX adjustments. Great effort was extended to design a VOX circuit in the early prototype box. This was a difficult task because of the supply current limitation from the radio. Several versions were tried, but none had the proper amount of hysteresis (the difference between turn-on and turn-off levels) for a reliable VOX circuit. At the last minute, a decision was made to forego this convenience — a decision that later proved fortunate. After the mission, W5LFL reported that the cabin background noise was so strong that he sometimes had difficulty understanding people even when their signals were full quieting into the receiver. That amount of noise would very likely have upset even our best efforts at VOX reliability.

Conclusion

Although the bulk of the work on this project was done after hours and at home on weekends, there were some things that just had to be taken care of during normal business hours — phone calls to agencies involved, equipment to be obtained for the next phase and other tasks. We sincerely acknowledge the support of our supervisors and management at Motorola in Fort Lauderdale and in Schaumburg, Illinois.

Stepping back and looking at what we've learned from this project, the results are mostly positive. The circuit is really nothing out of the ordinary: an audio amplifier and a voltage regulator. Electronically, our expertise improved because we entered the

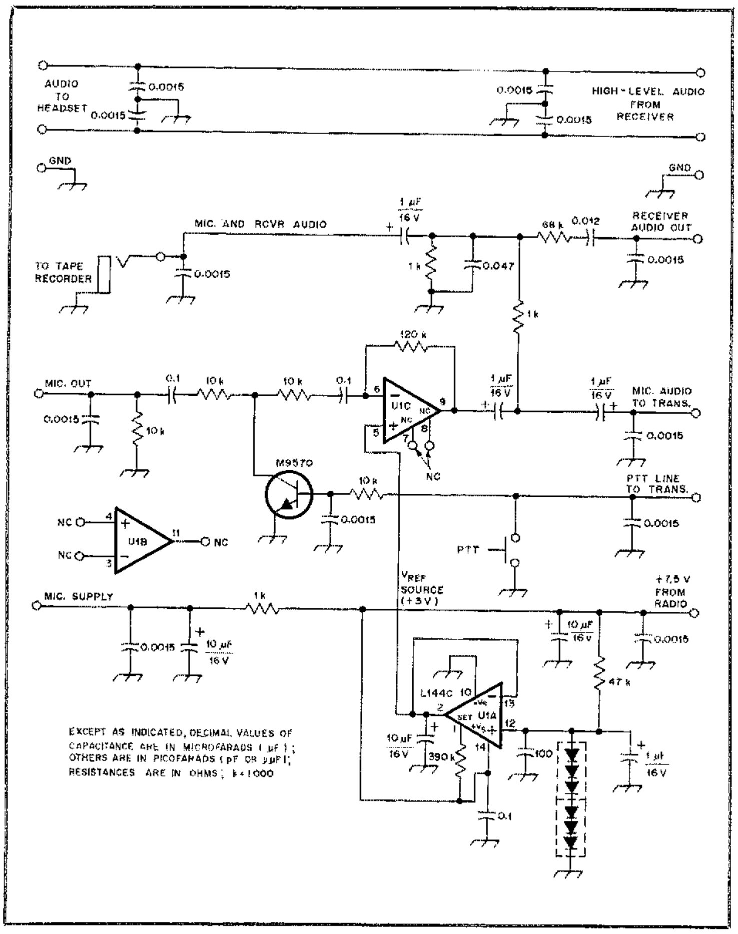


Fig. 4 — Schematic diagram of the interface circuit between the MX300-S radio and the NASA headset and tape recorder. U1 is a Siliconix L144CJ triple, micropower, programmable op-amp.

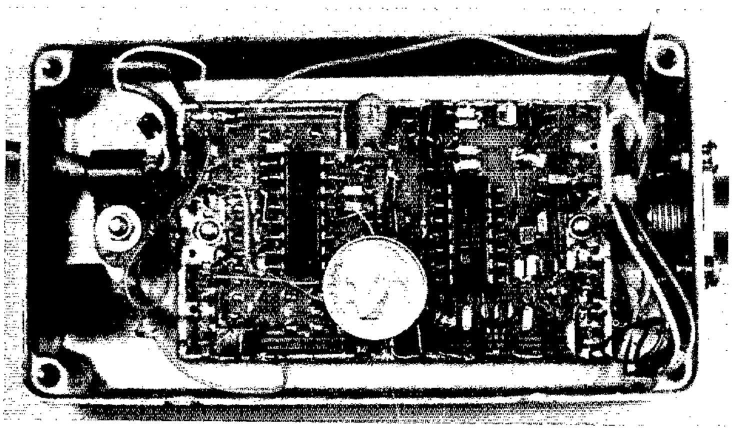


Fig. 5 — Inside the interface box. This version was built with an extra IC for a possible VOX circuit. The dime provides a comparison of size for the chip (leadless) components on the circuit board. *(photo by WB4YUC)*

new, tiny dimension of leadless components. Those things are usually placed on circuit boards by means of automatic machinery, not by shaky fingers and tweezers!

Also, working with all the great people involved in the space program was very educational and uplifting. Working to specifications and a deadline far outside what is normal in Amateur Radio provided a challenge that we're happy to have met, and would gladly do again.

Now, about that first manned mission to Mars . . .

Notes

[1]Amateur Satellite Program News, *QST*, October 1983, p. 77.

[2]Motorola, MX300-S and Handie Talkie are trademarks of Motorola, Inc.

Strays

MOVING, CHANGING CALL?

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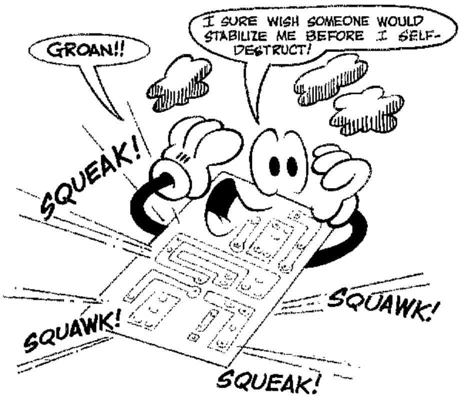
Next Month in QST

If there's one question on most of our minds right now, it's "how do I go about taking an exam?" Now that the FCC is phasing out its test sessions, you'll need to know how to find available test sessions, how to apply, what to expect at the exam site and (naturally) what to study to be able to bring home a new license. A September article will spell it all out, clearly, simply and concisely.

With the fall season nearly here, antennas once again are becoming a priority. September *QST* will provide two very different — but equally effective — designs: The full-wave loop antenna, which need not be at heights that would make the Wallendas swoon, and a ground-plane antenna for the 30-meter band that can be mounted in a tree. In addition, those not yet immersed in the subject will learn the pros and cons of wire, vertical and beam antennas in the First Steps installment.

Some Basics of VHF Design and Layout

BEGINNER'S BENCH



Follow the guidelines in this article, and enjoy peak stability and performance from your homemade solid-state VHF gear.

By Doug DeMaw,* W1FB

Blown transistors, squealing signals and lumpy tuning are the common signs of a poorly designed or assembled VHF power amplifier. Have you experienced the futility of trying to make a 2-meter amplifier perform correctly? I think each of us has bitten our lips in private despair while trying to tame a problem amplifier — not once, no doubt, but many times! On the other hand, perhaps our amplifiers operated smoothly, but power output was substantially below the rated value for the circuit. Such maladies are not uncommon. Fortunately, the preventive steps are not difficult or costly. Let's discuss some of the causes for substandard performance and compile a set of notes that can be used for all VHF amplifier designs.

What Can We Expect for Efficiency?

It was a simple matter for designers of vacuum-tube circuits to obtain amplifier efficiencies of 70% for class-C amplifiers, 60% for class-B and 30 to 40% for class-AB operation. The predictable operating angles for tubes employed at their rated frequencies are well established, and those angles dictate the tube efficiency. Generally speaking, we can expect slightly lower efficiency for solid-state amplifiers, respective to the operating angle. Most manufacturers rate their power transistors at 50-55% efficiency for class-C operation, with lower percentages for class-A and class-B angles. One thief of power is heat — power transistors produce considerably more internal heat than is developed with most small vacuum tubes. Internal resistances and reactances within the transistor contribute further to poor efficiency. On the plus side, however, we have no filament power to waste when using transistors. Additional RF power is lost in transformers and other matching networks when using transistors, but in the long term our trade-off in efficiency is worth the benefits of small size, instant operation and device longevity.

Efficiency is determined by comparing the dc input power of the amplifier stage (in watts) against the RF power output of the stage. Thus, if our hypothetical amplifier required 3A of current with a collector voltage (V_{cc}) of 13, our dc input power would be 39 W (I × E). If our RF output power happened to be 19.5 W, we would observe an efficiency of 50% (19.5/39 = 0.5). This would be typical for a class-C solid-state bipolar-transistor RF amplifier of proper design. The rule does not hold for MOS power FETs. Their efficiencies approach, and in some instances exceed, those of vacuum tubes.

Harmonic Output

The industrial literature does not mention the potential problems we may encounter with harmonic output when using RF bipolar devices. Vacuum tubes generate harmonic currents by virtue of "envelope distortion." Excessive grid drive to a tube can worsen the condition. The transistor produces harmonic currents through envelope distortion, but it also generates intense harmonic energy via varactor (variable reactance capacitor) action of the internal junction. Specifically, the junction capacitance changes with the sine-wave amplitude of the driving voltage (signal). This nonlinearity of operation is tailor-made for harmonic production. Unfiltered output from the collector of a transistor amplifier will usually show the harmonics to be a mere 10-13 dB below the power level of the desired output frequency (fundamental). The FCC regulations are very specific about acceptable levels of harmonic and other spurious output energy (−60 dB for VHF amplifiers, and −40 dB for HF-band amplifiers). Although these regulations apply to commercial equipment, they are required by the ARRL for all published circuits. If we are to be conscientious amateurs, we will strive also to meet the criterion in our designs. It will help to prevent TVI, RFI and unwanted interference to other services.

Because of the strong harmonic currents in the output of a solid-state power amplifier, we must take measures that are seldom used in vacuum-tube designs. Harmonic filters are the order of the day. Don't be misled by the simple amplifier circuits you find in the manufacturers' data sheets. They are designed for use in testing a device (TUT, or "transistor under test") to determine its performance at 50 ohms of load resistance. I must confess that I have duplicated a number of these published circuits only to find that they did not work with the values given. So, beware!

A typical data-sheet test circuit is shown in Fig. 1. Most VHF amplifiers are shown in circuits for 175 MHz, but that is close enough to 145 MHz for our purposes. "King Tut" (Q1) in this example remains unidentified for our discussion. Consider it typical of the devices we might obtain for VHF work. At first glance, the circuit looks pretty good for amateur use. But, upon

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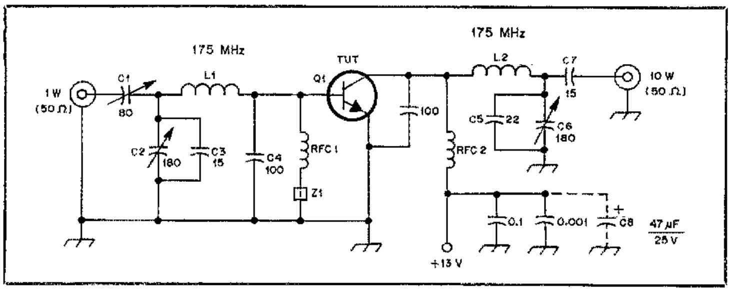


Fig. 1 — Circuit example for a typical VHF amplifier as depicted in the manufacturer's data-sheet literature. See text for a discussion about this and similar circuits.

duplicating it we may find to our dismay that it won't work at all, or if it does, it will exhibit instability, low output and copious harmonics. Remember that this is published in the literature as a *test* circuit, and is not a circuit that one should attach to an antenna.

My recent experience with a circuit of this general configuration (taken from a data sheet) was dismal. With 1 W of input drive I obtained 0.5 W of output! The output tuning network had a definite peak, but the input network had little effect on the power output. The coils (L1 and L2) were built precisely as the data sheet dictated. Careful layout was used, also.

Why did this happen? Well, it seemed a bit unusual to place 100 pF of capacitance from base to ground in a VHF amplifier (C4 of Fig. 1). I removed the "suspect" capacitor and, lo, I was able to extract 10 W of RF output! I suspect that the value listed on the diagram was in error, and should have been 10 pF. Yet, other circuit examples for VHF use — same manufacturer — had the 100-pF value listed. Other similar amplifiers showed *no* base capacitor.

Further testing proved that low-frequency instability was taking place. I added C8 (standard practice) to bypass low-frequency energy, and the self-oscillation ceased. A tendency toward VHF instability was observed while adjusting the input and output networks. I added a ferrite bead (Z1) in series with the base RF choke, and the fault vanished. Addition of Z1 lowered the Q of the choke, which degraded the tuned-base, tuned-collector condition that was present. A 100-ohm resistor in parallel with RFC1 would probably have cured the problem, too, but at a slight loss in effective driving power.

Harmonic output was fierce, as expected. A harmonic filter would need to be added to this amplifier if it were ever used on the air. I learned also that shunt capacitors C3 and C5 were not necessary. These wasted parts were removed. Apparently, they were specified to prevent C2 and C6 from being adjusted for too low a capacitance. The minimum capacitance of the two mica trimmers was high enough to avoid using fixed-value capacitors C3 and C5. Also, greater matching flexibility can be had if we replace C7 with a 30-pF trimmer capacitor.

This exercise was included to illustrate that you should not accept a published circuit as "gospel." Try it out, then manipulate the design to make it conform to your needs.

Dealing with Instability

A well-designed solid-state amplifier should show no instability (self-oscillation), regardless of the load connected to it. In other words, it should be stable even if the input and output terminals are left open. Unfortunately, many amplifiers are stable in that mode, but when made to conduct (drive applied) they go into spasms of self-oscillation. These oscillations may occur at a variety of frequencies, with some as low as the audio-frequency region. If the amplifier "takes off" too vigorously, the transistors may self-destruct from excessive heat or from junction puncture during periods of excessive voltage spikes. Therefore, we should always do our initial testing of a new circuit at reduced supply voltage. I like to commence with 5 or 6 V of V_{cc} when testing a 12- or 13-V circuit. The voltage is increased slowly while looking for instability symptoms; this way, the transistors are less likely to be damaged.

Few amateurs own or have access to a spectrum analyzer, but that would be the best instrument for testing an amplifier. A good scope with a bandwidth suitable for use at the operating frequency or higher may be a good alternative. We may "sniff" for spurious responses by means of a sensitive wavemeter when placing the wavemeter coils near the amplifier output network. The wavemeter method is the least expensive and most practical technique for amateur work.

What are the major causes of amplifier instability? Well, a lack of good grounding may head the list; that is, effective grounding of the parts on the circuit board — those that are returned to ground. This means we need to keep the leads as short as possible. We must also ensure that the ground foils on the PC board are wide and direct. Fig. 2 shows two PC-board patterns. One is good, but the other is unsuitable for VHF work. In fact, it would not be acceptable for most HF-band work. Note the long circuit-board ground foils at B of Fig. 2. These act as unwanted inductances, which can completely spoil the circuit performance — especially at VHF and higher. Remember, small excessive lead lengths present reactances that are in series with the components. In some cases we have inductive reactances in series with inductors, and in other cases we have capacitors in series with inductive reactances. This unwanted condition can render our matching networks unsuitable for the task assigned to them.

The long emitter lead at B of Fig. 2 can cause instability and a loss of gain. The loss of gain is caused by emitter reactance that has the same effect as placing a resistor in series with the emitter lead. This is known as *degenerative feedback.* A secondary effect of degenerative feedback in some amplifiers is a change in the base impedance. The foil pattern at A of Fig. 2 is recommended to minimize unwanted inductive reactance. In other words; the greater the area of the PC-board foil, the lower its effective inductance. These considerations were not as important when we designed with vacuum tubes because of the high input and output impedances of the tubes. But power transistors have very low terminal impedances. At times these impedances are less than 1 ohm! Therefore, small reactances can cause a host of troubles when we work at these low-impedance levels.

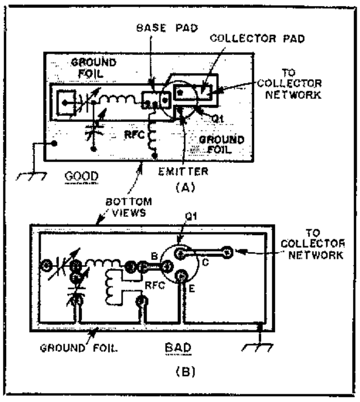


Fig. 2 — Good and bad layout examples for a VHF circuit board. The illustration at A (good) shows lots of copper ground foil, with large pads for attaching the components and keeping the ground leads short. The standard donut-pad/tape format at B is *unsatisfactory* for VHF circuits, and is not suggested for HF-band projects as well.

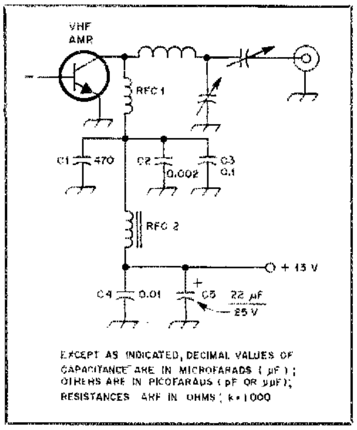


Fig. 3 — The schematic diagram shows part of a VHF amplifier circuit. The bypass capacitors and RF chokes comprise an effective decoupling network for a wide frequency range (see text).

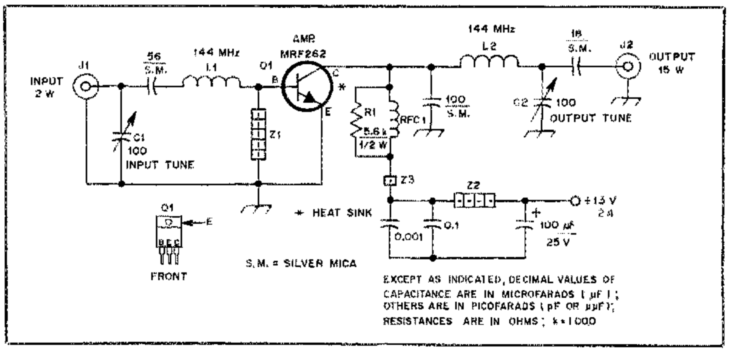


Fig. 5 — Schematic diagram of the 15-W class-C amplifier. It is suitable only for CW and FM use. Q1 would require forward bias on the base in order to use the circuit for linear amplification of SSB or AM signals. Fixed-value capacitors are disc ceramic unless noted otherwise. The polarized capacitor is electrolytic or tantalum.

C1, C2 — 100-pF mica compression or ceramic trimmer.
J1, J2 — SO-239 coaxial connector.
L1, L2 — Two turns of no. 14 wire, 5/16 in ID by 3/8 in long.
RFC1 — 13 close-wound turns of no. 24 enam. wire on a 5.6-kΩ, ½-W carbon-composition resistor.
Z1 — Five 40-μ_i miniature ferrite beads (Amidon no. 63 material) on a piece of bus wire.
Z2 — Four 850-μ_i miniature ferrite beads (Amidon no. 43 material) on a piece of bus wire.
Z3 — A single 850-μ_i ferrite bead, no. 43 material.

Leads that are too long can also set up tuned circuits for spurious frequencies, and that can lead to self-oscillation. It is good practice, also, to use double-sided PC board (copper on both sides). The surface on one side is etched for the desired pattern, but the opposite side of the board is left with all of the copper in place. That side acts as a ground plane, which helps to prevent RF ground loops (current flowing where it is not wanted). This also aids stability. The ground foils on the etched side of the board should be connected to the ground plane at several points. I drill no. 60 holes through the board and use short pieces of bus wire (soldered on each side) to join the grounds.

The component leads that do not return to ground must also be kept short. Fixed-value capacitors are especially critical, for it is almost impossible for us to clip their leads short enough for VHF use. Leadless ceramic chip capacitors are best, but they are difficult to buy and are very costly. Most commercial designs contain them. They are soldered directly to the PC-board foils, hence no leads. I favor silver-mica capacitors as an alternative. I snip the leads off near the body of the component, leaving just enough to make my solder connections to the PC board. Leadless chip capacitors are also effective.

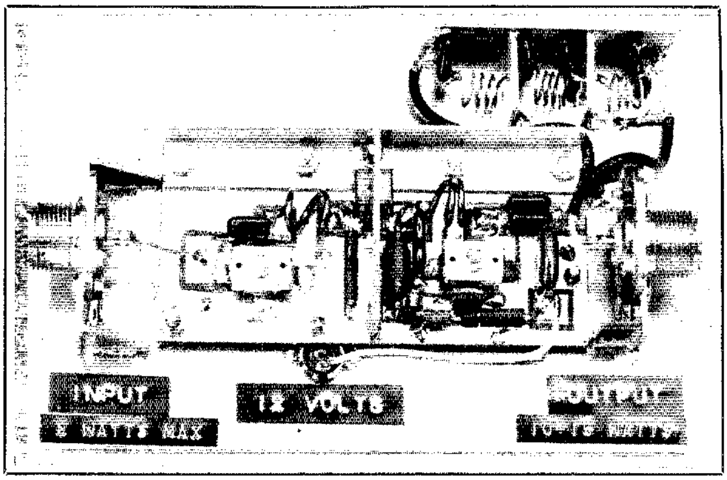


Fig. 4 — The assembled 15-W, 2-meter amplifier. The small harmonic filter of Fig. 6 is seen at the upper right. A shield divider is installed across the center of the transistor to isolate the amplifier input and output circuits. This amplifier is seen in its test fixture. It can be packaged to suit the builder.

Another important step toward stability is proper layout. The input and output circuits of the amplifier should be as far from one another as possible. Unwanted coupling between network coils can be a problem when seeking stability. When in doubt, place a shield divider across the transistor (ground it well) to isolate the input and output parts of the amplifier.

Collector bypassing is still another matter of importance. Fig. 3 illustrates the use of various values of bypass capacitance, plus a decoupling choke. Note that three bypass capacitors (C1, C2 and C3) are used below RFC1. They, because of their assorted values, provide effective bypassing at low frequency, high frequency and VHF. RFC2 is added to further clean up the +13-V line, and C4/C5 serve for additional bypassing. C5 is used to bypass the voltage bus at VLF and audio. If this is not done (RFC2 and bypass capacitors), RF energy can follow the supply line into other stages of the transmitter (or vice-versa). Wandering RF of this kind can cause feedback that encourages instability.

A Workshop Project

It's always nice to follow a rhetorical deluge like this with something we can use for hands-on experience. A proven practical 2-meter amplifier is shown in Fig. 4. It is resting in a test fixture, along with a harmonic filter. With 1 W of input power, the output is on the order of 10 W after

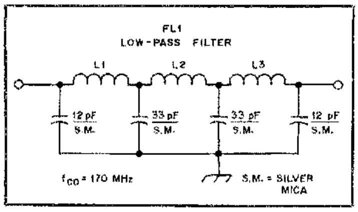


Fig. 6 — Schematic diagram of the seven-element low-pass harmonic filter. The capacitors are silver mica and are used to support the three coils above the PC board. Capacitor leads are cut very short to minimize stray inductance. Shield dividers are used between the coils to aid input/output isolation. Small pieces of double-sided circuit board are used for the partitions. All coils contain four turns of no. 20 wire, 5/16-in ID by 3/8 in long. The filter cutoff frequency is approximately 170 MHz, and the terminal impedance is 50 ohms.

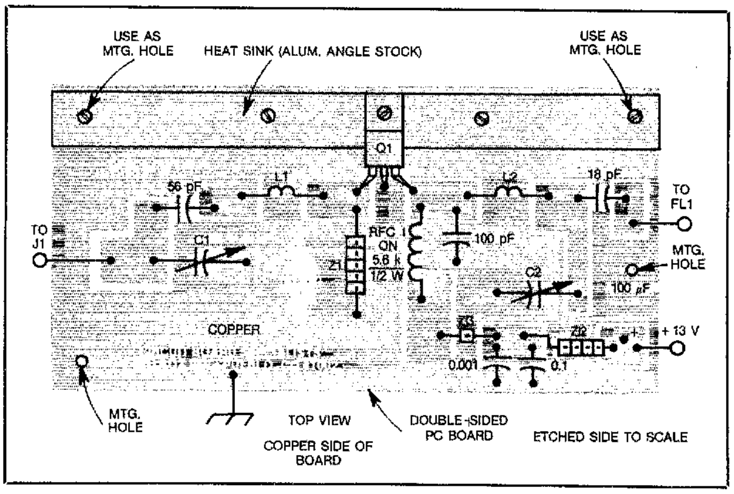


Fig. 7 — Parts-placement guide for the 2-meter amplifier. All of the components are mounted on the etched side of the double-clad board. Through-grounds are placed at several points (see text).

filtering. An output power of 15 W will result when the drive is increased to 2 W. A small shield divider separates the input and output halves of the amplifier. It is made from a piece of double-sided PC board, but flashing copper or brass would serve just as well.

Fig. 5 shows the schematic diagram of the amplifier. It evolved from one of those test circuits on a data sheet, but has been refined to deliver good performance. A Motorola MRF262 is used. It is a plastic-encased TO220 style of transistor.

C1 and C2 are the only adjustment devices used. However, if you want to get fancy, you may use trimmers in place of the input 56-pF capacitor and the 18-pF output capacitor. This will give you added tuning flexibility for the two matching networks. I find that I can obtain the rated output power while using fixed-value capacitors at those points.

Z1 is the base RF choke. I chose ferrite beads in order to keep the Q low in that part of the circuit. If you use a wire-wound choke at Z1, it should have an inductance of roughly 0.5 to 1 μH. This will yield a reactance of approximately 450 ohms from base to ground, which is recommended. RFC1 is wound on a ½-W resistor, and is similarly low in inductance. Z2, also made from a string of ferrite beads, functions as part of a decoupling network for the supply line.

The Harmonic Filter

Fig. 6 shows the circuit for the seven-section low-pass filter. It can be enclosed in a PC-board box to ensure good isolation, but will work as shown on a piece of PC board. Use dividers between the filter sections to provide reasonable ultimate attenuation (resulting from good isolation between the input and output of the filter). The cutoff frequency of this 50-ohm filter is approximately 170 MHz. FL1 ensures that the amplifier complies with FCC emission regulations.

Construction

The amplifier is laid out in accordance with the earlier text discussion. Rectangular isolated pads are formed on a piece of double-sided PC board. A skilled layout person can shrink the size of this amplifier considerably, should a smaller unit be desired. Care must be taken to provide ample heat sink area if that is done. The sink used in this model is a piece of store-bought hobby aluminum angle. It is 4 inches long, and has lips that are ½-inch high. The thickness of the stock is 1/16 inch.[1] Silicone heat-sink grease is used between the angle stock and the PC board, and between Q1 and the angle aluminum. Smaller amplifiers will require a heat sink of commensurate area.

Mica compression trimmers are used at C1 and C2, but ceramic trimmers can be substituted if you have them on hand. L1 and L2 are wound from no. 14 enameled copper wire. The large wire gauge helps to minimize losses by increasing the effective conductive area of the wire. We need to keep in mind the "skin-effect" rule for

[1]Notes appear on page 22.

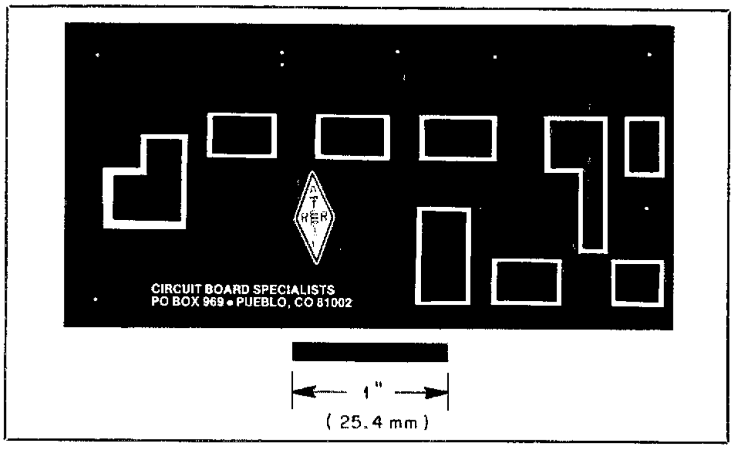


Fig. 8 — Circuit-board etching pattern for the solid-state amplifier of Fig. 5. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil. The components are mounted on this side of the board.

conductors versus oper ating frequency: The penetration of the wire becomes progressively less as the operating frequency is increased.

All of the components are placed on the etched side of the board. Fig. 7 shows the parts placement of the amplifier. A full-scale PC pattern is shown in Fig. 8.[2]

Adjustment

Connect a low-power transmitter or transceiver to J1. Place a 50-ohm dummy load at the amplifier output (J2). *Warning:* Make certain that your exciter can deliver no more than 2 W of output. Power input beyond that amount can destroy Q1 of Fig. 5. Next, apply the operating voltage and observe a wattmeter that has been inserted between J2 and the dummy load. Tune C1 and C2 for maximum output power from Q1. Readjust the capacitors two or three times for maximum output power. There will be some interaction, however slight. Do not use this amplifier on the air unless you include FL1 of Fig. 6 in the output line.

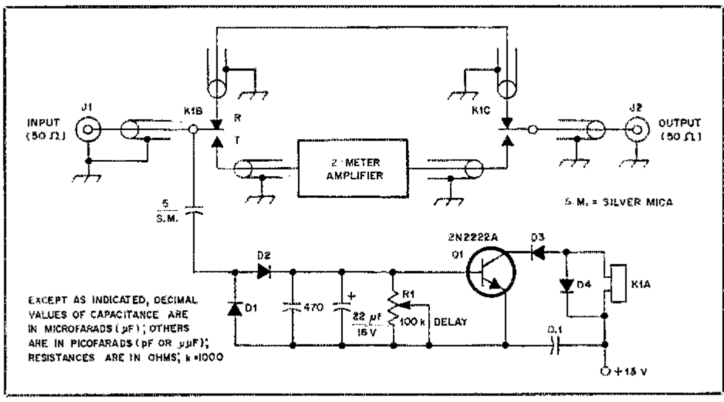


Fig. 9 — Suggested circuit for a switch-around device to permit use of the amplifier with hand-held transceivers. Some RF energy is sampled at J1, rectified by doubler D1/D2 and fed to a timing network that is connected to the base of a dc amplifier/relay driver (Q1). R1, a 100-kΩ control is set for the delay desired between transmit and receive. D1, D2, D3 and D4 are 1N914 small-signal silicon diodes; observe polarity of the diodes. K1 is a small dc relay for 12 V, and is a DPDT type.

Use with a Hand-Held Transceiver

Should you desire to use this amplifier with your hand-held radio, you can try the suggested circuit of Fig. 9. It will enable you to have the required "switch-around" feature during receive periods. Set R1 for the amount of delay you desire. The block diagram shows how to use the switching circuit with the amplifier.

Final Comments

The guidelines given here apply to all solid-state amplifiers. I hope some of your knotty problems have been resolved after reading this installment. A little care and thought in your design and layout will ensure good amplifier performance.

Notes

[1]mm = in × 25.4.

[2]Circuit boards and parts kits for this project are available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002, tel. 303-542-5083.

New Books

ELECTRICITY AND ELECTRONICS

by Dale R. Patrick and Stephen W. Fardo. Published by Prentice-Hall, Inc., Englewood Cliffs, NJ. First Edition, 1984. Hard-bound, 8-5/8 × 11-1/4 inches, 542 pages including index. $21.95.

The authors, who are employed by the Department of Industrial Education and Technology at Eastern Kentucky University, wrote this book for high school and vocational-technical school students. It can also serve as a text for industrial training programs, as a reference book and, to some extent, as a text for home-study courses. Newcomers to electricity and electronics — and that includes many budding radio amateurs — should find this book to be a valuable learning tool.

The book is composed of 18 chapters, eight appendixes and an index. A wide spectrum of subjects is covered: basic electricity, ac and dc motors, electronics basics, transistors, power supplies, oscillators, amplifiers, communications systems, digital electronics and electronic power control.

Large, easy-to-read type combined with many well-done illustrations and clear photos make reading easy. Each chapter contains a brief introduction, followed by a list of "Important Terms" (a glossary) to prepare you for the upcoming text. The body of information covered by that chapter follows. After the study material, there's a comprehensive review. Pages of "Student Activities" comprise the last section of each chapter. This is where you're encouraged to work on some suggested projects to gain a better understanding of the material just covered: the "learn-by-doing" stage.

Appendixes 1 through 8, respectively, contain a periodic table and an alphabetic list of the elements, some hints on soldering, pictures (only) of commonly used electrical tools, electronic and electrical symbols, the use of subscripts in schematic components identification, a discussion of right angles and a table of trigonometric functions, capacitor color codes, and powers of 10 and common logarithms. I think better use could be made of the appendixes; much of the material could have been arranged to fit within pertinent chapters.

Some difficulties may be encountered by those who want to use this book as a self-study course because there are no answers provided for the review questions — a sore point of many otherwise good textbooks, as is this one. Also, certain individuals may not have access to specific items of test equipment (such as an oscilloscope) necessary to perform the measurements required in a number of the projects. Possession of, or at least use of, a VOM is an absolute necessity; nobody contemplating entrance into the fields of electricity and electronics should be without this most basic piece of test equipment. How one overcomes the question/answer and equipment problems depends (to a degree) on individual motivation. Nevertheless, the book contains a wealth of information that is well presented. Instructors of basic electricity and electronics classes should find this book of value. — *Paul K. Pagel, N1FB*

Microcomputer Processing of UoSat-OSCAR 9 Telemetry

Are you interested in what satellites are "saying"? Here are some pointers to get you started examining satellite-transmitted data.

By Robert J. Diersing,* N5AHD

UoSAT-OSCAR 9 was built by members of the Electrical Engineering department of the University of Surrey, England. The satellite was placed into orbit on October 6, 1981. An on-board telemetry system provides data derived from monitoring 60 analog sensor channels and 45 digital status points. Analyzing the data can be a fascinating pastime. (A detailed description of UoSAT-OSCAR 9 may be found in *The Satellite Experimenter's Handbook*, published by the ARRL.)

A second UoSAT, OSCAR 11, was launched on March 1 of this year. The satellite was initially silent, but the engineers and scientists have restored it to operation. It is now transmitting telemetry while its condition is evaluated.

*Assistant Professor of Computer Science, Corpus Christi State University, 4129 Montego, Corpus Christi, TX 78411

Satellite Telemetry System

UoSAT-OSCAR 9 transmits the systems status and experiment measurements in ASCII using FSK with 1200- and 2400-Hz tones and even parity. These frequencies are close enough to the Bell 202 standard tones of 1200- and 2200-Hz that a type 202 modem will work well. (UoSAT-OSCAR 11 tone frequencies are reversed from the Bell 202 standard in their binary meaning.) The data rate can vary between 110 and 1200 bauds, but 1200 bauds is the rate most used.

Different telemetry formats are in use. These are shown in Figs. 1-4. The format shown in Fig. 1 is the older, standard form, combining the spacecraft status and telemetry values. Of the two newer formats, that shown in Fig. 2 has the same 60 telemetry values, but with the spacecraft status deleted and a checksum added for each value. The Fig. 3 format is one in which only certain channels are transmitted repeatedly after having been recorded at regular time intervals during the entire orbit. A sample of the UoSAT-OSCAR 11 telemetry is shown in Fig. 4. I'll concentrate on describing how to get the telemetry data into a computer in a form that will allow you to analyze it within the limitations of your hardware and programming experience.

Telemetry Reception and Capture System

The system in use at N5AHD consists of several processes: (1) orbit prediction, to know when to listen; (2) data capture, live or on audio tape; (3) demodulation of the data and its storage on diskette; (4) editing of the raw data to exclude detectable errors; and (5) analysis and display

```
AMSAT 10101 10000 00000 10000 01110 00011 00001 11001 00000
AMSAT 10101 10000 00000 10000 01110 00011 00001 11001 00000
00110 01160 02765 03001 04001 05433 06370 07303 08486 09482
10100 11100 12000 13366 14314 15188 16420 17885 18442 19438
20170 21470 22724 23024 24006 25422 26419 27267 28493 29611
30280 31180 32666 33235 34012 35333 36401 37401 38509 39313
40070 41110 42736 43102 44044 45000 46002 47467 48526 49502
50070 51000 52274 53089 54637 55450 56463 57488 58486 59507
```

Fig. 1 — Standard format of a UoSAT-OSCAR 9 telemetry frame. The first two lines indicate which spacecraft systems are active. Telemetered values from the spacecraft systems and experiments are contained in the next six lines.

```
UoSAT Computer-generated checksummed telemetry
Format: Per channel, sum 5 data digits (0-9), print as (A-Z,a-p)

00110C01190L02762R03001E04001F05623Q06687b07681W08442S09463W
10100C11080K12000D13370O14311K15660S16572V17234R18373W19400O
20150I21160K22727U23117O24010H25418U26428W27283W28458b29584c
30290O31430L32668Z33256T34011J35366X36399e37342T38475b39209X
40090N41090O42744V43019R44141O45001K46003N47410Q48497g49446b
50100G51090P52274U53091S54930V55412R56458c57458d58428b59463b
```

Fig. 2 — The checksummed standard telemetry format. Status lines are deleted, and the letter between measurements can be used to check the validity of the preceding five digits. The message shown above the frame is transmitted by the spacecraft before each frame.

```
0BD5014006400240014002400B003024002407A      01077086680000006680008B629
0BDC0540C119D6750440E187044UF449094016       01087086680000006680008B628
0BE0024005400840054005400340024080039l       01097086680000006680006901F
0BE70540024001409372014002400240024017       010A708667000000668000554 5C
```

Fig. 3 — These columns show two examples of whole-orbit telemetry dump format. With this form, several channels can be sampled by the spacecraft throughout an entire orbit, and the information retransmitted. The data consists of a frame sequence number followed by the measured values and a checksum. Usually, the weekend code-store will tell when the whole-orbit data was collected and what channels were included from the previous week.

```
UOSAT-2                  8402245221000
0051510l039B0201120301020402350502 8F060251070315080329090260
105150110000120056130103140051150004160007177364187368197 36A
2051532103222266772300012400172500072607742773672873682 97369
305152310165322 84F330000340007350305360005377366383 53E39353F
4076364100054268804300074400004550564600024773614835 3949346C
505617510172526616532631541110558 52F560003573607587 36F593539
60210561 7BC76280 0C630041641003651C0E661405673406680 00E69000F
```

Fig. 4 — UoSAT-OSCAR 11 checksummed telemetry sample. *This is* the most common format transmitted to date, but other formats are possible during data collection for and after attitude maneuvers.

of the captured data (see Fig. 5).

Software Configuration

The software I use is written in several programming languages for various reasons. The orbital prediction phase is handled by a program written in PL/I-80.[1] I prefer to do the orbit-prediction phase with a program that compiles to machine language rather than BASIC, which is much slower.

Data capture is done with one of two programs, both of which are written in Z80™ assembly language. One program captures the received characters by polling the serial port to which the modem is attached. It places the characters into a buffer, whose contents can later be transferred to disk. The other program uses interrupts to capture the received characters from the serial port and place them into a buffer. In the meantime, data is taken out of the buffer and sent to another computer for real-time display of decoded telemetry.

The data editing and analysis programs used in steps 4 and 5 are also written in PL/I-80. This is done primarily because of the faster execution times and better file-handling features that are available.

Hardware Configuration

I use a Cromemco Z-2D microcomputer. This is an S-100 bus system, and it uses a CP/M™-like operating system called CDOS. I find most programs are transportable between CP/M and CDOS systems; the programs described in this article operate on a CP/M system. The other system components are a Cromemco SCC (single-card computer), a 16FDC floppy-disk controller, 64 kbytes of memory, a TUART (Twin Universal Asynchronous Receiver-Transmitter) digital interface, a Heath H-19 terminal and a Novation 4202B modem.

Data Capture Procedure

Capturing the data transmissions on a quality cassette tape recorder, with the help of a discriminator meter and an audio-level meter, should pose no problems. Even though you may wish to place the data directly into memory, the cassette tape provides an excellent backup in case you run into problems. If you decide to use the computer to capture the data as you receive it, you may have to spend some time reducing computer RFI so your receiver will operate properly.

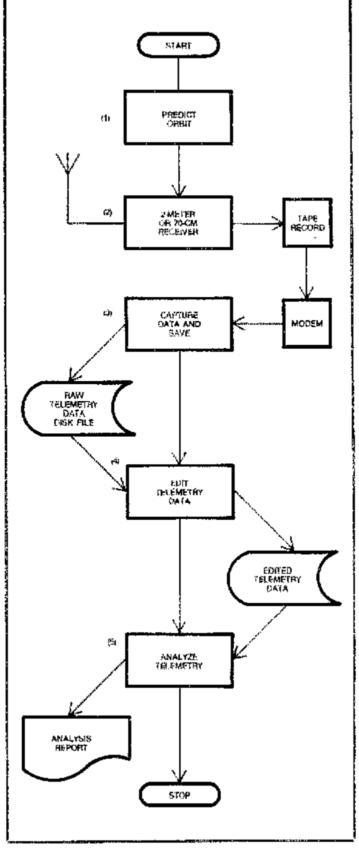


Fig. 5 — Flowchart of the UoSAT-OSCAR 9 telemetry capture and analysis system used at N5AHD.

To capture UO-9 data, the following steps are required:

1) Audio is fed to the modem directly from the receiver or from the audio tape player. When recording, be sure the audio level is not too high. Even though the limiter circuits in commercial modems are good, it would not hurt to pay some attention to impedance matching. You should check to see if the 2400-Hz tone is much lower in level than the 1200-Hz tone; you may have to pick up the audio just after the discriminator rather than at the speaker leads.

2) The modem output is connected to a serial input port of the computer. The physical connections are defined by the RS-232-C standard.

3) Software that will accept the signals from the computer serial port and store the data in memory must be written (or obtained). This software must also be able to save the captured data in a file on an external storage device, such as a floppy disk.

4) The computer must have an external data-storage device (disk drive or cassette tape). This way, the data-analysis programs can process the data without having to make the conversion of analog (audio) signals into digital signals again.

The Data-Capture Problem

The time it takes the computer to process a single character must be less than the time it takes for the next character to arrive. With data arriving at 1200 bauds, it is usually necessary to write the capture program in the computer's native language. This means writing in assembly language for, say, the Z80. Even if the computer's BASIC interpreter allows access to serial ports, BASIC probably will not be fast enough to process data at 1200 bauds. Rather than attempting to teach assembly language programming, I'll show flowcharts for the data-capture program. There will be an explanation of these later.

Serial Ports and Operation

A data "port" can be thought of as a

[1]Orbit-prediction software is available from the AMSAT Software Exchange, Box 27, Washington, DC 20044.

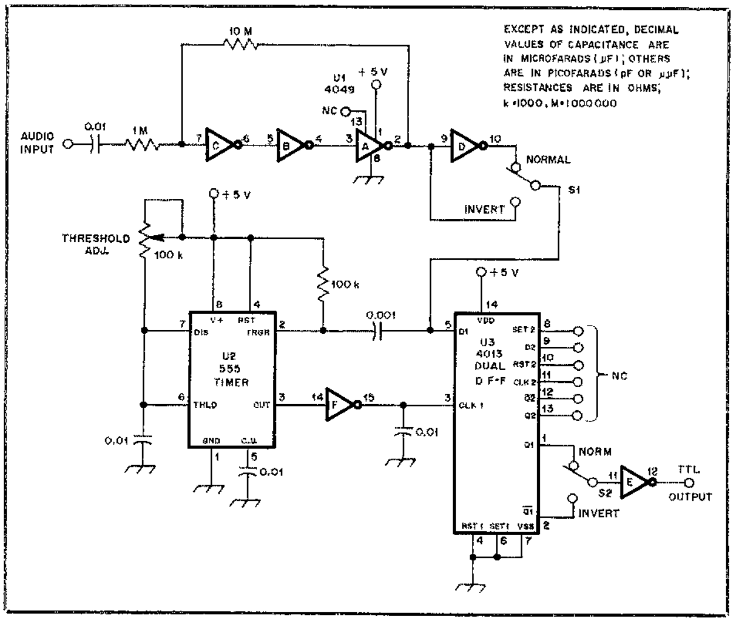


Fig. 6 — A simple demodulator for UoSAT-OSCAR 9 use. The incoming audio should be noise free. This circuit does not regenerate clock pulses, but should work fine for all asynchronous signals. The current drain of this circuit is about 5 mA at 5 V. For initial adjustment, feed an 1800-Hz tone into the input and move the THRESHOLD ADJ. potentiometer until the output of U1 is on the verge of changing state. *(tnx to Steve Gomez, KE5O, for this circuit)*

mechanism by which the microprocessor has access to the data presented. It is a combination of hardware and software.

Serial transmission and reception is a mode in which one bit at a time is sent or received. Since information is transferred bit by bit, the receiver must know the rate at which the transmitter is sending. In this case, the satellite is the transmitter and the receiver is the computer. If the satellite is transmitting at a rate of 1200 bits per second (bit/s or 1200 bauds), the computer must check for incoming bits at the serial port at a rate of 1200 bauds.

A modem is a *mo*dulator/*dem*odulator. In this application, the modem changes audio frequency shifts picked up at the radio receiver into different voltage levels to be sent to the computer serial port. The voltage levels should be in accordance with the RS-232-C standard.

Some microcomputers are supplied with serial ports. Check your hardware manuals to see if a serial port is available. You may be able to use the printer port if it is a serial type. If you need to purchase a serial interface, you can generally find them advertised in many microcomputer magazines. Two interfaces I have used are the Cromemco TUART and the Solid State Music IO-4. Both of these have two serial and two parallel ports on a card that plugs into an S-100 bus system. You can also purchase serial interfaces for the Apple® II and Radio Shack TRS-80® microcomputers. Radio Shack model III and IV computers purchased with two disk drives probably already have a serial port. The TRS-80® Color Computer also has a serial printer port.

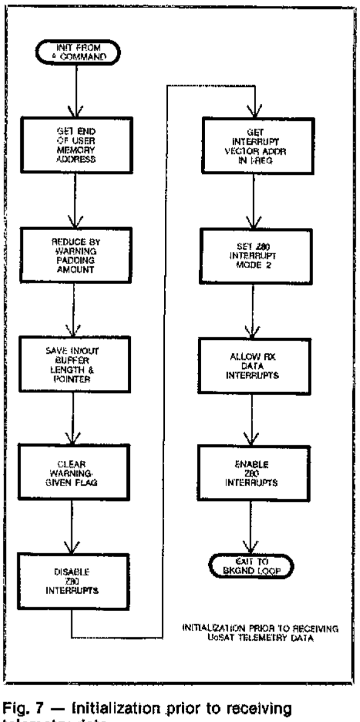


Fig. 7 — Initialization prior to receiving telemetry data.

About Modems

Where do you get a modem? You have two choices: Build one, or purchase one. The schematic diagram for a simple demodulator is shown in Fig. 6.

If you purchase a modem, be sure it is a Bell type 202 modem and not a 212 type. The type 212 modems are popular for 1200-baud transmission over telephone circuits, but do not operate on the proper tone frequencies for this application, nor do they use FSK at this data rate. Type 202 modems show up from time to time as surplus items,

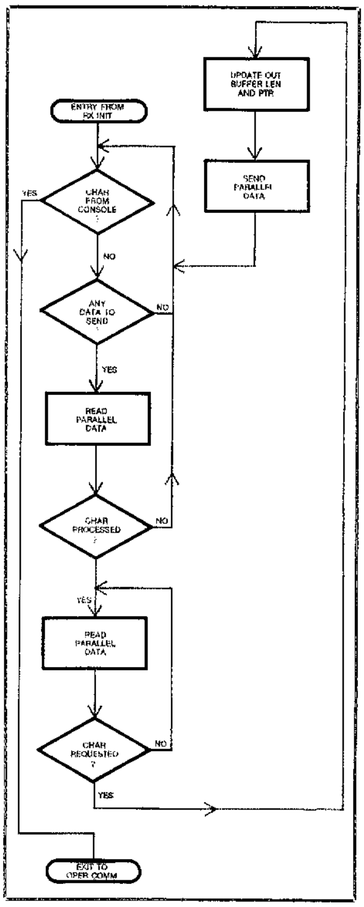
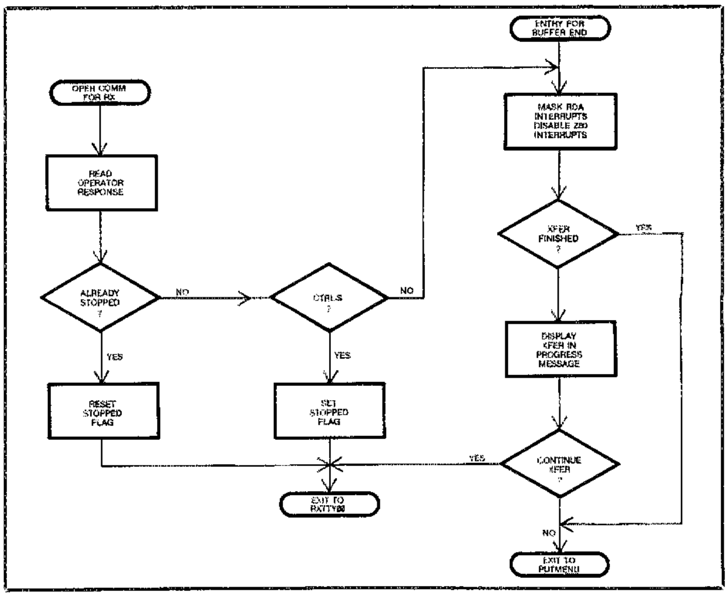


Fig. 8 — The background processing loop communicates with the operator, or transmits data to another computer for decoding and display.

Fig. 9 — Operator communications routine. →



so keep your eyes open for them.

Connecting the Modem and Serial Port

Once the modem and serial interface are on hand, simply connect the serial output of the modem to the serial input of the computer. Only two wires are required: one for data, and one for signal ground. If you have trouble getting data through, the transmit and receive data lines (pins 2 and 3 on the DB-25 connector) might need to be reversed. This is because the RS-232-C specification defines two types of equipment configurations: data terminal equipment (DTE) and data circuit-terminating equipment (DCE). Since these are complementary ends of a circuit, the signals will be reversed at one end. Also, there may be modem signal lines that have to be permanently wired to a logic low or high level. This is because modems control data going in both directions. For our work, the modem needs to be in the receive mode.

All of this may sound complicated, but you will likely find a description of the signals in the modem documentation. Sometimes there are switches inside or on the rear of the modem that change the configuration of some of the signals. If you happen to have a modem that has switches or jumper positions for full-duplex or four-wire operation, you should enable these options.

Software Interface to the Serial Port

Rather than trying to explain the operation of a Z80 (or other) assembly language program, I have divided the functions needed to process serial modem data into separate routines. Flowcharts for these routines are included. Here is a list of the necessary functions and some brief comments about each.

Initialization Prior to Reception

The initialization routine (Fig. 7) must set the operational characteristics (such as the data rate and word length) of the serial port. It is possible that these items are not software programmable, but are hard-wired on the interface. The pointers to the internal received-data buffer must be initialized. If you are detecting received data via interrupts, the proper interrupts must be allowed (unmasked), and the proper interrupt mode for the processor must be specified. It is not necessary for received data to be processed by interrupts. I have included this method because I use it on occasion.

Background Processing

This routine (Fig. 8) executes in between received characters. In a non-interrupt-driven system, it will probably do only two things: check for intervention from the system operator, and see if another

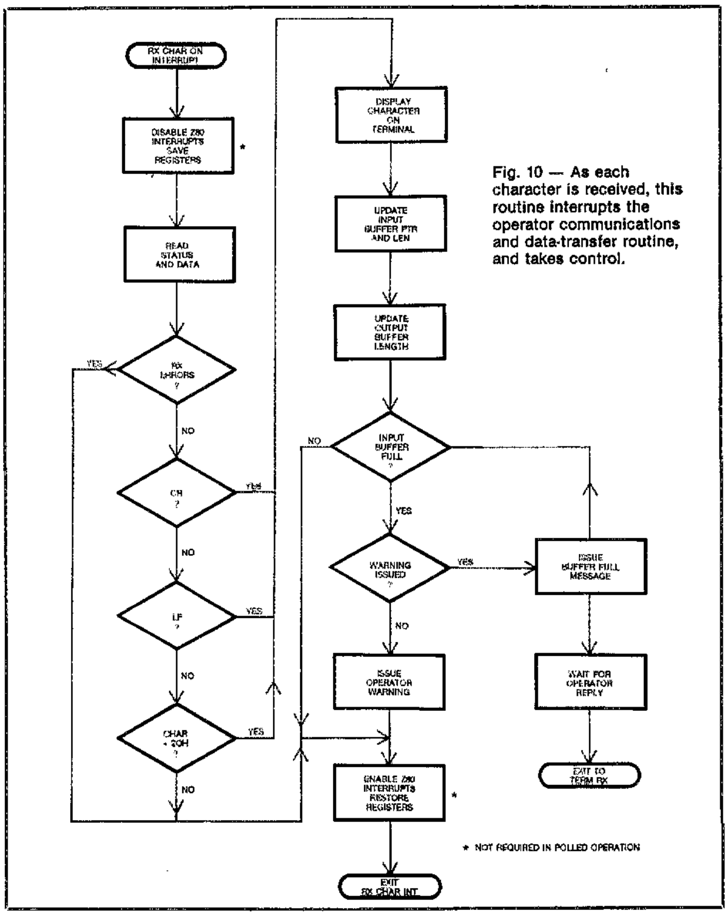
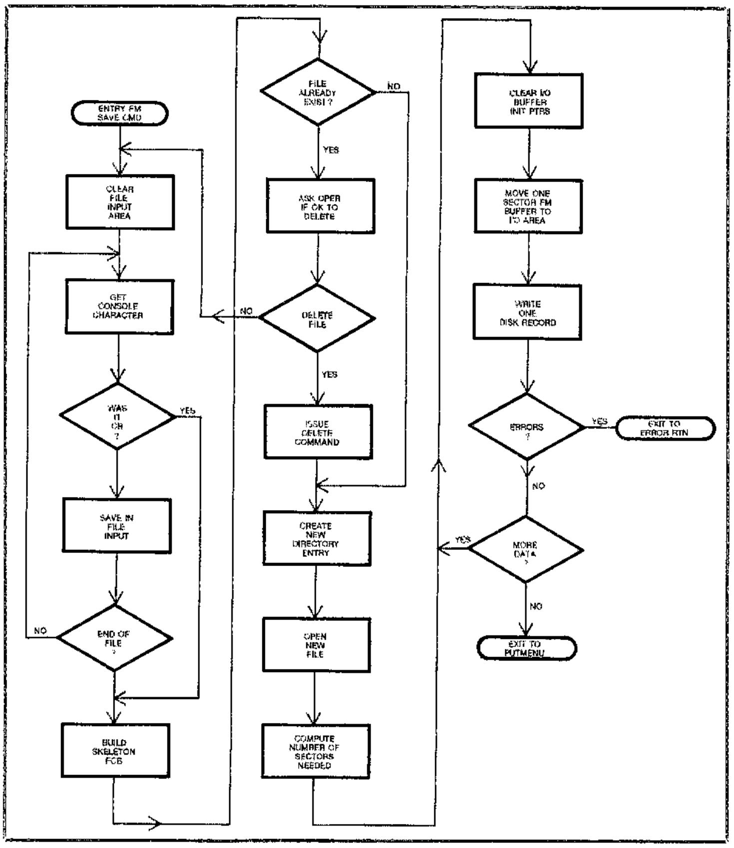


Fig. 10 — As each character is received, this routine interrupts the operator communications and data-transfer routine, and takes control.

Fig. 11 — This routine takes the telemetry data in the computer buffer and saves it on disk. →



character has been received from the modem. In the interrupt-driven system, this routine would still check for operator communications, but the arrival of a new character would be signaled automatically by the interrupt. In my interrupt-driven system, this routine has the additional task of sending the received data to another computer for real-time display.

Operator Communications Routine

At some time during the data-capture process, it may be desirable for the operator to temporarily, or permanently, suspend data capture. The operator communications routine (Fig. 9) processes these requests accordingly. If transmission to another computer is in progress, the operator is warned and can allow it to finish, or abort, the process. If termination is requested and reception is interrupt-driven, the receive-data interrupt must be masked again.

Receive Characters from Modem Routine

If reception is not interrupt-driven, this routine (Fig. 10) would become a part of the operator-communications loop and would be executed if a character is ready to process. In an interrupt-driven system, it is automatically executed as a result of the receive-data interrupt. In either case, the overall function is the same except that in noninterrupt-driven (polled) systems, interrupt-related functions would not be included.

The character-receive routine must accept the character from the modem and perform minimal data error checking. As an example, it could filter out control characters. It must place the character in the buffer and update the buffer pointer and length. Finally, it must decide if the buffer is about to fill up. If so, the operator is given a warning before the condition occurs.

Save Telemetry on Disk

Once reception has ended, the data may be saved on disk. This routine (Fig. 11) must ask the operator for a file name and then check to see if it already exists on the disk. If it does, a new name can be entered or the old file deleted. The amount of space needed is computed, and then the data is moved from the buffer to the I/O buffer, one sector at a time. The only other necessary action is to check for errors after each write to the disk. It is possible that the disk could fill up and the operator would need the chance to save the information on another disk.

Editing and Analysis

Now that the data has been captured on

```
 UoSAT OSCAR 9 --- DATE: 84.059 = 02/28/84 --- TIME: 2138 UTC --- ORBIT: 13288
--------- DATA RATE: 01200 BPS --- MODE: ASYNC --- BEACON FREQ: 145.825 ---------
              ---- SPACECRAFT SYSTEMS STATUS ----

 1) 145 MHz BEACON           ON           2) 435 MHz BEACON           OFF
 3) PRIMARY COMPUTER         ON           4) CCD CAMERA MODULE        OFF
 5) RADIATION DETECTOR - A   ON           6) MAGNETOMETER EXPT.       ON
 7) 7 MHz BEACON EXPT.       OFF          8) 14 MHz BEACON EXPT.      OFF
 9) 21 MHz BEACON EXPT.      ON          10) 28 MHz BEACON EXPT.      OFF
11) 2.4 GHz BEACON EXPT.     OFF         12) 10.47 GHz BEACON EXPT.   OFF
13) 145 MHz COMMAND RX       SQUELCHED   14) 435 MHz COMMAND RX       SIGNAL
15) STATUS CALIBRATE                     16) BATTERY CHG REG STATUS   B
17) H F BEACON EXPT. SYNTH.  OFF         18) TELECMD DECODER STATUS   GROUND
19) MAGNETORQUER             OFF         20) PRI COMPUTER BLOCK LOAD  DISABLE
21) SEC COMPUTER DATA O/P    ACTIVE      22) SEC COMPUTER CLOCK       INT FAIL
23) SEC COMPUTER PROCESSOR   RUNNING     24) SEC COMPUTER POWER DOWN  ON
25) 14 MHz SYNTH LOCK        OUT         26) 28 MHz SYNTH LOCK        OUT
27) 21 MHz SYNTH LOCK        OUT         28) RADIATION DETECTOR - B   OFF
29) TIP MASS UNCAGE CONFIRM  YES         30) SPEECH SYNTH POWER       ON
31) VISUAL MEMORY DISPLAY    OFF         32) GRAV GRAD BOOM MTR PWR   OFF
33) SEC COMPUTER POWER       OFF         34) H F BEACON EXPT. POWER   ON
35) NAV MAGNETOMETER PWR     ON          36) COMPUTER MEM ERR BIT - 1
37) COMPUTER MEM ERR BIT - 2             38) COMPUTER MEM ERR BIT - 3
39) STATUS CALIBRATE                     40) PRI COMPUTER UART O/P    ACTIVE
41) GRAVITY GRAD BOOM MOTOR  FORWARD     42) MAGNETORQUER POWER       FORWARD
43) MAGNETOMETER EXPT.       CALIBRATE   44) NAVIGATION MAGNETORQUER  SAFE
45) GRAVITY GRAD BOOM MOTOR  SAFE
```

Fig. 12 — An example of the decoded spacecraft systems status. The data shown here are decoded from the lines beginning with "AMSAT" as shown in the raw telemetry sample (Fig. 1) for UoSAT OSCAR-9.

the diskette, what can be done to improve its integrity? Several things, and these are accomplished during the editing phase. The edit phase simply reads the captured data and writes a new file containing only error-free records. Some items that can be checked during the editing phase are

1) The length of the telemetry lines that were saved. If any are of incorrect length, the whole line can be discarded.

2) Proper line data. Are the lines spaced properly? Are frame numbers ascending and between the proper limits? Do the values within the lines make sense? Do the checksum calculations yield the proper result?

It is impossible to detect every kind of error, but a good editing job will save you headaches later. You should also add some type of indication as to when the data were collected. (See Figs. 12 and 13.) I add a header to the output file. The header contains the satellite name, data, time, data rate, orbit number, beacon frequency and transmission mode.

The analysis phase consists of reading the edited telemetry file and substituting the values into the calibration equations. You can collect data over a long period of time and then produce graphic displays for that period.

UoSAT OSCAR 9 ——— DATE: 84.059 = 02/28/84 ——— TIME: 2138 UTC ——— ORBIT: 13288
———— DATA RATE: 01200 BPS ——— MODE: ASYNC ——— BEACON FREQ: 145.82 ————
——— SPACECRAFT TELEMETRY ——— 1 ———

CHANNEL	PARAMETER	RAW VALUE	ACTUAL	UNITS
00	SEC COMP CURRENT	110	132.000	mA
01	SOLAR ARRAY CURRENT +X	020	222.400	mA
02	BATTERY HALF VOLTAGE	773	7.807	Volts
03	RADIATION DETECTOR A O/P	001	41.600	Count
04	RADIATION DETECTOR B O/P	001	41.600	Count
05	MAGNETOMETER HX-COARSE	528	1176.150	nT
06	MAGNETOMETER HY-COARSE	529	2837.620	nT
07	MAGNETOMETER HZ-COARSE	713	27425.480	nT
08	BATTERY PACK-A TEMP	458	3.232	Degrees C
09	+X FACET TEMP	472	0.404	Degrees C
10	VISUAL DISPLAY & CCD CURRENT	100	84.000	mA
11	SOLAR ARRAY CURRENT +Y	150	368.000	mA
12	2.4 GHz BEACON POWER O/P	000	0.000	mW
13	RADIATION DETECTORS EHT VOLTS	370	370.000	Volts
14	RADIATION DETECTORS CURRENT	307	40.180	mA
15	MAGNETOMETER HX-FINE	628	2111.850	nT
16	MAGNETOMETER HY-FINE	564	970.380	nT
17	MAGNETOMETER HZ-FINE	537	479.520	nT
18	BATTERY PACK-B TEMP	393	16.362	Degrees C
19	-X FACET TEMP	416	11.716	Degrees C
20	PRI COMP CURRENT	160	162.000	mA
21	SOLAR ARRAY CURRENT -X	200	424.000	mA
22	BATTERY/BCR 14V BUS	715	15.101	Volts
23	SUN SENSOR +Z AXIS	112	0.566	Volts
24	10.4 GHz BEACON CURRENT	008	-7.760	mA
25	MAGNETOMETER TEMP	419	11.110	Degrees C
26	MAGNETOMETER CURRENT	439	54.573	mA
27	TELECOMMAND RX CURRENT	283	31.773	mA
28	RADIATION EX TEMP +X1	468	1.212	Degrees C
29	+Y FACET TEMP	589	-23.230	Degrees C
30	BATTERY CHARGE CURRENT	310	930.000	mA
31	SOLAR ARRAY CURRENT -Y	390	636.800	mA
32	POWER COND MODULE +10V	667	10.338	Volts
33	TELEMETRY SYS CURRENT	256	8.672	mA
34	2.4 GHz BEACON CURRENT	004	-3.002	mA
35	145 MHz BEACON POWER O/P	357	459.250	mW
36	145 MHz BEACON CURRENT	395	98.358	mA
37	145 MHz BEACON TEMP	358	23.432	Degrees C
38	PRI COMP TEMP -X1	483	-1.818	Degrees C
39	-Y FACET TEMP	220	51.308	Degrees C
40	+14 V LINE CURRENT	090	257.400	mA
41	+5 V LINE CURRENT	100	64.000	mA
42	POWER COND MODULE +5V	739	5.518	Volts
43	SUN SENSOR -Z AXIS	036	0.182	Volts
44	HF BEACONS CURRENT	139	35.638	mA
45	435 MHz BEACON POWER O/P	000	0.000	mW
46	435 MHz BEACON CURRENT	003	-10.881	mA
47	435 MHz BEACON TEMP	424	10.100	Degrees C
48	SEC COMP TEMP +Y1	505	-6.262	Degrees C
49	+Z FACET TEMP	458	3.232	Degrees C
50	+10V LINE CURRENT	100	300.000	mA
51	-10V LINE CURRENT	090	39.000	mA
52	POWER COND MODULE -10V	275	4.113	mA
53	NAV MAGNETOMETER Y-AXIS	115	-100631.062	nT
54	NAV MAGNETOMETER Z-AXIS	863	-99783.333	nT
55	NAV MAGNETOMETER X-AXIS	299	38423.625	nT
56	SPEECH SYNTH CURRENT	462	45.001	mA
57	CCD IMAGER TEMP	469	1.010	Degrees C
58	TELEMETRY SYS TEMP -Y1	441	6.666	Degrees C
59	-Z FACET TEMP	477	-0.606	Degrees C

Fig. 13 — A sample decoded telemetry frame. The channel numbers 00-59 correspond to the first two digits in the 5-digit telemetry groups. The values in the column RAW VALUE are the other three digits from each channel. These are substituted into the proper calibration equation by the analysis program, and the values shown in the right-hand column result.

Summary

This information should provide a starting point for those of you who would like to make a permanent record of the data being transmitted by UoSAT-OSCAR 9. Even though the system I described is dependent on the hardware in my computer system, I hope you will be able to apply the principles shown here to your own computer system.

Strays

STRAY HINTS

☐ "Strays" are those interesting fillers used when space allows in *QST*. Think you have an item with Stray potential? Here are some hints to help your submission become one. (1) Be sure the information will be of interest to most readers of *QST*. (2) Submit your material before deadline — the 8th of the second month preceding desired publication (i.e., arrive at Hq. before August 8 for October *QST*). (3) Any photographs you send should be good quality, black-and-white glossy prints. Color prints, slides and instant photos do not usually reproduce well.

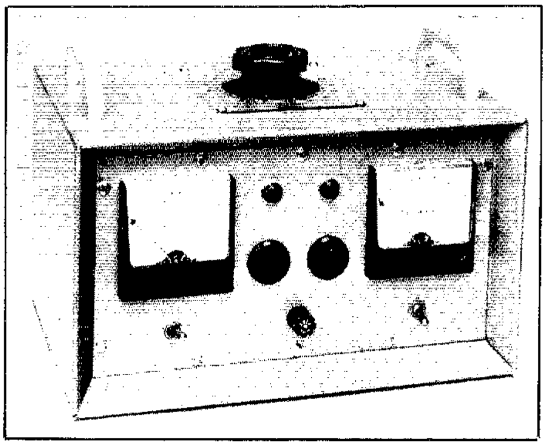
Items submitted are normally acknowledged, but that doesn't necessarily mean that your Stray will be appearing in *QST*. We receive far more material than we can find room for. If you want your material returned, please include a statement to that effect and an s.a.s.e.

Follow the above hints and maybe your Stray will find a home in *QST*. — *Andrew Tripp, KA1JGG*

SCOUT JAMBOREE NEEDS VOLUNTEERS

☐ The Amateur Radio Program at the 1985 National Scout Jamboree, scheduled for July 24-30, 1985 at Fort A. P. Hill, Virginia, is looking for a few good amateurs to volunteer for staff positions. If you'd like to have a great time mixing Amateur Radio with Scouting, contact Leo Kluger, WB2TRN, Recruitment Program Manager, ARRL.

A Variable AC-Voltage Source



If you've ever needed a variable source of ac voltage, you know how valuable it can be. Build this unit over a weekend from junk-box or flea-market parts.

By John E. Magnusson,* WØAGD

Quite often, when troubleshooting equipment, it is convenient and time-saving to have a variable ac-voltage supply to power the unit under test. Use of such a supply is less expensive than continually installing fuses with greater amperage ratings until the defective part finally reveals itself by becoming red hot or filling the room with smoke! Too often the "new fuse" procedure also results in the original defective part taking one or more other circuit components "along for the ride" to oblivion.

Some examples of hard-to-find defective components include (1) a rectifier diode that does not show a short with the low voltage of a digital multimeter applied to it, but fails under normal operation, and (2) a power-supply filter capacitor that breaks down at 30 to 50% of its rated working voltage, but appears to be okay when you disconnect one end from the circuit and check it with a volt-ohmmeter. These are only two familiar examples with which you may struggle until the component breaks down completely or, in total exasperation, you check every suspect item.

Help

To shorten the troubleshooting cycle, a variable ac-voltage source is the answer. You can gradually increase the ac-voltage input to the device under test as you make a few measurements. Simultaneously monitoring the ac-voltage input and the output voltage of a power supply should provide an answer before the input voltage has been increased to the level that causes fuse failure.

Let's say you have a 12-V power supply that has no output voltage with 50% of the line voltage applied. If you have ac voltage at the transformer connections to the rectifiers but no dc voltage at the filter capacitor(s), the problem must be with the rectifiers. If you have dc voltage at the filter capacitor but it disappears before the voltage threshold that causes the fuse failure, the bad component must be the capacitor, or one of the sections in a multisection capacitor. Granted, these are simple examples, but they serve to point out the usefulness of the variable ac supply.

Let's Build One

Scattering a bunch of test leads, meters and an autotransformer on the workbench can prove to be lethal. To keep things tidy and safe, I assembled the variable ac-voltage supply shown in the photos and schematic diagram.

Acquiring Parts

QST ads and flea markets are excellent sources of parts. Flea markets produced the two meters and recessed front panel (shadow box) cabinet. This enclosure provides protection for the meters and the bat-handle switches. Variable autotransformers are available under various trade names, such as Variac™ and Varitron™. Although the variable transformer I used is rated for only 8-A ac, this is a CCS (Continuous Commercial Service) rating. Therefore, ICAS (Intermittent Commercial and Amateur Service) use at 50% overload should not be reason for concern.

Circuit Description

Fig. 1 is a schematic diagram of the unit. S2 is used to switch line-voltage meter M2 from the input line of T1 to the output of T1. This allows the unit to be used as a line-voltage monitor whenever it is not in use as a variable-voltage source. While the unit is in use, M2 provides a quick means of reading the incoming line voltage. DS2 monitors the output of T1.

If installed at point B, M1 shows the amount of current being drawn through T1. This helps you stay below the fuse-failure threshold of the equipment being tested. It also gives an indication of any intermittent arcs in the unit under test, as it is more sensitive to such load changes than the ac voltmeter. M1 and M2 are bypassed with 0.005-μF/500-V ceramic capacitors.

F1 provides protection for the variable transformer and ammeter. S1 is the ON/OFF switch, and DS1 is the accompany-

*5329 Gladstone, Lincoln, NE 68504

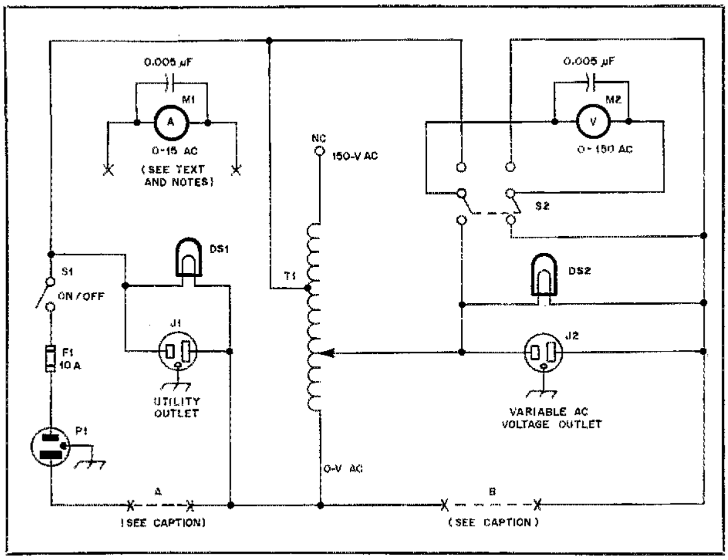


Fig. 1 — Schematic diagram of the variable ac-voltage source. With the ammeter installed at A, the meter will read the sum of the currents drawn from the utility and variable ac outlets. If the ammeter is installed at B, it indicates only the current drawn from the variable ac voltage outlet. (Refer to April 1984 Hints and Kinks for information concerning safe ac-power wiring practices.)

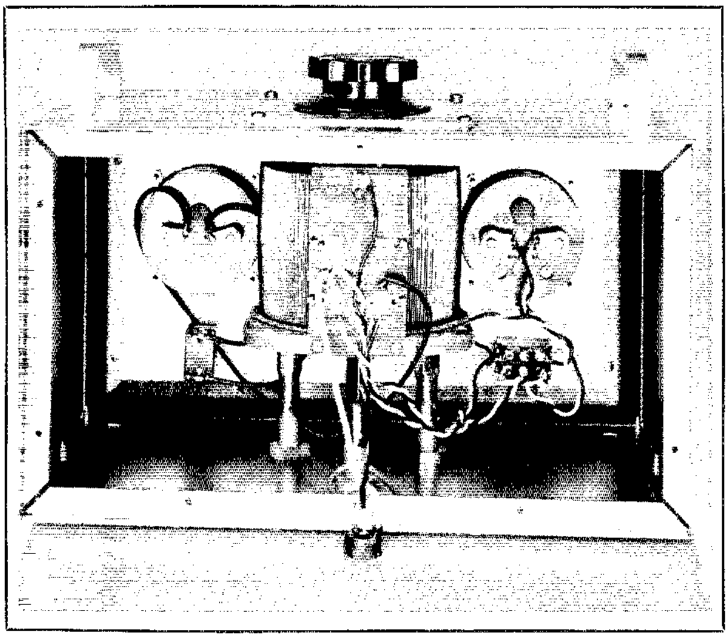


Fig. 2 — An inside view of the variable ac-voltage controller.

ing pilot light. If you're leaving the workbench for a period of time, you need not disconnect the line cord from the wall outlet; just flick the switch.

Two ac outlets are provided. J1 is a convenience outlet for use with your VTVM or other test equipment. J2 carries the variable-voltage output.

Construction

Only aesthetics need be considered when laying out the front panel; parts placement is not critical. I mounted T1 on the inside cabinet top. Two carrying handles make it easy to transport the unit as well as providing some protection for the transformer-adjustment knob.

Fig. 2, an inside view of the power unit, shows the mechanical support of T1. The spacers I used came from my "junk box." Spacers can be made easily from aluminum or copper tubing or small-diameter threaded nipples available from hardware or plumbing stores. An insulated clamp secures the line cord at the rear panel.

Summary

You'll find the construction of this unit to be a relatively inexpensive and easy weekend project. I'm sure this variable ac-voltage supply will be a worthwhile addition to your work bench.

Strays

QEX: THE ARRL EXPERIMENTERS' EXCHANGE

☐ Wonder what you've been missing by not subscribing to *QEX,* the ARRL newsletter for experimenters? Among the features in the July issue were:

• A 9-minute "ID Timer with Tone and Display," by Donald G. Varner, WB3CEH
• A "Coax-Loss Program for the HP-97 and TRS-80C," by I. L. McNally, K6WX
• New computer programs for electronic circuit analysis, signal processing and scientific graph printing, in the "Bits" column.

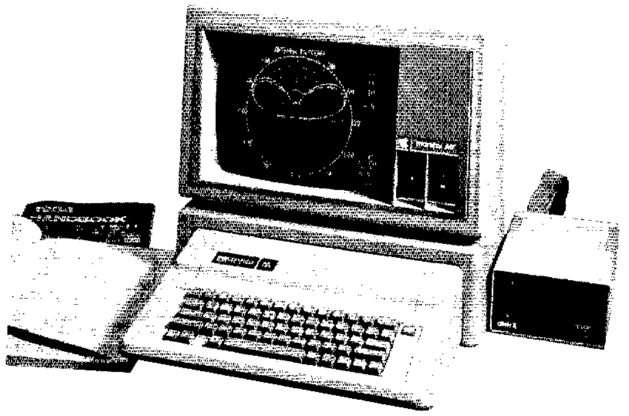
QEX is edited by Paul Rinaldo, W4RI, and Maureen Thompson, KA1DYZ, and is published monthly. The special subscription rate for ARRL members is $6 for 12 issues; for nonmembers, $12. There are additional postage surcharges for mailing outside the U.S.; write to Headquarters for details.

IMPROVING STATION AUDIO SUBJECT OF TRN TALK

☐ "Microphone Equalization for Radio Communications" will be the subject of a talk by noted audio expert Bob Heil, K9EID, on the North American Teleconference Radio Net on September 14 at 7:30 P.M. CDT. Heil, author and lecturer on audio systems, will describe practical ways to improve the sound and effectiveness of your radio station, among other things.

Access to TRN is provided by more than 180 gateway stations, mostly VHF repeaters, linked together to cover virtually every metropolitan area in the U.S. and much of Canada. For information on linking your repeater into the net, send an s.a.s.e. to Honeywell ARC, Mail Station MN26-4201, Honeywell, Inc., Honeywell Plaza, Minneapolis, MN 55408.

The Effects of Real Ground on Antennas



Part 4[†]*:* Vertical antennas: Some people swear by them; others swear at them. What do the computers say?

By James C. Rautio,* AJ3K

Vertical, ¼-wavelength, ground-plane antennas are popular because they use little space, require a single support, are easily incorporated into phased arrays and offer the *potential* for low-angle radiation. Vertical antennas radiate equally well in all directions — or, as some say, they radiate equally poorly in all directions.

As with most antennas, ¼-wavelength verticals have advantages and disadvantages. First the good news! The input impedance of a ¼-λ vertical above a perfect ground is 35 ohms, half the input impedance of a dipole in free space. With the impedance cut in half, the current will be double that of a dipole. Since it is current (not voltage) that determines how well an antenna radiates, we seem to have an antenna that is better than a dipole. In fact, with the current doubled, we might expect the antenna to be up to a full 6 dB better. Now for the bad news. The ¼-λ vertical has only half the length of a dipole. This means the 6-dB advantage of a vertical is cut to 3 dB. Also, we are comparing a vertical over a perfect ground to a dipole in free space. Neither of these characteristics is very realistic! If we place the dipole over a perfect ground, however, the direct ray radiated from the dipole can add with the ray reflected from the ground for up to 6 dB more gain than the same dipole in free space.

Thus, a ¼-λ vertical can have up to 3 dB more gain than a dipole in free space. But a vertical over perfect ground has a peak gain 3 dB less than a dipole over perfect ground. If a vertical is automatically 3 dB poorer than a dipole, why should we even consider using one? Fortunately, the vertical antenna may actually have superior gain at low radiation angles, if it is designed properly.

Before we can design a vertical, it is helpful if we can analyze it. In past installments of this series, I have used a program called Annie on the Apple® II computer (which is now available for the Commodore-64™ computer) to analyze antennas over a real ground.[1] Can we use Annie to analyze verticals? There is a problem here. Annie's analysis technique (reflection coefficients) loses precision when the antenna is less than a few tenths of a wavelength above ground. To see how much precision is lost, I modeled a vertical antenna as a group of monopoles. A monopole (see Part 2) is exactly half of a dipole. A single, vertically oriented monopole represents the ¼-λ antenna, and the ground radials are formed by a series of monopoles on the ground. Annie can include up to 48 radials.

The results of the Annie analysis on the Apple computer were then compared with the results of the Numeric Electromagnetic Code — Method of Moments (NEC) program. This large computer program, run on a VAX 11-780® computer, can be considered to give exact results. The Annie analysis is always within 2 dB of the NEC analysis. This is a good agreement in view of the 20-dB price difference between the two computers! The results of this analysis are compared in Fig. 1.

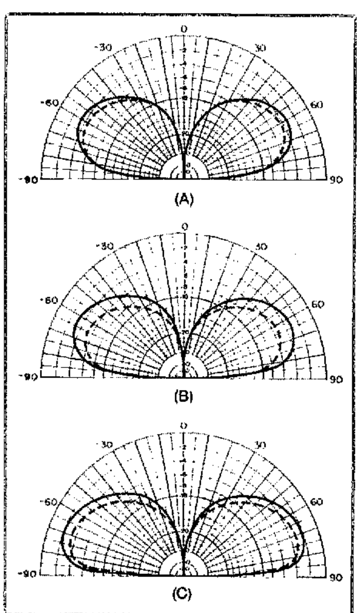


Fig. 1 — The NEC analysis (solid line) and Annie analysis (dashed line) for (A) poor ground, X = 0.1, E_r = 7; (B) good ground, X = 1.0, E_r = 15, (C) very good ground, X = 10.0, E_r = 30. X = conductivity (mS/m) divided by frequency. There are 48 quarter-wavelength radials on each vertical. Add 3 dB to values shown.

Annie makes an approximate analysis of vertical antennas available to radio amateurs. Brian Edward, N2MF, has gone one step further and used NEC to analyze precisely a wide variety of vertical antennas. His work is the subject of a future *QST* article.

Arrays of Verticals

Verticals are excellent antennas for building large arrays. They may be phased to create a directional antenna, and the phasing can be changed electronically to point the array in different directions. Care must be taken to account for the coupling between verticals, as described by Forrest

[1]Notes appear on page 35.

*4397 Luna Course, Liverpool, NY 13088

[†]Parts 1, 2 and 3 of this series appeared in February, April and June 1984 *QST*.

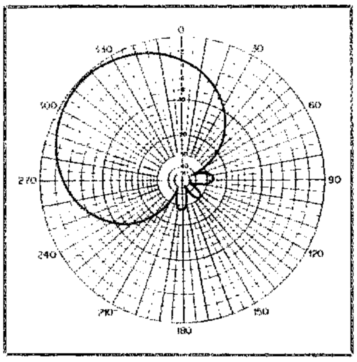


Fig. 2 — A four-element phased array of verticals over perfect ground can provide an excellent front-to-back ratio. The four elements are positioned around the circle at the 45° points. Add 9 dB to all values.

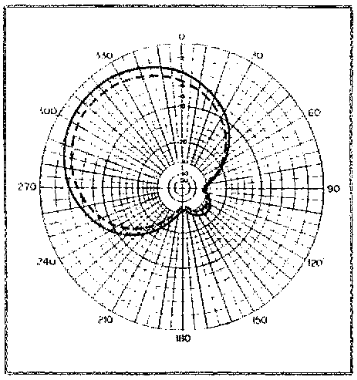


Fig. 3 — A real ground caused the side lobes of the array of Fig. 2 to melt into one and the peak gain to drop. The solid curve is for a very good ground, the dashed line for a poor ground. Add 6 dB to all values.

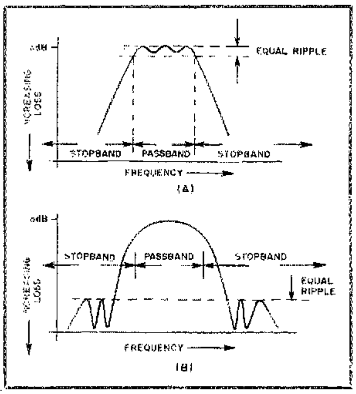


Fig. 4 — The Chebyshev filter can be designed for (A) equal ripple in the passband or (B) equal ripple in the stopband.

The Inverted V Revisited

Reactions to Part 2 of this series (on inverted Vs) varied tremendously. In that article, I stated that an inverted V is significantly poorer than a horizontal dipole. Several hams felt my conclusion was consistent with their experience. One even told me that he went right out and tore down his inverted V. (I forgot to mention that inverted Vs are better than *no* antenna!) One person, however, took exception to my conclusions, and wrote to tell me about it.

I had stated that the reason an inverted V is not as good as a dipole is because the vertical part of the antenna currents tend to cancel. Well, Ken Leiner, N4LC, suggested the following "thought experiment." Take a 100-W transmitter and perfectly match it to a lossless dipole. Now measure the total power radiated into space. The radiated power should be 100 W. Next, form the dipole into an inverted V. With the inverted V also perfectly matched to a 100-W transmitter, measure the total power radiated into space. This power should also be 100 W. But how can that be if half the antenna current cancels as I suggested in Part 2?

At this point, the answer became embarrassingly obvious. Yes, the vertical antenna currents cancel, but the input impedance of the inverted V has decreased (from that of a dipole), which allows the total antenna current to increase just enough to cause the total 100 W to be radiated. The vertical currents cancel, but the horizontal currents increase to make up for it. This means that the inverted V should be just as good as a dipole.

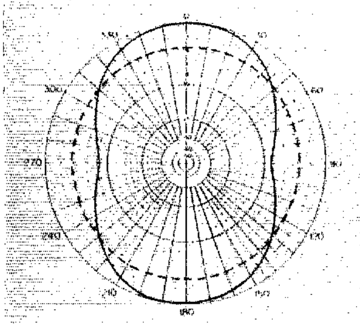
To check this conclusion, I used a numerical antenna analysis program (NEC) to analyze an inverted V in free space. Sure enough, the inverted V input impedance was about 38 ohms (down from the 73 ohms of a dipole) and the antenna current had increased, which compensated for the vertical components cancelling.

The maximum gain is still a ½ dB below that of a dipole. Where did the ½ dB go? When we changed the dipole into an inverted V, that power was taken from the broadside gain and radiated off the ends. In fact, that ½ dB of broadside power starts to fill in the null off the end to make the inverted V a more omnidirectional antenna than a dipole.

What about the effect of ground? NEC was also used to analyze the inverted V above an average ground (5 mS/m, epsilon relative = 15, f = 3.5 MHz). The apex was 0.2 wavelength high with an apex angle of 90°. This antenna was compared to a dipole 0.2 wavelength high.

Ground causes quite a bit of the inverted-V power to be radiated off the ends. In fact, at low radiation angles over perfect ground, there is more radiation off the ends than there is broadside to the antenna. Unfortunately, when we look at an inverted V from off the end, what do we see? It looks like a vertical antenna, and sure enough, the radiation off the end is vertically polarized. A good share of this radiation is absorbed by the ground. The total result for the dipole and inverted V is shown in the accompanying figure. The net result is that the inverted V over average ground is actually about 3 dB down from a dipole. As an omnidirectional antenna, however, it is substantially better.

Thanks to Ken Leiner, N4LC, for a point well taken, and thanks also to Dick Pitzeruse, K2NY, and Brian Edward, N2MF, for the NEC analysis.



The solid line represents the pattern for a dipole, and the dashed line is the pattern for an inverted V. The center of both antennas is 0.2 λ above ground. Add 3 dB to all values.

Gehrke, K2BT, in a series of *Ham Radio* articles.[2]

Gehrke's articles analyze a number of vertical phased arrays over perfect ground. Then he designed feed networks so that each element of the array would be excited with the proper phase signal. I used Annie to repeat one of his array analyses. The array has four verticals at the corners of a square 0.272 wavelength on a side. Two diagonal elements were driven 90° behind one corner element with the remaining corner lagging 180°. The results shown in Fig. 2 agree with his calculations. The array looks quite good over perfect ground. The maximum gain is almost 9 dB better than a dipole in free space, which means it is 3 dB better than a dipole above perfect ground.

What is the effect of real ground? Fig. 3 shows Annie's results for a good and a poor ground. First, the side lobes all melt into one lobe. Fortunately, that lobe is still very small. As for peak gain, the edge of the plot has been reduced to less than 6 dB greater than a dipole in free space. Notice that the array has a peak gain that isn't even as good as a dipole over perfect ground. Since the low-angle radiation of a horizontal dipole over real ground is nearly the same as over perfect ground, the situation does not look good.

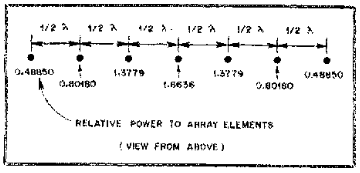


Fig. 5 — The locations (as viewed from above) of the verticals in a Chebyshev antenna array. Each element is labeled with its relative amount of power.

But what do we want from the vertical array? We want low-angle radiation. A dipole must be quite high to provide low-angle radiation. The angle of radiation from the vertical will be low with a high-conductivity ground or, to a lesser extent, with a large radial system.

If properly designed, the vertical array we just analyzed could have significantly better low-angle radiation than a dipole. This makes it a potentially good DX antenna.

Filter or, Rather, Antenna Design

In the last installment, I mentioned that there is a strong similarity between signal processing in the frequency domain (filters) and in the spatial domain (antennas). An antenna can notch out a signal coming from a certain direction just as easily as a filter can notch out a signal at a certain frequency.

If you have worked with filters, you may have heard of Chebyshev filters. These filters are designed to have a frequency response equal to one of a group of equations known as Chebyshev polynomials. A Chebyshev filter can provide equal ripple in the passband (Fig. 4A) or in the stopband (Fig. 4B). Steinberg describes how to design an antenna array that is similar to a filter that has equal ripple in the stopband.[3] The array Steinberg used as an example is shown in Fig. 5. All elements are driven in phase, and the weights are the relative amounts of power going to each element.

Fig. 6A shows the pattern over perfect ground when the elements are spaced ½ wavelength apart. Note that the "equal ripple in the stopband" has translated to equal side-lobe levels. Note also that there are 12 nulls. When the elements of an array are spaced ½ wavelength apart, there are always 2(N – 1) nulls, where N is the number of elements. In this case, we have seven elements and 12 nulls. (How many nulls does a one-element array have?

Now, suppose we want to electrically point the array in another direction? This is done by phasing the elements. For example, if the first element is kept at its present phase and the second is delayed by 45°, the

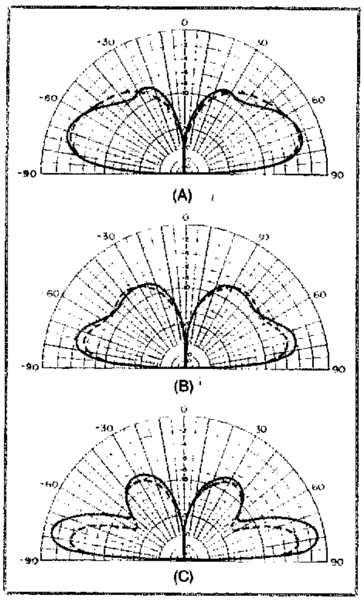


Fig. 7 — The 5/8-λ vertical with 48 quarter-wavelength radials and the same: (A) poor, (B) good, and (C) very good ground as Fig. 1. The solid line is the NEC analysis, and the dashed line is the Annie analysis. Add 2 dB to all values.

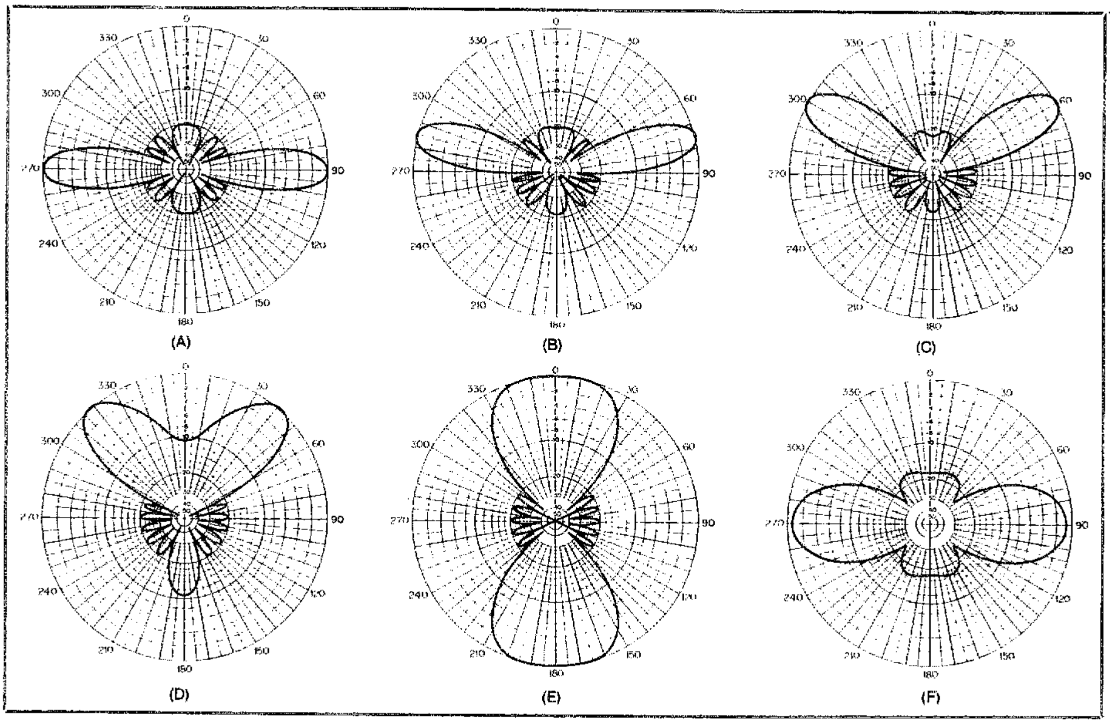


Fig. 6 — Patterns of the Fig. 5 array over perfect ground. At A, all elements are in phase; for B, each element has been shifted 45° from the previous element. At C, the elements are shifted 90°; at D, the shift is 135°; and, at E, the phase is shifted 180° for each element. The pattern at F is with all elements fed in phase, but with a poor ground. Each vertical has 32 quarter-wavelength radials. Add 11 dB to values shown.

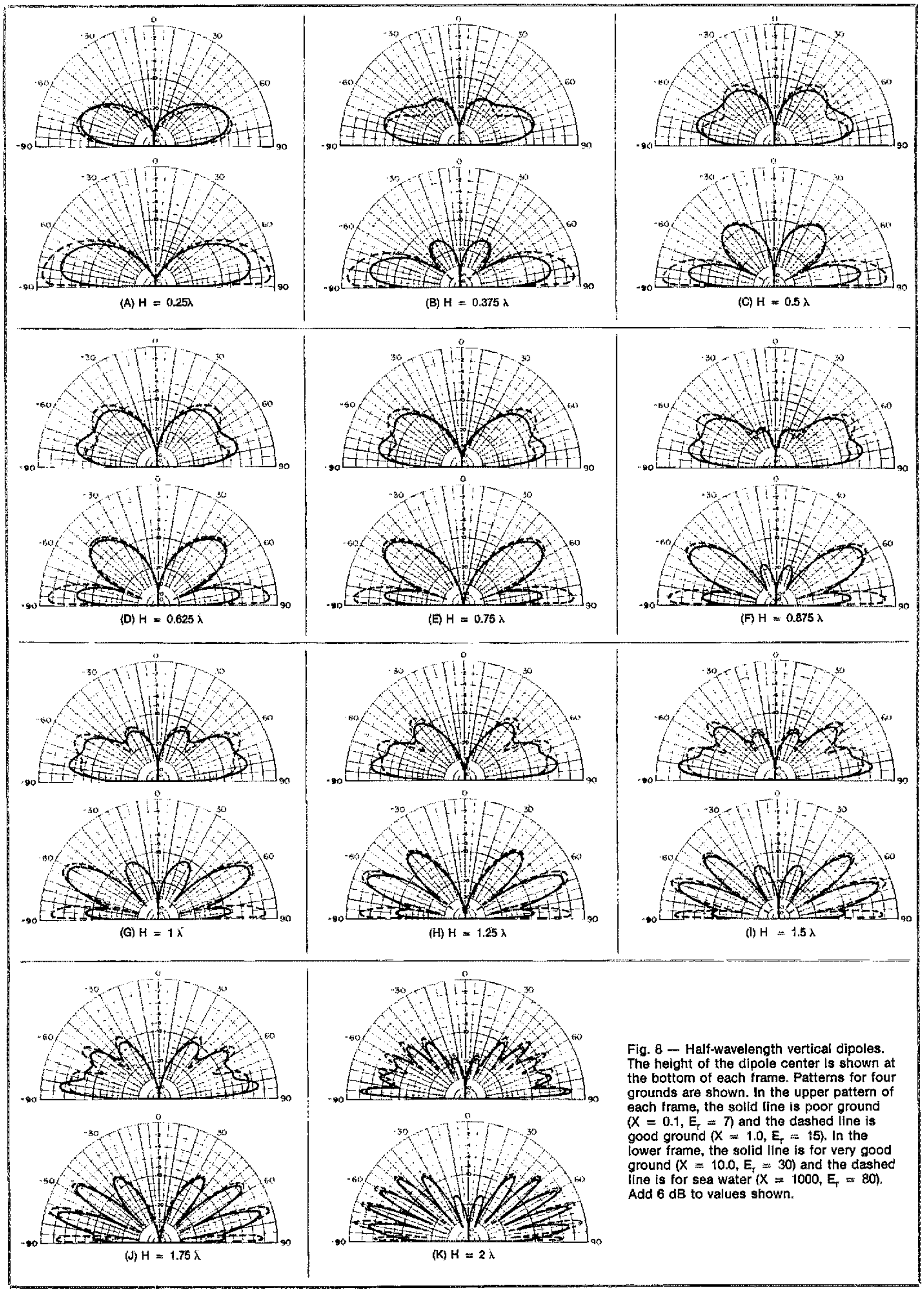


Fig. 8 — Half-wavelength vertical dipoles. The height of the dipole center is shown at the bottom of each frame. Patterns for four grounds are shown. In the upper pattern of each frame, the solid line is poor ground ($X = 0.1$, $E_r = 7$) and the dashed line is good ground ($X = 1.0$, $E_r = 15$). In the lower frame, the solid line is for very good ground ($X = 10.0$, $E_r = 30$) and the dashed line is for sea water ($X = 1000$, $E_r = 80$). Add 6 dB to values shown.

third by 90° and so on, we will have the pattern of Fig. 6B. Note that there are still 12 nulls.

The other parts of Fig. 6 show still other phasing arrangements. Fig. 6A has a very narrow beamwidth, while Fig. 6E has a wide beamwidth. In these plots, we are looking down on the array from above. The array elements are placed on a line that goes from the top of the page (zero degrees) toward the bottom (180°). So an observer at zero degrees would see the elements lined up, one in back of the other, while an observer at 90° would see the verticals all spread out. This gives us a clue as to why the beam is narrower in one direction than another. If you are standing in the direction of the main lobe of the pattern, the bigger the array looks to you, the narrower the beamwidth will be. This is analogous to signals having a narrower bandwidth for wider, or longer, pulses. Compare slow- to high-speed CW signals.

Fig. 6F shows the pattern that results if the ground conductivity is poor (X = 0.1). As before, the nulls melt away and the gain of the array is reduced.

You may wonder why we don't design an antenna that is like a filter with "equal ripple in the passband" or in the direction of the main lobe. When designing filters, we work with a mathematical concept known as poles and zeros. The poles represent parallel resonances, and the zeros represent series filter-circuit resonances. Zeros are simply the antenna-pattern nulls. To design an antenna that has equal ripple in the passband, we would need to use poles in the solution. Here we come to a basic difference between filter design and antenna design: The antenna designer cannot use poles (well, at least not the mathematical kind!).

Is 5/8 λ Better?

Vertical antennas 5/8 λ long are often used to obtain better low-angle radiation. Fig. 7 shows the results of Annie and NEC analysis. Even for the 5/8-λ vertical, Annie's results are always within 2 dB of the more accurate NEC results.

Both NEC and Annie give us a big surprise. The pattern of a 5/8-wavelength vertical above poor ground (Fig. 7A) is better at all angles than above average ground. Except for within about 15° of the horizon, a poor ground is better than a very good ground! What the computers are telling us is that with a poor ground, if you can put up a 5/8-wavelength vertical instead of a ¼-wavelength one, by all means do it. The benefit is especially significant at higher frequencies. We have been estimating how good the ground is by using the variable X defined as conductivity (mS/m) divided by frequency (MHz). The higher the frequency, the poorer the ground for a given conductivity.

There is something unusual in Fig. 7. The very good ground pattern (Fig. 7C) has a

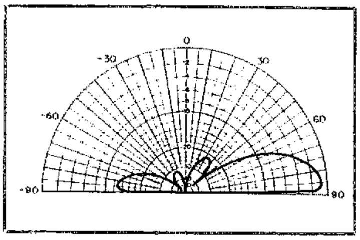


Fig. 9 — The horizontal-plane radiation pattern of two vertically oriented Yagi beams spaced ½ λ apart and fed in phase provide 15-dB gain over a free space dipole (9 dB better than a dipole above perfect ground). This pattern is at 5° above the horizon. Add 16 dB to all values.

null in it that is washed out in the poor ground pattern of part A. Since the only thing that was changed between patterns is the ground, that null must be caused by increasing the ground conductivity. We will run into this effect again.

Brewster Angle

The vertical, or theta-cut, pattern of an antenna is determined by the vector sum of the direct ray from the antenna and the ground-reflected ray. For horizontal polarization, the amount of the reflected ray that gets absorbed and with what phase the ray is reflected vary only a small amount. Vertically polarized rays, however, can vary widely with only small changes in conductivity or angle.

Foremost among these effects is something known as the Brewster angle.[4] If we have a perfectly insulating ground, then, at some angle, all of the vertically polarized wave is absorbed by the ground and none is reflected. This can hurt the pattern, because it is the reflected wave that provides an antenna with an extra 6 dB of gain over that same antenna in free space. Horizontally polarized waves are unaffected by this Brewster-angle absorption.

If the ground is not a perfect insulator, only some of the reflected wave will be absorbed at the Brewster angle, or, more properly, pseudo-Brewster angle. If the ground is a perfect conductor, none of the reflected wave is absorbed.

Fig. 8 shows a large number of vertical dipoles over various kinds of ground. It is similar to the chart for horizontal dipoles presented in Part 1 of this series. There is one extra curve, for X = 1000 and epsilon relative = 80. This is sea water, with a conductivity of 10,000 mS/m and a dielectric constant of 80. If your antenna points out over the ocean, that's the curve to use.

Some impressive patterns are possible with the ocean nearby. Fig. 8B shows a vertical dipole only 0.375 λ high. The maximum radiation is 5° above the horizon. Little wonder those DXpeditions can turn out such good signals with simple vertical antennas!

To see what the Brewster angle does, look at patterns from a half-wave dipole with its center ¾ λ above ground (Fig. 8E). The curve for X = 0.1 (a poor ground) isn't good, but at least it has a fair amount of low-angle radiation. That strange, washed-out null is there, however, just like it was with the 5/8-λ vertical.

As we might expect, that null is caused by the lack of any reflected wave at the Brewster angle. So, if we increase the ground conductivity (which is easy to do on a computer!), the reflected wave should increase in strength and improve the pattern. What happens is that the null becomes deeper and sharper. This means that the reflected ray is actually out of phase with the incident wave, rather than in phase. We were better off with the reflected wave being absorbed by the poor ground.

Fig. 9 shows the vertical-plane pattern of two Yagi beams side by side and driven in phase, also 0.375 λ high. That is 25 feet high on 20 meters.[5] What Annie is saying is, if you are pointing your antenna out over the ocean, make sure it is vertically polarized and you will have a great time, even if it is only 25 feet high.

Conclusion

Vertical antennas can be good DX performers, if designed properly. With a good ground and a large number of long radials, a ¼-λ vertical can do a good job. With a poor ground, the 5/8-λ vertical is a good alternative. If you're fortunate enough to have an ocean in your back yard, a modest vertical antenna will work wonders. Caribbean, anyone?

Notes

[1]Annie runs on the Apple® II+ (48 or 64 kbyte) or //e, or the Commodore-64™ computer. It is available for $49.95 ($39.95 for the C-64 version) plus $2 handling (NY residents add sales tax). Include full name and call. Sonnet Software, Dept. Q., 4397 Luna Course, Liverpool, NY 13088.

[2]F. Gehrke, "Vertical Phased Arrays," *Ham Radio*, May and June 1983.

[3]B. Steinberg, *Principles of Aperture and Array Design*, (New York: John Wiley & Sons, 1976). pp. 111-119.

[4]C. Hutchinson, "DX and the Brewster Angle," *QST*, May 1983, p. 43.

[5]m = ft × 0.3048.

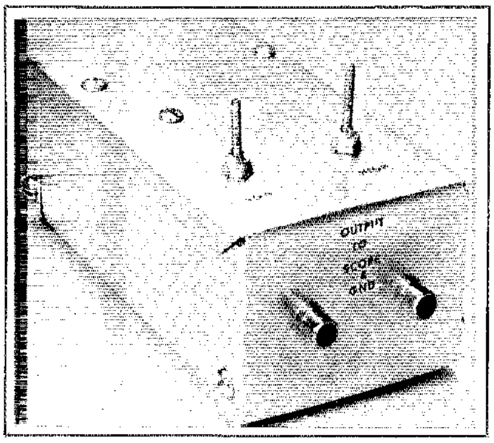
Strays

***QST* congratulates...**

☐ Benjamin G. Shatz, N6COG, of Pacific Palisades, California, on achieving the rank of Eagle Scout.

☐ Doug Smith, KE4KP, on being appointed to the Alabama Forestry Commission.

A Passive RTTY Scope Adapter



This simple project can help you tune in the world.

By Albert F. Lescard,* K1TJV

Nowadays, many of us have a computer in our shack and use it to operate Baudot or ASCII radioteletype (RTTY) and CW. After connecting our computer and modem, we may find ourselves hunting for an RTTY tuning-scope output. Until recently, many modems did not have scope output connections. Many operators like to copy commercial RTTY stations that use various shifts and speeds. Without a scope to display the familiar cross pattern, it's difficult to determine the frequency shift of the received station. Some amateurs own modems equipped only with 170-Hz-shift filters. By using mark- or space-only copy, it is possible to receive stations using shifts other than 170 Hz. If you have a scope, tuning in the station is easy. A special tuning scope is not required. Almost any oscilloscope may be used in this service. Simply connect the mark- and space-filter outputs to the X and Y scope inputs.

The adapter described here connects between your receiver or modem audio output jack and your tuning scope. The adapter needs no power supply. When initially adjusted to display an 850-Hz-shift cross pattern, it is useful with shifts as low as 170 Hz. It can be assembled in an evening, and many parts may be available from your "junk box."

Circuit Description

Refer to Fig. 1. T1 is used to step up the low-level audio input signal to about 5 or 10 V. This potential is applied to the filters. The filters separate the mark and space tones, and feed the signals to the horizontal and vertical scope channels. While a filament transformer is shown being used here, an audio output transformer is also suitable. The 4- or 8-ohm winding of the transformer should be connected to J1.

Construction

J2 and J3 are mounted at one end of the enclosure, about 1¼ inches apart.[1] The audio input jack, J1, is mounted in the center of the opposite end of the box. T1 is placed close to J1, and a six-lug terminal strip is mounted across the middle of the box. The terminal strip simplifies mounting the capacitors and making interconnections among the various components. Two 5/16-inch-diameter holes are drilled in the top of the box near J2 and J3, and the inductors are secured in these holes. The physical layout of my adapter can be seen in Fig. 2.

Tune-Up

Connect the outputs of J2 and J3 to the

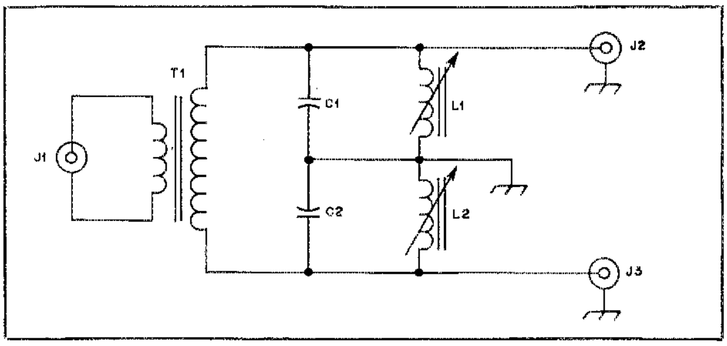


Fig. 1 — Schematic diagram of the RTTY Scope Adapter.

C1 — 0.1 µF/250 V, paper or Mylar.
C2 — 0.05 µF/250 V, paper or Mylar.
J1 — 1/8-inch-diameter, two-conductor phone jack (Radio Shack 274-251).
J2, J3 — Phono jack (Radio Shack 274-346).
L1, L2 — Adjustable inductor, 30-105 mH (J. W. Miller 9007 or equiv.). Available from Bell Industries, J. W. Miller Division, 19070 Reyes Ave., P.O. Box 5825, Rancho Dominguez, CA 90224. [Editor's Note: TV width coils may be used with appropriate changes in capacitor values.]
T1 — 6.3-V filament transformer or audio output transformer.
Misc. — Aluminum box, 2-1/8 × 3 × 5-inch (HWD) (Radio Shack 270-238); six-lug terminal strip (Radio Shack 274-688).

[1] mm = in × 25.4.

*39 Maplewood Ave., Tyngsboro, MA 01879

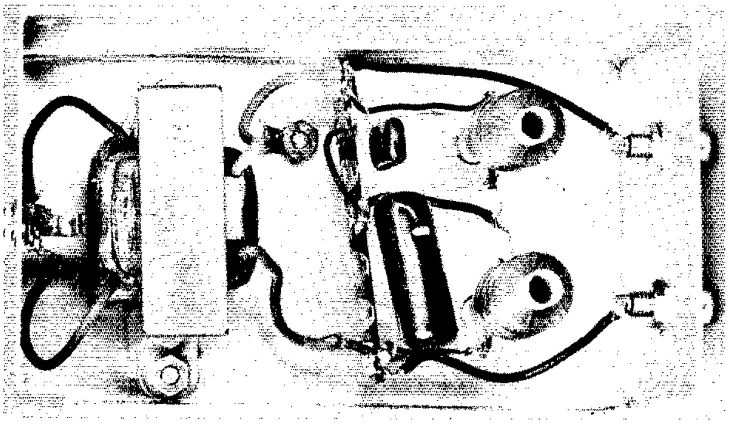


Fig. 2 — An inside view of the scope adapter.

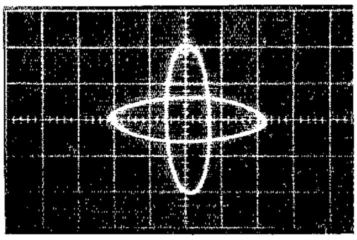


Fig. 3 — Scope display with the adapter set for 170-Hz shift and the signal properly tuned in.

scope terminals, and J1 to an audio source producing a 2125-Hz mark tone. An audio signal generator, or tones from your receiver or modem may be used. Adjust L1 for a maximum indication on the scope. While feeding in a 2925-Hz space tone, adjust L2 for a maximum indication on the other scope axis. The scope adapter is now ready for use with all shifts from 850 Hz to 170 Hz. If the adapter is to be used only on the ham bands, L2 may be peaked for 2295 Hz (170-Hz shift), but the performance of the adapter will suffer if used to display shifts greater than 170 Hz.

Strays

QST congratulates...

☐ the following radio amateurs on 50 years as an ARRL member:

- Lyle W. Mabbott, W7KMF, of Dubois, Wyoming
- Esmond K. Volz, W4WTW, of Palm Harbor, Florida
- Reginald R. Cain, Jr., W4CYC, of Phenix City, Alabama
- Norman T. Dennis, W5YB, of Pensacola, Florida
- Lloyd Frohring, W8PMJ, of Chagrin Falls, Ohio
- Roger W. Barton, W2LOG, of Ithaca, New York

I would like to get in touch with...

☐ anyone in the Minneapolis area interested in working on a cable television show about ham radio. George Fisher, KCØKM, Programming Operations Supervisor, Rogers Cablesystems, 10210 Crosstown Circle, Eden Prairie, MN 55344, tel. 612-941-9820.

☐ anyone with information on converting a Vexilar Model 400 marine VHF transceiver for amateur use on 2 meters. Otto Strecker, N5EO, 214 N. 11th St., Tonkawa, OK 74653.

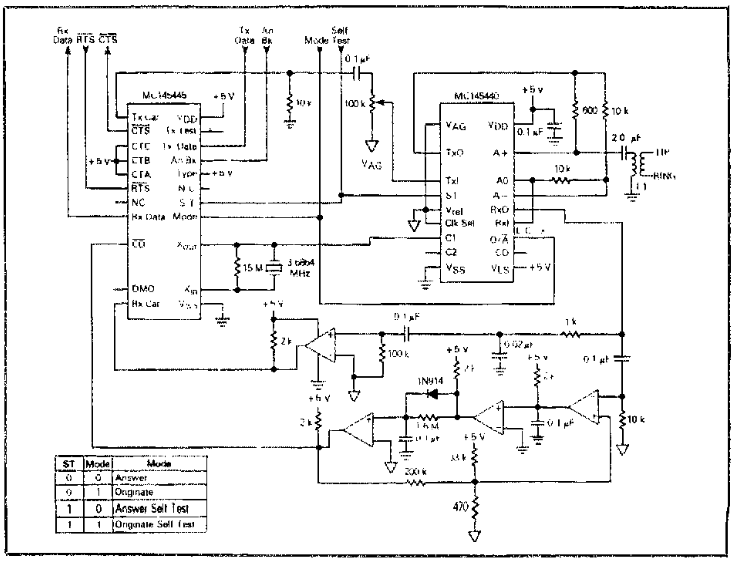
New Products

MOTOROLA MC145445 CMOS 300-BAUD MODEM

☐ Combining the MC145445 modem IC with a Motorola MC145440 filter IC provides you with the major components to make up a 300-baud Bell 103 modem. By tying pin 18 (TYPE) low and substituting an MC145441 filter IC for the '440, a CCITT V.21 modem may be constructed. Fig. 1 is a schematic diagram of a typical modem, taken from the Motorola data sheet.

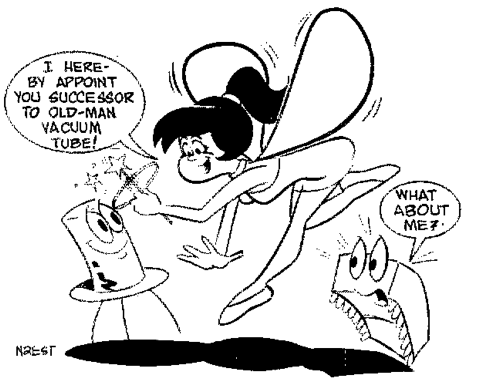
The MC145445 uses differential delay detector demodulation and provides high-performance, low-cost modem operation with a low bit-error rate. Some of the features of this 22-pin package include: eight selectable RTS/CTS delay options, an answer-back tone generator, a carrier-detect input and TTL compatibility.

The MC145445 is priced at less than $9 in quantities of 1000. Contact your local Motorola sales office or nearest distributor for further information. — *Paul K. Pagel, N1FB*



• *First Steps In Radio*

The Magic of Transistors



Part 8: Invented by Bardeen, Shockley and Brattain at Bell Labs in 1947, the transistor has made our modern electronic world possible. Let's look at how they're used in Amateur Radio.

By Doug DeMaw,* W1FB

Doesn't everything today have transistors in it? Well, not quite. The vacuum tube remains "king of the hill" in terms of power versus cost in some applications. But, most small electronics gadgets and home-entertainment devices rely 100% on transistors or versions of the transistor (integrated circuits, or ICs).

Why is a transistor better than a tube? There are many reasons: greater reliability, increased longevity, lower cost, smaller size and reduced heating. The vacuum-tube equivalent of a 2N3904 transistor (available these days for as little as 15 cents, and smaller than a pea) would be as large as a tube of lipstick, and would cost $8 or $10 new. Furthermore, the tube would be fragile, whereas the transistor could take a pretty heavy buffeting before it became damaged. If we were to regress in the technology, and attempt to build a personal computer or a calculator from vacuum tubes, it would fill an entire living room with racks of equipment and large power supplies. I helped develop one of the first military computers in the early 1950s while employed in a research lab. Known as the MIDAC computer (Michigan digital automatic computer), it was used for BOMARC missile guidance. It filled a huge room, and stood in 6-foot equipment racks lined up side by side in 10-foot rows![1] The same system today could be reduced to the size of an office typewriter (without the radar display tube and electrical joysticks). Dozens of vacuum tubes were used in but one of the many circuits. Today, a single postage-stamp-size IC could be used in place of the tubes.

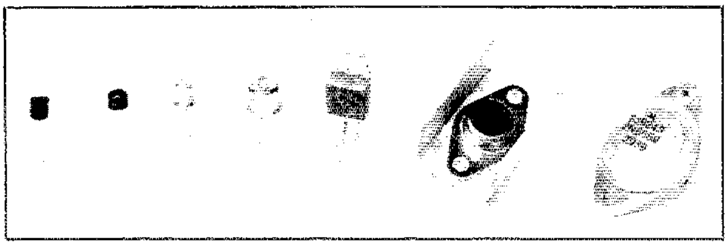


Fig. 1 — Left to right are low-power, medium-power and high-power transistors. There are many case styles for transistors.

What is a Transistor?

A transistor is an active semiconductor with three or more terminals. The name was derived from "transresistor" for "transfer resistor." It is made from silicon or germanium crystals that are usually formed into a junction or sandwich, as are the diodes we discussed last month in *QST*. The main difference is that a transistor has three elements (emitter, base and collector), whereas the diode has only a cathode and anode. The transistor can amplify signal current, but the diode cannot. Also, a transistor requires an operating voltage (it is an *active* device) for it to amplify. A diode, on the other hand, is a passive device; it does not need an operating voltage to make it rectify or clamp. It does, however, need an *applied* voltage if it is to perform a task for us. Junction transistors are commonly referred to as "bipolar transistors," sometimes abbreviated BJT (bipolar junction transistor). Fig. 1 illustrates a variety of styles and sizes of bipolar transistors.

How does a transistor compare to a tube in general terms? Look at Fig. 2 and you will observe a similarity in the symbols for the two components. Each one contains three working terminals, but the tube has two additional terminals (filaments), which are necessary for heating the cathode. Without the heaters or filaments, the tube cannot function. The transistor needs no heater. Some tubes have what are called "directly heated cathodes." They have no cathode element, and the filaments serve double duty as the heater and cathode. Those tubes reach operating conditions

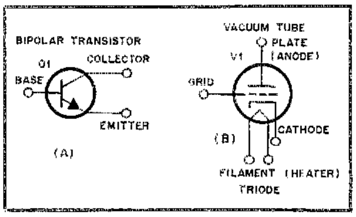


Fig. 2 — Symbol (A) for a bipolar transistor. A triode vacuum-tube symbol is included (B) for illustrating the similarity between the two triode devices.

[1]m = ft × 0.3048.

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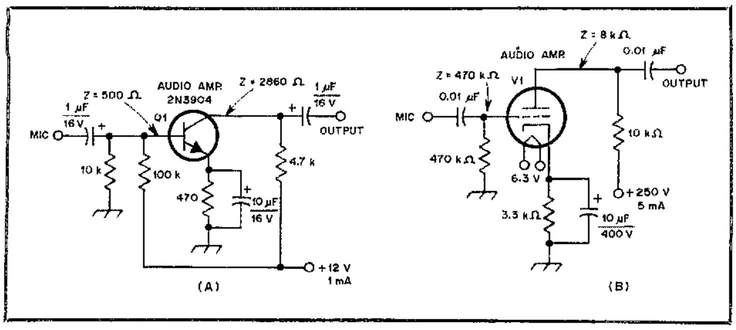

Fig. 3 — A practical circuit example for a transistorized audio amplifier (A) and a tube amplifier (B). Note the differences in the operating voltages and impedance levels (see text).

(from turn-on) almost as quickly as transistors do.

The example of Fig. 2B shows a triode tube that requires a warm-up time. It has separate filament and cathode elements. The transistor of Fig. 2A can be compared to the triode tube. That is, the base equates to the grid, the collector to the plate and the emitter to the cathode. Both are triodes (three electrodes), and both devices amplify ac or RF energy. The transistor amplifies current, however, while the tube amplifies voltage (ac).

Additional differences are (1) the transistor requires much lower operating voltage than does the tube, and (2) the tube has higher impedances at its terminals than does a transistor. For example, the input impedance of the transistor might present an effective impedance (ac equivalent of dc resistance) of 500 ohms at the base (base to ground), but the tube in a similar circuit could have a grid-to-ground input impedance of 1 megohm or greater. Similar comparisons can be made between the transistor collector and tube plate. Therefore, different design methods are needed for the two devices.

Let's look for a moment at Fig. 3. It shows a transistor and a tube in similar circuits. Note the differences in the operating voltages and terminal impedances. You can see there is quite a difference between the two circuits, even though they are each capable of providing approximately the same amount of amplification. The term "Z" is electronic shorthand for "impedance." You will run across this expression many times in your studies. You will observe also from Fig. 3 that the values of the resistors and capacitors are substantially different for the pair of circuits.

Additional Transistor Types

Actually, there are two types of bipolar transistor. One is called an NPN transistor, and the other is a PNP device. Symbols for the two varieties are given in Fig. 4. The NPN (negative-positive-negative) unit requires a positive operating voltage on the base and collector, but the PNP (positive-negative-positive) device needs a negative voltage on the base and collector. The distinguishing feature in the symbol that separates the two types is the direction of the emitter arrow. Observe that the arrow points out for an NPN transistor, while it points in for the PNP unit. Most transistors today are of the NPN kind, except those used for audio work. At the beginning, most transistors were PNP types, because germanium was used instead of silicon for the internal structure.

There are numerous types of tubes — some containing more than three elements. Some have four elements (two grids), and they are known as tetrodes. There are also pentodes and heptodes. In a like manner, we have transistors with an additional element. A common example is the dual-gate FET (field-effect transistor). The symbols for that and a single-gate JFET (junction FET) are shown in Fig. 5. As is the case with bipolar transistors, we have N- and P-channel FETs. The arrow in the symbols indicates the polarity of the device. At A of Fig. 5, we can see a JFET. It has an internal sandwich type of junction, as does the bipolar transistor. The dual-gate MOS (metal-oxide silicon) FET at B of Fig. 5 has a thin layer of oxide as insulating material between the gates and the remainder of the device. The drawing at C of Fig. 5 illustrates in simple terms the names of the elements within an FET. We can equate the FET to the triode tube by saying that the gate and grid are related, as are the drain and plate, and the source and cathode. The major difference between FETs and bipolar transistors is that the input impedance of the FET is similar to that of a triode tube — usually 1 megohm or greater. The effective Z is usually determined by the value of the gate-to-ground resistor used. A practical comparison between a tetrode tube and a dual-gate FET is shown in Fig. 6. We can see that the two transistor gates are used in a similar manner to the pair of grids in the tube example. A popular dual-gate MOSFET is the RCA 40673. Another is the Texas Instruments 3N211 device. When it comes to JFETs, you may recognize the

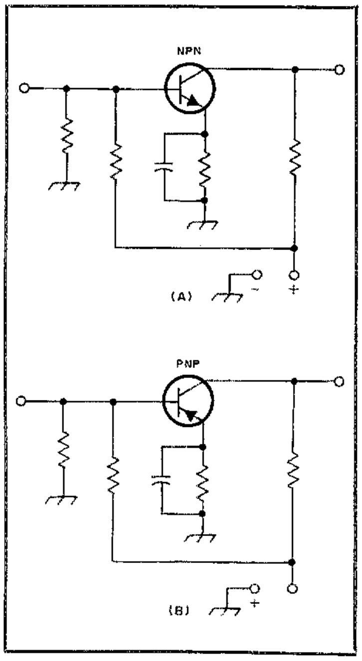

Fig. 4 — An NPN transistor (A) uses a positive collector voltage. The PNP transistor (B) requires a negative collector potential. Note the direction of the arrows for the two devices.

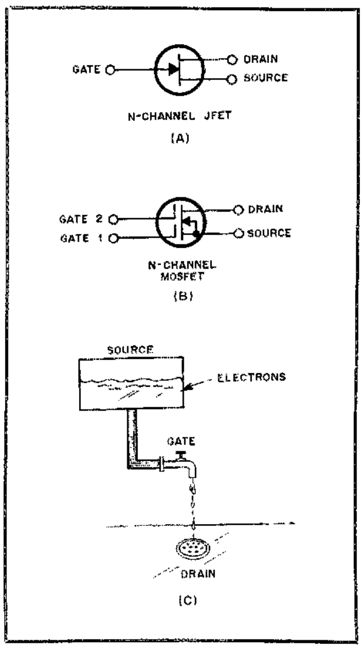

Fig. 5 — A JFET symbol is shown at A. A dual-gate MOSFET symbol is seen at B. The drawing at C shows how an FET operates.

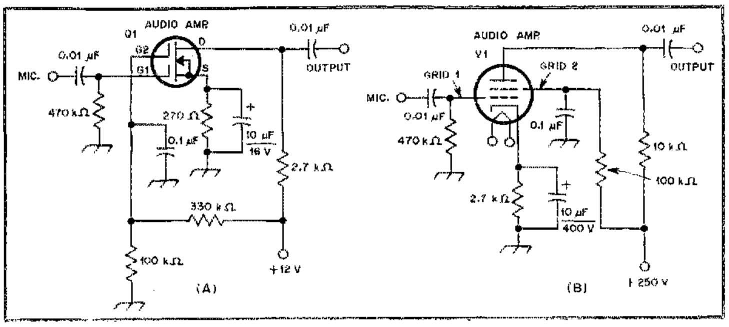

Fig. 6 — Circuit examples of a dual-gate MOSFET (A) and a tetrode tube (B) to show the similarity between the two devices.

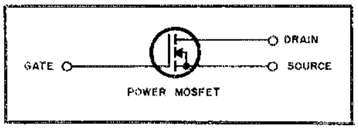

Fig. 7 — Circuit symbol for an MOS power FET of the enhancement-mode variety.

number MPF102, which is an almost generic type of JFET nowadays.

Power Transistors

Thus far we have discussed only those transistors used for small-signal (low-power) applications. But, transistors can also accommodate large amounts of power. By combining many power transistors, we can build audio or RF amplifiers that deliver more than 1000 W of output power. Although no single transistor can do that job by itself, it is entirely possible to obtain more than 1000 W of output power from a single vacuum tube. It is in this area that the tube is still "king of the mountain."

There are high-power bipolar transistors and high-power MOSFETs, too. The electrical symbol for a power FET is somewhat different from that of a small FET (see Fig. 7). FETs with the three lines in place of the single drain-source line (as in Fig. 5B) are called "enhancement-mode FETs." When a single drain-source line is used it signifies a "depletion-mode FET." The difference is beyond the intent of this discussion, but it is worth mentioning to help avoid confusion.

Power transistors can generate a large amount of internal heat when they are operating. For this reason we need to use *heat sinks* to help keep them cool. Cooling fans are used on big tubes for the same reason. Excessive heat is the enemy of all electronics parts. A heat sink is a metal device that conducts the internal heat of the transistor outward. Many heat sinks are made from extruded aluminum, and they may have several rows of cooling fins on them. The transistor must be mated firmly to the heat sink to reduce "thermal resistance." Otherwise, the heat sink may be ineffective and the transistor will be destroyed. A thin layer of silicone grease is generally applied between the transistor body and the heat sink to aid the thermal bond. Some typical heat sinks are shown in the photograph of Fig. 8.

A power transistor can draw several amperes of current when a relatively low operating voltage is applied. Conversely, most power tubes require very high voltage, but draw milliamperes, rather than amperes, of current. The input and output impedances of high-power transistors are very low, often less than 1 ohm! This makes it quite difficult to work with them unless special input and output matching techniques are employed.

Glossary

heat sink — a metal clip or plate to which a transistor can be attached for the purpose of conducting heat away from the transistor.
heptode — a type of vacuum tube that contains seven electrodes.
JFET — a junction field-effect transistor.
MOS — abbreviation for metal-oxide silicon.
MOSFET — a field-effect transistor that uses MOS material as the gate insulation.
NPN — designator for a bipolar transistor that requires a positive base and collector operating voltage.
pentode — a type of vacuum tube that contains five electrodes.
PNP — designator for a bipolar transistor that requires a negative base and collector operating voltage.
substrate — the crystalline foundation (usually silicon) on which an IC is formed.
tetrode — a vacuum tube that has four electrodes.
thermal resistance — the effective resistance to the passage of heat between two objects bonded together.
Z — abbreviation for impedance.

Combining Transistors

Everyone has heard about integrated circuits. You may think of them as large families of transistors residing under one roof. It is possible to have literally hundreds of transistors within a single IC. ICs help reduce the parts count in a circuit, leading to more-compact assemblies. The shortfall is that if one tiny internal transistor fails, the entire IC must be replaced! A number of ICs are shown in Fig. 9. ICs are available for amplifying signals to a moderate power-output level, but they are not as husky in that respect as big discrete (individual) transistors are.

ICs may contain MOSFET or bipolar transistors, or a mixture of both. They also contain diodes, resistors and capacitors. The internal workings of a simple IC are shown in Fig. 10. It is designated U1. U, the standard symbol for an IC, stands for "unrepairable." The innards we see at A of Fig. 10 are those of an RCA CA3045 transistor-array IC. Since all of the transistor leads come out of the case separately, we can use this IC in the same

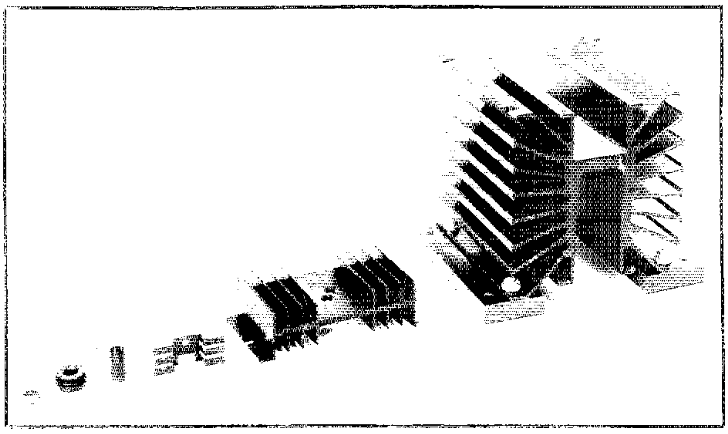

Fig. 8 — Transistor heat sinks, like transistors themselves, come in a variety of shapes and sizes.

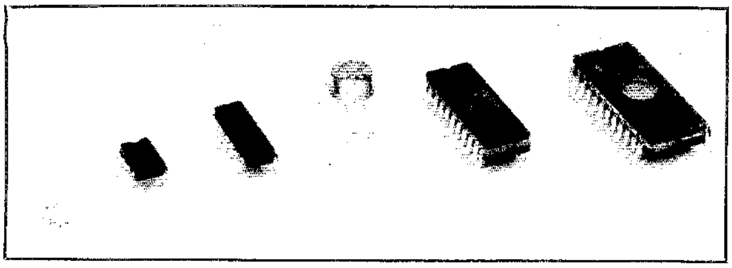

Fig. 9 — Some ICs. Each pin on the case is connected to an internal component, such as a transistor, diode, capacitor or resistor.

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manner as five discrete transistors. Yet they are all contained in a compact assembly. The illustration of Fig. 10B is the physical format of a 14-pin, dual-in-line-package (DIP) IC. The CA3045 is one of the very simple ICs. Hundreds of transistors, resistors, capacitors and diodes can be similarly housed. The really big ICs are called LSI chips (large-scale integration). They may have as many as 40 pins coming from the case. Many LSI ICs can be found in computers and similar equipment.

There are two prominent classes of ICs. Those designed expressly for use in ac and RF circuits are referred to as linear ICs, and those meant for digital and logic applications are called logic ICs. Some hams refer to them as "analog chips" and "digital chips," respectively. The loose term "chip" refers to a piece of silicon crystal on which the IC is formed. This material is known as the "substrate."

Transistor Housing

There are numerous trappings in which a transistor may dwell. You will read about and hear mention of such things as TO-5, TO-3, TO-220, TO-92, TO-18, TO-59 and many other numbers. Don't let this confuse you. It merely signifies the physical format of the case in which the device is contained. The greater the power capability of the transistor, the larger the case it is built into. Many of the cases are designed

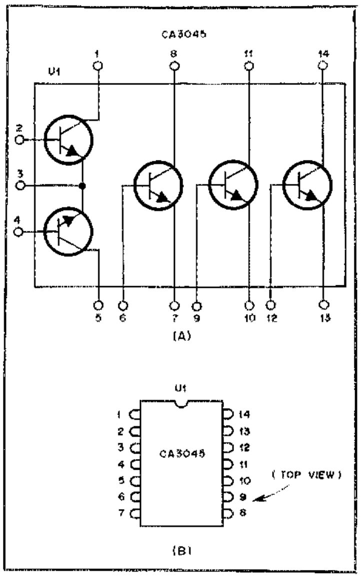

Fig. 10 — Internal circuit (A) of a simple IC. It resembles the device at B when it is enclosed in its case.

to permit the transistor body to be mated with a heat sink. Small transistors may be in tiny metal or plastic cases, since they need no heat sinks.

Final Comments

We have skimmed the surface in our discussion of transistors. But, for those of you who are new to radio, this treatment should lay the groundwork for further learning.

Strays

TIS DO'S AND DON'TS

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For us to respond promptly to your inquiries we must have:

1) your name

2) your amateur call and license class (tell us if you're not licensed)

3) your membership expiration date

4) a stamped, *business-size* envelope bearing your mailing address for our reply (IRCs acceptable from outside the U.S.).

When writing, please observe the following guidelines so we may provide the best possible service to the greatest number.

1) Before writing for technical assistance, search your files of *QST* and other ARRL publications. The answer you need may be there, available immediately. Consult the annual index of articles in each December issue.

2) Please do not ask for comparisons among commercial products. Choice of equipment is largely a matter of personal preference. Consult Product Review information in *QST;* compare manufacturers' specifications in their brochures.

Do not ask for information on articles published in other magazines. Write to the editor or author of that article.

Do not request custom designs for amateur gear.

Do not ask advice on nonamateur matters. We cannot respond to questions about CB, marine radio, hi-fi, etc. (unless they concern interference caused by amateur gear).

3) Use a typewriter when possible; otherwise, write or print *clearly.* Please be reasonable in the number of questions you ask; try to limit your questions to three per letter.

4) When writing, please come right to the point, and be sure to share with us whatever experience you have had with the problem in question. This will avoid our reply covering a ground you've already been over.

5) Address all technical questions to Technical Information Service, American Radio Relay League, 225 Main St., Newington, CT 06111. — *Bob Schetgen, KU7G, Technical Information Specialist*

Product Review

Conducted By Paul K. Pagel,* N1FB

Kenwood TW-4000A 2-m/70-cm FM Dual Bander

POWER ON. V. GO TEN GO, GO, GO.
POWER ON. V. FIVE POINT FIVE, FIVE, FIVE.

Egad! A talking radio! Kenwood's FM Dual Bander knows more Japanese than I do! (The voice-synthesizer option for the TW-4000A has Japanese and English vocabularies. A switch inside the rig selects the language. More on this later.)

The TW-4000A is Kenwood's latest high-tech VHF/UHF FM transceiver. The 25-W rig sports a liquid-crystal display panel that shows frequency, offset, memory channel, received-signal strength in S units and a relative-power-output bar graph that doubles as a modulation indicator when used in low-power transmissions. All function switches are backlit with a pleasant green.

Kenwood supplies an UP/DWN 16-button DTMF mike. The review unit is supplied with the optional VS-1 voice synthesizer and TU-4C programmable subaudible tone (CTCSS) encoder.

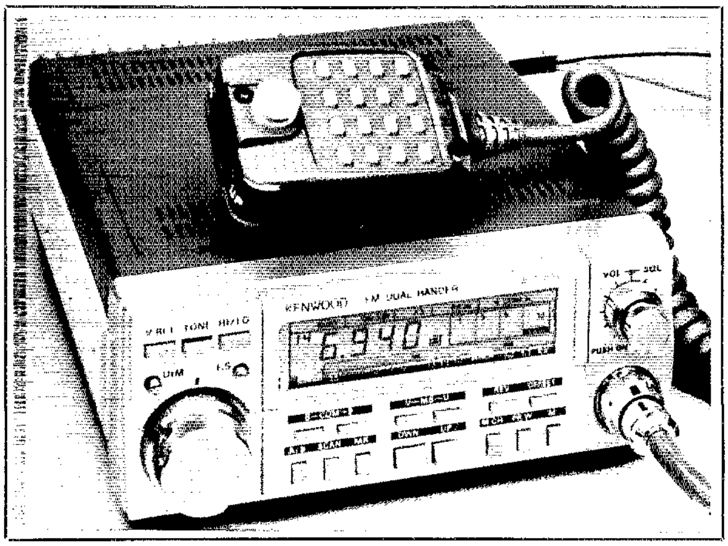
Ten memory channels store frequency and offset. Memory zero can be used to program those "oddball splits," and can be used for crossband (2-m/70-cm) operation. In the "Priority Watch" (PR.W) mode, the rig switches back to Channel 1 for one second of every 10, regardless of mode. Each time the priority channel is checked, the rig beeps. This priority channel watch is a "listen only" function. For example, you have your favorite 2-meter simplex frequency programmed as Channel 1, and you're waiting for a net to start. In the meantime, you are in a QSO through a 440-MHz repeater. Press the PR.W button, and every 10 seconds, the 2-meter simplex frequency will be checked. Press the PR.W key again to cancel the watch.

A programmable scanning feature adds to the versatility of the rig. This gives the operator freedom to choose the scanning sequence. In the Memory Recall (MR) scan mode, you can scan all memory channels, only the VHF channels or only the UHF channels. Any 1-MHz segment of a band can be searched in the VFO scan mode. The COM function is interesting — press the COM 8 or COM 9 key and then press the SCAN button. Memory Channels 8 and 9 are alternately scanned every five seconds, ignoring other channels. To stop the COM scan, press the COM-8 or COM-9 button, or key the microphone. This scan mode does not stop when a signal breaks the squelch. Scanning direction can be controlled by the UP/DOWN controls on the mike or front panel. Want to skip a memory channel during each scan? Press M.

The dual VFOs tune in 5- or 10-kHz steps (2 m) and 5- or 25-kHz steps (70 cm), selectable by the front panel F.S. (Frequency Step) switch. Tuning may be accomplished using the front panel VFO knob or the UP/DOWN mike buttons.

The CTCSS encoder option mounts inside the radio and is programmed with DIP switches. There are two independently programmable encoders, giving you one "reed" frequency for each band. (It looks like a simple matter to expand this by wiring some outboard toggle switches to each DIP switch.)

A spring-loaded "slide lock" mobile mounting bracket is furnished with the rig. I found this an excellent mounting scheme for those, like me, who are wary of "radio rip-off." Simply match the securing bosses to the slots on the bracket and slide the radio right in. It's much easier to remove and stow the radio with this bracket than it is with those wrap-around or thumb-screw type brackets.



Kenwood TW-4000A 2-m/70-cm FM Dual Bander

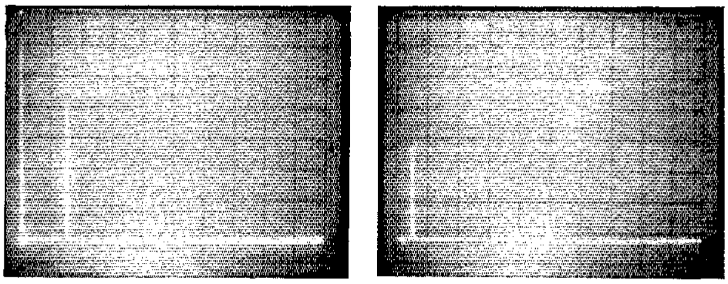
Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: VHF — 144.00-148.00 MHz; UHF — 440.00-450.00 MHz.	142-148.995. 440-449.975.
RF output power: 25-W HI (both bands); 5-W LOW (internally adjustable to about 10 W).	VHF: 25 W (HI), 1.7 W (LOW); UHF: 24 W (HI), 3.6 W (LOW).
Spurious requirements: Less than −60 dB.	See photograph.
Power requirements: 13.8-V dc ±15%.	
Current drain (at 13.8-V dc):	
Rx — 0.6 A with no signal;	570 mA
Tx — 7.5 A (HI), 3.3 A (LOW); approx. 2 µA for backup.	6.1 A VHF, 6.6 A UHF (HI); 2.6 A VHF, 2.8 A UHF (LO).
Receiver type: Dual-conversion superheterodyne; 1st IF — 30.865 MHz, 2nd IF — 455 kHz.	
Sensitivity: SINAD 12 dB less than 0.17 µV; S+N/N more than 30 dB at 0.63-µV input.	0.13 µV/12 dB SINAD, 0.76 µV/30 dB quieting (145.45 MHz); 0.15 µV/12 dB SINAD, 0.88 µV/30 quieting (443.5 MHz).
Audio power output (8-ohm load): More than 2.0 W, 10% THD.	1.9 W.
Size (HWD): 2.7 × 6.3 × 8.5 in (60 × 161 × 217 mm).	
Weight: 4.18 lb (2.0 kg).	
Color: Gray, silver, green.	

Operating Impressions

I used the TW-4000 as a mobile rig (with the MA-4000 dual-band mobile whip) and as a base station. Fortunately, I was able to operate the radio while on vacation in sunny Southern California, where 440 machines seem to be in abundance. I made quite a number of new friends while on the air.

The radio itself performed flawlessly, although the voice box developed a case of laryngitis. The voice synthesizer did not work properly when I first got the rig — the "woman" inside would only talk when the V.RCL (Voice Recall) button was depressed and held down. No automatic voice announcement was heard even with the bottom panel V.ON/OFF (Voice On/Off) switch ON. A trip to the Kenwood facility in Compton

*Assistant Technical Editor



(A) (B)

Fig. 1 — Worst-case spectral displays of the Kenwood TW-4000A. At A, the output power is approximately 28 W at a frequency of 146 MHz. The fundamental has been reduced in amplitude approximately 30 dB by means of notch cavities to prevent analyzer overload. At B, the output power is about 25 W at a frequency of 445 MHz. The fundamental has been reduced in amplitude approximately 42 dB by means of notch cavities to prevent analyzer overload. In both cases, vertical divisions are each 10 dB and horizontal divisions are each 100 MHz. The TW-4000A complies with current FCC specifications for spectral purity.

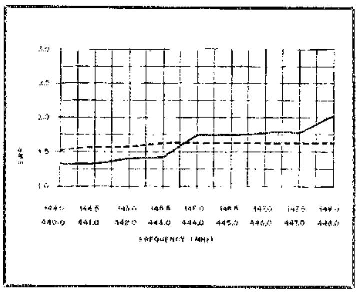


Fig. 2 — SWR curve for the Kenwood MA-4000 2-m/70-cm mobile antenna. Antenna was mag-mounted to the top center of a pickup truck cab. All measurements were taken with a Sola Basic Dielectric Directional RF wattmeter, Model 1000, 50 ohms. Solid line refers to 2 meters; dashed line to 70 cm.

revealed that a small jumper wire should have been cut when the VS-1 was installed. How embarrassing!

This solved the operational problem, but a few days later the voice became intermittent. So, back to Kenwood it went. An oscillator was replaced. Now the laryngitis is cured, and no malfunctions have reappeared. (A few QSOs with other '4000 users indicate that this problem is an isolated case.)

Programming the radio is surprisingly simple, once you get the hang of it. Simply press the M.CH (Memory Channel) button, which selects the channel number, dial in the desired frequency with either VFO, select the offset using the OFFSET switch and, finally, press M. A beep tells you that the radio will remember your channel selection. A built-in lithium battery backs up the memories, even when the radio is disconnected from the power source.

With the optional VS-1 voice synthesizer, you're never alone. "She" announces "power on" when the rig is powered up. (Interestingly, "power on" is "power on" in Japanese.) Any change in control settings makes her talk.

When the VFO frequency is changed, she says, "V" (for VHF) or "U" (for UHF), followed by the last four digits of the VFO setting. Using the example at the beginning of this review, the VHF frequency is 145.555 MHz. Memory channel number, frequency offset and VFO in use are also announced. Kenwood has thoughtfully provided a control on the voice module to adjust the voice level, as well as a switch (V.ON/OFF) to turn the automatic voice announcement off. When the V.ON switch is OFF, the front panel V.RCL (Voice Recall) button can be used to hear the voice on command. ("Power on" is announced regardless of either switch setting.) I noticed that after a few days of use, the novelty of the voice wore off, and I preferred to hear it only on demand.

On-the-air reports indicate that the transmitted audio is constantly crisp and clear, and 25 W of RF power helps in fringe areas. The compactness of the radio does not adversely affect the ease of operating the front-panel controls; however, the tone-pad mike, with its small rubber buttons, is a bit hard to use. My fingers aren't particularly large, but punching the little rubber keys seemed difficult while mobile. Similarly, I found it hard to keep my fingers off the UP/DWN buttons while holding the mike. At best, this spoils reception; at worst, you can "swish" the VFO while transmitting. A dial-lock feature seems to be needed here. But, after a short period of use, you'll learn to keep your fingers away from the buttons.

The priority-watch function is nice, but it can be annoying sometimes. If you are in QSO, the rig jumps to Channel 1, almost always at the wrong moment. I found that the best time to use the PR.W is when you're listening to the radio on a "dead" night.

The antenna connectors on the rear panel are SO-239s. I thought it a bit strange and felt a bit disappointed that type of connector is used at the 440-MHz port. I expected to see a BNC or N connector there so there could be absolutely no question which port is which. Kenwood does provide UHF and VHF labels, which don't stick very well, to mark the antenna cables.

I had the opportunity to get some operating impressions from Kitty Hevener, WB8TDA, ARRL Handicapped Program Coordinator. Kitty is particularly concerned about a radio's operating ease for physically handicapped individuals. She felt that the TW-4000's small push-button controls would be difficult for persons with limited fine-motor skills to manipulate. On the plus side, Kitty felt that the voice synthesizer and the detents on the VFO knob (the setscrew hole and bevel) would enhance a visually impaired person's ability to locate specific frequencies.

Final Comments

The '4000 is an awesome rig. Everyone is first fascinated by the green glow of the front-panel controls. Then they smile when the radio talks! Kenwood is on the right track for what the mobile operator wants. After getting used to the radio's quirks, I had no problem reaching for the right controls while operating mobile at night.

Owners of this radio have two rigs in one little box. Using the MA-4000 dual-band antenna, there is but a single spike sticking out of the car. And, by adding the VS-1 voice module, you'll never be alone. Who knows? Maybe more hams will become familiar with the Japanese language by using the radio with the module switched to the JA position!

Price classes: TW-4000A, $600; VS-1 voice synthesizer, $40; TU-4C two-frequency programmable CTCSS encoder, $40; MA-4000 dual-band antenna, $45. Contact the Trio-Kenwood Corp., 1111 West Walnut St., Compton, CA 90220, for more information. — *Wayne T. Yoshida, KH6WZ/W1*

MAGGIORE ELECTRONIC LABORATORY HI PRO MK I 2-m REPEATER

□ This is W1OD listening . . . ccccsh. If this sounds familiar, you've probably experienced 2-meter FM. Because of the low price of synthesized gear available for this mode, many HF operators have stepped up to the 144-MHz band. Many choices are available to the FM enthusiast, and repeater clubs have sprung up everywhere.

One element universal to 2-meter FM operation is the repeater. The Maggiore Hi Pro MK I is a unit that should be considered by the first-time repeater group that wants to start off right, or for the group interested in upgrading their machine to first-class status without a "3-kilobuck" price tag.

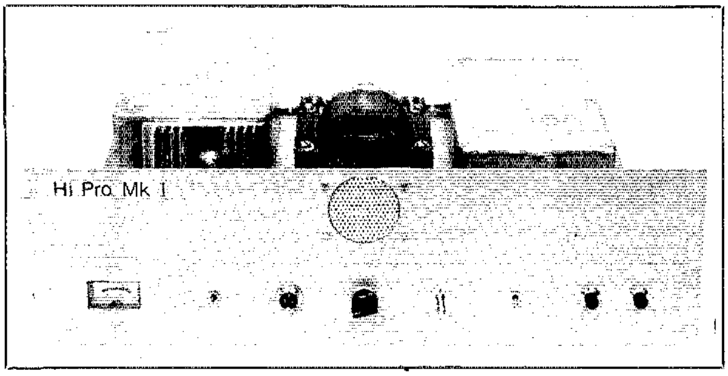
Mechanical Details

Mechanically, the Hi Pro is quite a rugged machine. The transmitter/power amplifier and receiver circuit boards are mounted atop the chassis in heavy-duty, cast-aluminum boxes for mechanical protection and electrical shielding. Shielding is important in repeater operation: without it, receiver desensitization becomes a problem, limiting repeater coverage.

The remaining components are contained on the underside of the heavy-duty chassis, of suitable size for convenient mounting in a standard 19-inch rack.[1] The organization of the components and cable harnesses is neat — there's plenty of room to install custom circuits for your machine. The review unit is a "bare-bones" unit, consisting of a receiver, transmitter/power amplifier and power supply. A built-in ac-operated power supply makes installation of the MK I a "plug-in and go" operation. Connections for external power (such as a 12-V battery for emergency power) and control are made via a terminal strip at the chassis rear.

A built-in 2½ × 1½-inch speaker may be used to monitor local audio. Audio level through this

[1]mm = in × 25.4.



Maggiore Electronic Laboratory Hi Pro MK I, Serial No. PO51176F

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Receiver sensitivity: 0.35 μV for 20-dB quieting.	0.30 μV for 20-dB quieting.
Audio output power: 2 W at less than 8% THD.	1 W at 10% THD.
Squelch sensitivity: Not specified.	0.46 μV (min.). 2.3 μV (max.).
Transmitter power output: 25 W min.	25 W.
Color: Gray.	
Size: (HWD) 5.5 × 18 × 12 in.†	
Weight: 15 lb.	

†mm = in × 25.4; kg = lb × 0.454.

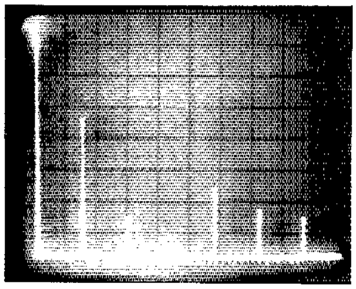


Fig. 3 — Worst-case spectral output of the Hi Pro MK I repeater before the final amplifier board was tightened down. Under these conditions, the transmitter does not meet present FCC spectral purity requirements. Horizontal divisions are each 100 MHz; vertical divisions are each 10 dB. The fundamental has been reduced in amplitude approximately 34 dB by means of notch cavities; this prevents analyzer overload. Power output was approximately 23 W at a frequency of 145.45 MHz.

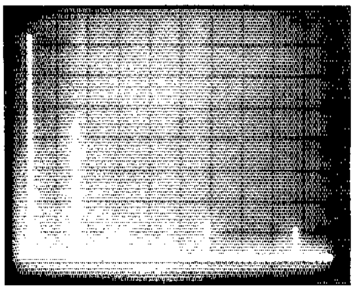


Fig. 4 — Spectral output of the MK I repeater after the final amplifier board was tightened down (see text). Horizontal divisions are each 100 MHz; vertical divisions are each 10 dB. The fundamental has been reduced in amplitude by 35 dB to prevent analyzer overload. Power output was approximately 23 W at a frequency of 145.45 MHz.

speaker is varied by a panel-mounted control. Three switches on the front panel control POWER ON/OFF, S-METER/DISC. and SIMPLEX/REPEAT. The latter control is handy for turning off the transmitter while adjusting the antenna system.

The Receiver

The receiver is contained in a 2-1/4 × 4-5/8 × 7-1/4-inch (HWD) cast-aluminum box. It is a crystal-controlled, dual-conversion superheterodyne, and uses a third-overtone (44-MHz) crystal to determine the operating frequency. A 3N204 is used in the front end, allowing the receiver to boast a 12-dB SINAD sensitivity of 0.32 μV. A 150-μV signal is required to register S9 on the meter.

The Transmitter

The MK1 transmitter is contained on two PC boards: one for the exciter, and another for the power amplifier. Both boards are housed in a sturdy 3¼ × 4½ × 7½-inch (HWD) cast-aluminum box.

The exciter is crystal-controlled, and uses a fundamental-cut 12-MHz crystal for frequency control. A tripler and two doublers are used after the oscillator to generate the 2-meter signal. Exciter output is 4W.

Final amplification is achieved by a single MRF240 operated class C. This circuit, when driven with the 4-W exciter output, generates approximately 25 W of RF output. Adequate heat sinks provide for continuous operation at ambient temperatures below 90° F. The manufacturer recommends fan cooling at temperatures above this level.

Alignment

Receiver and transmitter alignment is straightforward, and should present no difficulty to most users with access to a modest test bench. An FM signal generator and a VTVM are necessary for proper alignment. A purist might find an audio-distortion analyzer helpful in achieving maximum SINAD sensitivity.

Transmitter alignment requires a wattmeter, a frequency counter, a dummy load and a VTVM. After the oscillator is on frequency, certain exciter-board test points are monitored with the VTVM while adjustments are made. To align the final amplifier board, adjust the output LOAD and TUNE controls for maximum power output with minimum driver collector current.

In all cases, the manual clearly calls out each alignment procedure. Pictorial views of each circuit board, with all components clearly labeled, make alignment a simple task.

Operation

The Hi Pro MK I repeater has been in use at W1AW/R for several months, and few problems have been noticed. Our repeater site is atop Cedar Mountain in Newington, on the roof of a hospital. This is a heavily populated site, with several low-band VHF and two UHF transmitters at the same location. Antenna separation is less than 20 feet, providing a severe test of IMD performance. One of the VHF repeaters happens to be separated from our receiver input frequency by 11.155 MHz, the frequency of the second local oscillator. This resulted in a spurious response, and some squelch-breaking interference whenever the local ambulance company had a call! A ¼-wave stub with an anti-resonant circuit (an approximate 25-dB notch) was sufficient to totally eliminate the interference.

The transmitter is also rugged. At one point during testing, some receiver desensing was noticed, and the transmitted signal sounded weaker than normal. This situation lasted for two weeks before a trip to the site could be arranged. Someone had detuned the duplexer transmit cavities, and the transmitter was operating into a 5:1 SWR for two weeks! The damage? None! A tribute to a well-designed transmitter.

Some Comments

Two Maggiore units were tested during the review period. The first unit (s/n PO51176F) was obtained by the ARRL directly from the manufacturer. Another unit, procured from an outside source, was tested to verify specifications. As received, the second unit did not meet present FCC spectral-purity requirements: All spurious emissions must be 60 dB below the carrier. Fig. 3 shows the fourth harmonic reduced only 55 dB.

After some head scratching, the lab technician performing the tests noticed that the no. 4-40 screws used to mount the power-amplifier board to the transmitter cabinet were not fastened down — the nuts had never been installed. Installation of two nuts with lockwashers cured the problem. The spectral purity now meets present FCC specifications, as shown in Fig. 4. Results of the laboratory testing are given in the accompanying table.

Thanks to International Crystal Mfg. Co., 10

North Lee, Oklahoma City, OK 73102 for supplying crystals for the review repeater. Their assistance is appreciated.

The Maggiore Hi Pro MK I is available from Maggiore Electronic Laboratory, 845 Westtown Rd., West Chester, PA 19380. Price class: $1325. — *Michael B. Kaczynski, W1OD*

MIRAGE COMMUNICATIONS A1015 6-m AMPLIFIER

☐ Six-meter power amplifiers are few and far between these days. Declining interest in the band has caused manufacturers to devote their efforts to more lucrative bands, such as 2 meters. Mirage, a well-known manufacturer of VHF and UHF equipment, recently introduced a product to warm the hearts of 6-meter devotees. The A1015, a "brick" amplifier delivering 150-W output for 10-W input, is ideal for the operator with one of the 10-W solid-state rigs so popular these days.

The A1015 is a linear amplifier. It features a built-in preamplifier for the receiver, and the preamp is automatically switched out of the line during transmit. A remote-control head, model RC-1, is available should the amplifier be mounted away from the operating position. Although the review unit is not equipped with this option, it is especially attractive for mobile installations.

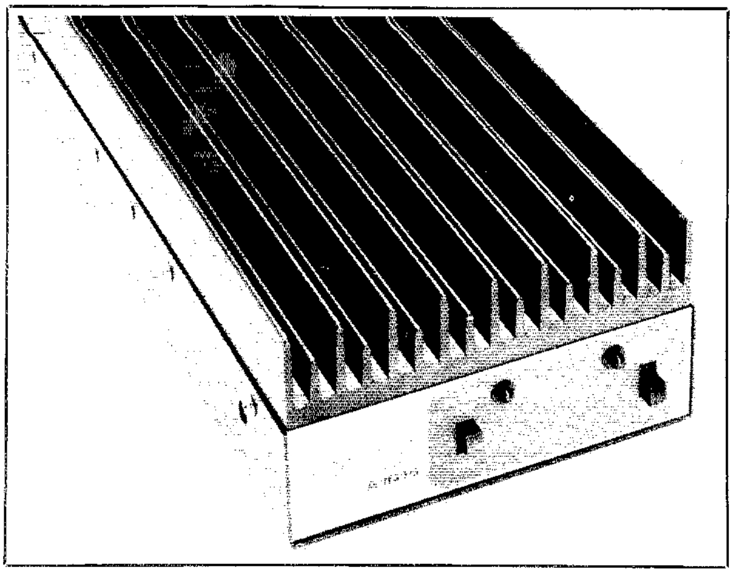
Two switches, POWER ON and PREAMP ON, adorn the front panel. The preamp may be switched on and off independently of the POWER ON switch — that control might be better labeled POWER AMPLIFIER ON. The rear panel holds two SO-239 coax connectors for input and output, a phono jack for TR control, a six-pin connector for the RC-1 and two leads for dc power.

The keying circuit in the A1015 is a bit different from that found in the run-of-the-mill brick. This rig does *not* incorporate an RF-sensing keying circuit. It *must* be hard-wired to key along with the station transceiver. The instruction manual is very explicit in warning that the key line must be hooked up before operating the amplifier. You may switch the A1015 into transmit by applying +5- to +15-V dc to the phono jack, or by shorting across it; the choice is yours. The amplifier comes wired for the +5- to +15-V option.

Changing to the shorting mode involves removing the top cover and moving a soldered jumper wire to a different pad on the PC board. My installation required this change, which was performed in about 15 minutes. Although some operators will miss the convenience of automatic RF-sensed antenna changeover, I find the TR delays inherent in most amplifiers employing that method of keying to be annoying. I much prefer to key the amplifier directly.

The A1015 employs a pair of MRF492 transistors in the power-amplifier section and a U309 in the receiver preamp. All components are mounted on a PC board, which is mounted directly on the heat sink that forms the entire top of the amplifier. A built-in thermostat turns off the A1015 if the heat sink temperature exceeds 170° F. High SWR will not damage the rig, and a 35-A fuse mounted internally on the PC board offers further protection.

Mirage recommends use of no. 8 wire between the A1015 and the power supply. This is sound advice in view of the 20-A current requirement. In my installation, I connected the short no. 10 wires from the brick directly to the power supply. The rest of my installation consists of a Yaesu FT-726R transceiver and a 3-element Yagi at 105 feet fed with about 140 feet of RG-213 coaxial cable.



Mirage Communications A1015 6-Meter Amplifier, Serial No. 165-484

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 50 to 52 MHz.	As specified.
Power output: 150 W or more with 10-W input.	153 W with 10-W input.
Receive preamp: 10-dB gain with 1.5-dB (±0.5 dB) noise figure.	10 dB with 2-dB noise figure.
Power requirement: 13.6-V dc at 18-22 A.	13.6-V dc at 20 A.
Input SWR: Not specified.	1.3 to 1 at 50.1 MHz.
Size (HWD): 3 × 5½ × 12 in†	
Weight: 5 lb.	

†mm = in × 25.4; kg = lb × 0.454.

Day-to-day 6-meter activity is light, even in New England, so I was fortunate to find a small aurora in progress the first night I used the amplifier. A few CQs yielded QSOs with stations in Quebec and western New York. The A1015 seemed to give me a big enough signal to work the aurora; all of the stations I called came back with good reports. The 150 W was plenty for groundwave operation around New England and south into New Jersey and Pennsylvania. It wasn't quite enough for successful scatter operation with my antenna, however. The receive preamp is effective, and its use allowed me to hear several stations that were marginal copy with it turned off.

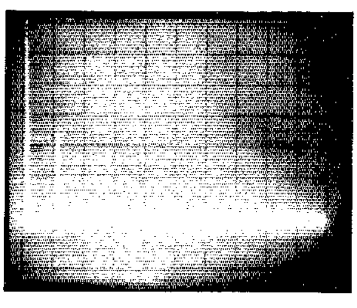


Fig. 5 — Worst-case spectral display of the Mirage A1015 amplifier. Vertical divisions are each 10 dB; horizontal divisions are each 50 MHz. Output power is approximately 125 W at 50.1 MHz. The fundamental (pip at the left of the photo) has been reduced in amplitude approximately 35 dB by means of a notch filter to prevent spectrum analyzer overload. All harmonics and spurious emissions are at least 60 dB below peak fundamental output. The A1015 complies with current FCC specifications for spectral purity.

The A1015 performed flawlessly during the six-week review period. Even during extended operation it became only warm, never hot, to the touch. It did just what a brick is supposed to do — sit quietly (except for the muted sound of clicking relays) and produce power. The instruction manual is informative and clear. Demonstrating extreme faith in their products, Mirage offers a five-year warranty on the A1015 (except for the power transistors, which are warranted for one year). This amplifier is worth considering if you want to upgrade your 10-W 6-meter station.

Price class: $280. Manufacturer: Mirage Communications Equipment, Inc., P.O. Box 1393, Gilroy, CA 95020. — *Mark Wilson, AA2Z*

Hints and Kinks

Conducted By Larry D. Wolfgang,* WA3VIL

A ONE-TRANSISTOR RF AMPLIFIER

☐ After using my modified Astro 103 for more than a year, I decided to add an RF amplifier to the receiver section.[1] I hoped to be able to dig a little deeper into the noise for some weak-signal DX stations. Others may be interested in duplicating this 11-dB-gain amplifier for a variety of applications. It can be used as an add-on RF amplifier for a receiver with a weak front end, to replace the RF stage, or as an IF amplifier.

Some time ago, I built and tested an RF amplifier module similar to that of Fig. 1. While testing this amplifier at a 0-dBm-input level, I ran into a problem that I wish I had more often. The IMD dynamic range of the amplifier was greater than the −65 dB limit of my spectrum analyzer. With the amplifier connected to my receiver, I measured an MDS of −130 dBm, an IMD dynamic range of −37 dB and a blocking dynamic range of 93 dB. All of the tests were performed at 14 MHz, for comparison with ARRL lab tests of Product Review equipment. The third-order intercept point was cut in half, but is still a respectable +9.5 dBm.

The unit I installed in my Astro 103 is built on a 1-3/8-inch square PC board.[2] The circuit traces were hand drawn, and the layout was for the parts I had on hand. The 2N5109 transistor requires a press-on heat sink. A 2N3866 transistor should also work in this circuit. I have found it necessary to hand select and test transistors to obtain the best results. L1 is wound on an FB-43-801 bead with no. 28 or smaller enameled wire. The secondary winding consists of 15 turns, tapped four turns from the supply end. The one-turn primary is polarized, so you may have to reverse the connections to obtain proper operation. The primary should be wound on the end of the coil farthest from the transistor. Don't forget to reset your S meter so it reads S9 with a 50-μV input signal.

Fig. 2 shows another amplifier that I built for further testing. I used an FT37-63 toroid core for the transformer on this unit. I measured the same characteristics for both amplifiers. The input and output impedance is 50 ohms with this circuit. I submitted the second amplifier to the ARRL for testing. Fig. 3 shows the spectrum analyzer display taken during one phase of their testing. [Besides the flat response curve shown here, our testing indicated that this amplifier is a solid performer. It has a low noise figure, good IMD characteristics and a flat response through the 6-meter band. — Ed.]

A circuit-board etching pattern is shown at Fig. 4 and the parts-placement diagram is given at Fig. 5.[3] You may have to experiment with the emitter resistor value a bit to maintain the transistor bias current in the range of 40-50 mA. This ensures the best operation of your amplifier.

[1]W. Cooper, "A New Mixer for the Astro 103 Receiver," Hints and Kinks, *QST*, Oct. 1983, pp. 41-42.
[2]m = ft × 0.3048; mm = in × 25.4.
*Assistant Technical Editor

[3]Circuit boards and complete parts kits are available from A & A Engineering, 7970 Orchid Dr., Buena Park, CA 90620, and from RADIOKIT, Box 411, Greenville, NH 03048.

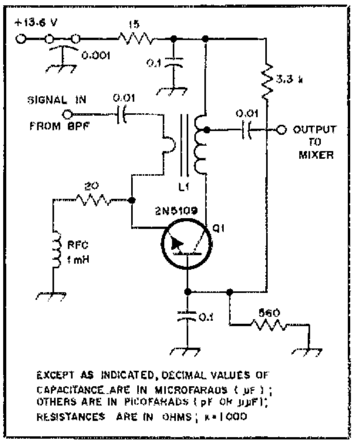


Fig. 1 — Schematic diagram of an RF amplifier built by AG4R. L1 is wound on an FT37-63 toroid core. The secondary winding consists of 15 turns, tapped down four turns from the supply side. The primary is a one-turn loop. You may have to reverse the leads from the primary to obtain the proper polarity.

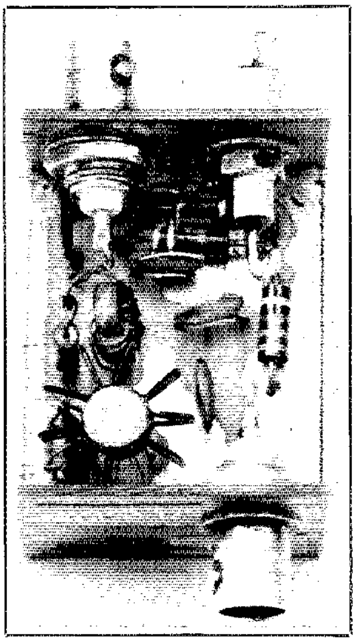


Fig. 2 — The prototype amplifier built by Wayne Cooper.

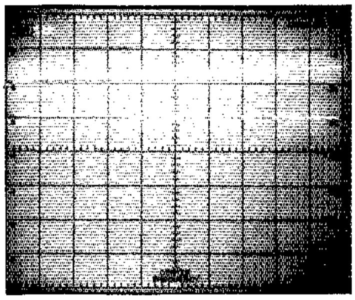


Fig. 3 — Spectral display of the frequency response of the RF amplifier. The lower trace represents the −30 dBm input signal, and the upper trace represents the amplifier output. The center frequency is 30 MHz. Each horizontal division is 5 MHz, and each vertical division is 10 dB.

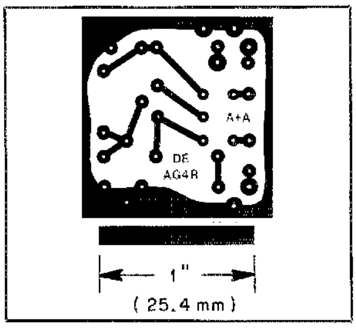


Fig. 4 — Circuit-board etching pattern for the amplifier. Black represents unetched copper. The pattern is shown actual size.

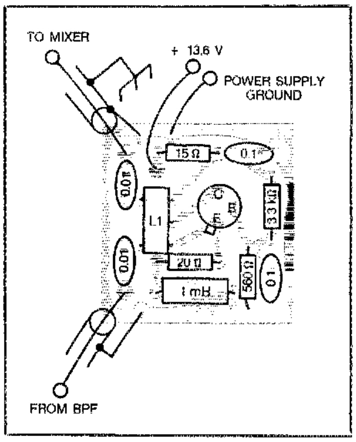


Fig. 5 — Parts-placement diagram for the RF amplifier board. The view is from the component side of the board. Gray areas represent unetched copper on the other side.

No preamplifier is going to be very useful under the strong-signal conditions found on our ham bands if your receiver has a negative third-order intercept point. A preamplifier can improve reception if there are no overpowering signals near the desired frequency. This amplifier has a low noise figure, which should make it ideal for many Amateur Radio applications. — *Wayne Cooper, AG4R, Miami Shores, Florida*

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Rohde, Dr. U. L. "Communications Receivers for the Year 2000." *Ham Radio*, Dec. 1981, p. 36.

WORLD-TIME-FINDER SLIDE RULE

☐ Universal Coordinated Time (UTC — from the French spelling, which is the accepted international version) is the standard method of establishing QSO time and date. The use of local time, or an incorrect conversion from local time to UTC, could mean the difference between getting QSL cards for an award or not. Many operators will check their logs only at the date and time when your QSL records the contact, so if your time conversion is wrong by an hour, you won't get a card.

Another complication involved in world-time conversions is the date change incurred when crossing the International Date Line, or when passing through local midnight. To convert time going from west to east, you must back up one day when you cross the date line, or advance one day when you pass local midnight. To convert going from east to west, just the opposite is true.

You should also be careful when recording the date. In the U.S., it is common to record month/day/year, but in many other countries the sequence is day/month/year. So 7/9 may be interpreted as July 9 or as 7 Sept. I avoid this possible confusion by spelling out the month.

My solution to these problems is to use a slide-rule-type device I call a world-time finder. Fig. 6 shows a template for the one I made. I type the lettering on adhesive labels, then cut out the pieces and place them on the master copy. You can photocopy Fig. 6 to obtain the necessary pieces. Cut out the two circles, and glue them to some stiff card stock (such as an index card). Laminate both circles between pieces of clear plastic material. Clear plastic adhesive material for this purpose may be found at most stationery stores. Clear Con-tact® paper should also be suitable.

Punch an appropriate-sized hole in the center, and fasten the assembly together with a small rivet. Use washers on the top and bottom to prevent the rivet from pulling through the paper. This completes the assembly.

The outer scale is simply a 24-hour clock face. At midnight there are two arrows with a plus and a minus sign. This is to tell you to change the date to either "yesterday" or "tomorrow," depending on which way you are going. The movable second scale includes a letter to help you identify the time zones, along with a label for the number of degrees east or west longitude from the Prime Meridian at the geographic center of that time zone. For example, 2100T would indicate 8 P.M. Mountain Standard Time.

Use the slide rule by aligning the time-zone letter you want to convert from with the desired hour. Now move around the scale to the zone whose time you want to find. Notice that if you cross either local midnight or the International Date Line along the way, you must add or subtract one day, depending on the direction. If zone U (PST) is set to 2000 on July 1, the time and date UTC is 0400Z on July 2. In Japan, which is 135° east longitude from Greenwich, England (9 hours later), the time would be 1300I on July 2. Note that this time conversion can be accomplished by going in either direction around the slide rule with the same result. In one direction you pass local midnight, and in the other you cross the date line. — *Robert Schlegel, N7BH, Roy, Washington*

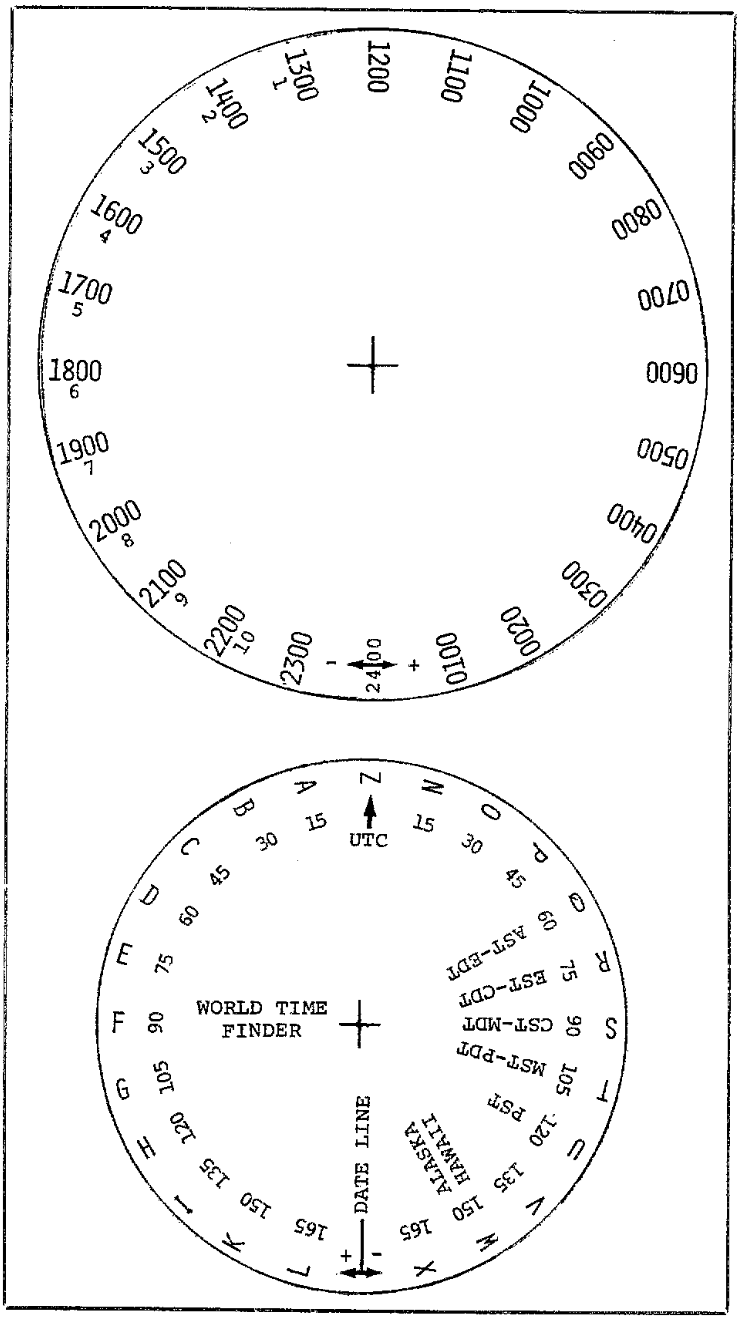

Fig. 6 — Full-size template to make Robert Schlegel's World-Time-Finder Slide Rule.

Technical Correspondence

Conducted By
Bob Schetgen,* KU7G

The publishers of QST assume no responsibility for statements made herein by correspondents.

INVERTED-V ANTENNAS OVER REAL GROUND

☐ I enjoyed reading AJ3K's fine article documenting ground reflections for 0.5-λ horizontal dipoles.[1] The demonstration of a vertically polarized electric-field component, in directions other than broadside, may come as a surprise to many amateurs.

The article might leave an impression that ground reflections are the only factor that affects antenna gain at different heights and for different ground characteristics. While that is true for horizontal antennas more than about 0.2-λ high, an additional factor comes into play for antennas at very low heights. That factor is the change in radiation resistance resulting from mutual coupling with the image antenna.[2]

If we assume a fixed power level and no ohmic losses, the difference in gain, $G_1 - G_2$, of dipoles 1 and 2 in different environments can be expressed by

$$G_1 - G_2 = 10 \log \left(\frac{R_{r1}}{R_{r2}} \right) \qquad \text{(Eq. 1)}$$

where R_{r1} and R_{r2} are the radiation resistances of dipoles 1 and 2, respectively. Therefore, if dipole 1 has the lower R_r, it also has the higher gain.

R_r can be expressed as the sum of the free-space radiation resistance ($R_{r(fs)}$) and the resistive component of the mutual impedance (R_{mut}) produced by out-of-phase coupling with the image antenna:

$$R_r = R_{r(fs)} + R_{mut} \qquad \text{(Eq. 2)}$$

and

$$R_{mut} = R_r - R_{r(fs)} \qquad \text{(Eq. 3)}$$

where

$R_{mut} = R'_{mut} \times R_H$

R'_{mut} = resistive component of the mutual impedance of the antenna and its image at a particular spacing

R_H = reflection coefficient for normal incidence[3]

R_{mut} becomes more negative as the height of a horizontal dipole is decreased. [At antenna heights less than about 0.3 λ — Ed.] This decreases R_r and increases gain.

AJ3K compares an 80-meter dipole at 20 ft (0.071 λ) with a similar dipole 1.2 λ above average ground.[4] Analysis of his results shows that he neglected the gain increase resulting from the deceased R_r of the lower dipole. We can determine this gain increase as follows: R_H, for AJ3K's average ground, is 0.72 (using Eq. 2 from his article). From Fig. 7 (p. 6-4) of *The ARRL Antenna Book*, R_r is 22 Ω when we estimate a perfect reflecting plane to be 10 ft below ground level at AJ3K's location. Then:

$$R'_{mut} = 22 - 73 = -51\ \Omega$$

for a perfect reflector and

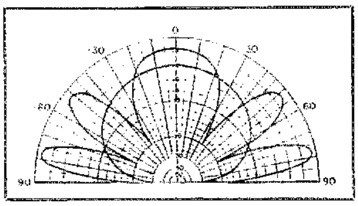

Fig. 1 — Radiation patterns for dipoles 0.071 λ (circular) and 1.2 λ (multi-lobed) above real ground (conductivity = 5 mS/m, dielectric constant = 15). For gain in dBd, add 6 dB to the values shown.

$$R_{mut} = -51 \times 0.72 = -37\ \Omega$$

for AJ3K's average ground. Then:

$$R_r = 73 + (-37) = 36\ \Omega$$

Thus, the gain, $G_1 - G_2$, is:

$$G_1 - G_2 = 10 \log \left(\frac{73}{36} \right) = 3.07 \text{ dB}$$

The dipole at 1.2 λ is so high that R_{mut} is insignificant. Thus, a gain of 3.07 dB must be added to the pattern of the low dipole to be consistent with actual performance.

Fig. 1 shows the vertical radiation patterns of the 0.071-λ and 1.2-λ-high dipoles using AJ3K's data, including the 3.07-dB gain increase for the lower antenna. Compare this pattern with Fig. 2 in the original article. The radiation pattern of the low antenna is not so dismal, especially at the high radiation angles needed for local coverage. At those angles, the low antenna only gives up 2 dB, or less, to the very high antenna.

If you are like most of us and can get your low-frequency dipoles only 15 to 20 ft off the ground, take heart! For coverage out to, say, 150 miles you would need an antenna *much* higher to get 2 dB of improvement (over average ground). The improvement would be less for better ground because R_H is larger and the reflecting plane is closer to the surface; there is greater mutual coupling. — *Mark Bacon, KZ9J, Decatur, Illinois*

The author replies: The method-of-moments program NEC (an industry standard for analysis of wire antennas) was used to analyze the 80-meter dipole at 20 ft above average ground. The pattern calculated by NEC compared very favorably with Mr. Bacon's results. It also agrees with my observation that the antenna works well for local contacts. I point out that for most local contacts (unlike DX) a loss of 6 dB (1 S unit) means little, which provides additional help to the masses (including myself) who have low antennas. The main point, that the low-angle radiation of an antenna depends on height, remains. My thanks to Mr. Bacon for drawing attention to this situation. — *James C. Rautio, AJ3K, Liverpool, New York*

[Details of Mr. Rautio's later analysis of inverted-V antennas appear as a sidebar to his article in this issue. — Ed.]

AN ACTIVE HF SWITCH

☐ A good dc-controlled HF switch is difficult to obtain. One can use small reed relays, but this tends to be an expensive solution because a single relay does not achieve good isolation. Insertion loss is very low with a relay switch, but the incoming signal is not buffered. T-network solid-state switches that use small-signal *diodes* (Fig. 2) have been popular for many years. They offer good isolation and reasonably low insertion loss, but again, there is no buffer action.

An improved HF switch can be built using transistors, rather than diodes, in the T network (Fig. 3). Active devices allow the switch to buffer the incoming signal and retain the isolation properties of its diode cousin. Furthermore, insertion loss is reduced.

When the switch is closed, the control signal to the 2N2222 is low. This allows the high-frequency PNP and NPN voltage-follower stages to operate as buffers that are useful throughout the HF range and into the VHF range as well. To open the switch, the control signal is held high (+12 V; I_b = 4 mA); this drives the 2N2222 into hard saturation.

Certain transistors exhibit a reasonably linear and small resistance near the origin of the I-V characteristic curves, when driven into hard saturation. The 2N2222 is one of those special transistors that makes a particularly good switch (R ≈ 2 Ω when I_b = 4 mA). When the 2N2222 is saturated, it completely removes bias from the voltage-follower stages and puts a well-controlled, harmless, reverse potential across the emitter-base junctions.

The 2N4209 and 2N5179 were selected for their low emitter-base capacitance (1.5 pF and 0.6 pF, respectively) and good high-frequency response. Metal-can packages are preferred over plastic ones because they provide minimal emitter-base capacitance.

I designed the switch for use in a 9-MHz IF strip, where it performs very well. Insertion loss is negligible and isolation approaches a theoretical 110 dB (calculated at 9 MHz with no

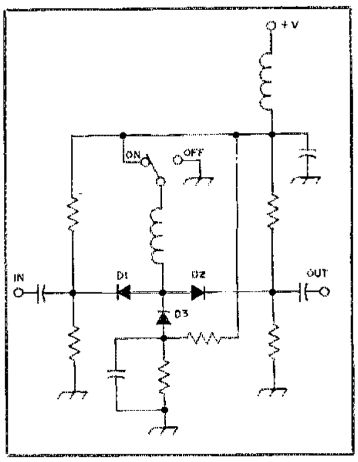

Fig. 2 — A typical T-network HF switch using small-signal diodes.

[1] J. Rautio, "The Effects of Real Ground on Antennas," *QST* Feb. 1984, pp. 15-18.

[2] G. Hall, Ed., *The ARRL Antenna Book* (Newington: ARRL, 1982), pp. 2-19, 2-20.

[3] C. Jasik, *Antenna Engineering Handbook* (New York: McGraw-Hill, 1961), p. 2-7.

[4] m = ft × 0.3048; mm = in × 25.4

*Technical Editorial Assistant

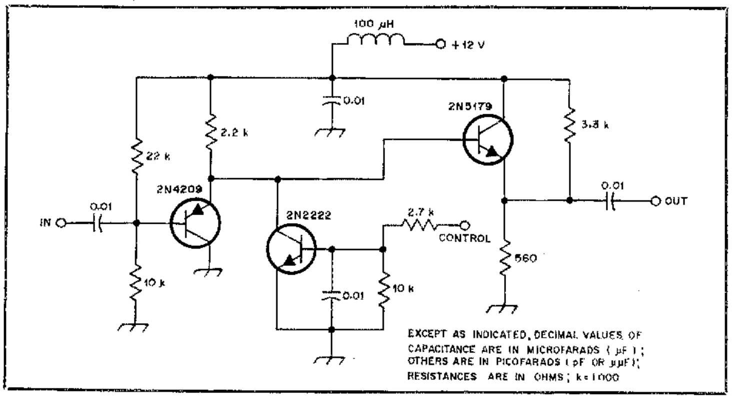

Fig. 3 — A T-network HF switch using active devices that provide excellent buffer action and reduced loss.

load) if good layout practices are followed. For maximum isolation, a shielded partition should be used between the voltage-follower stages. A load of about 500 Ω improves isolation still further at the expense of slightly increased insertion loss. A small-signal output impedance of 6 Ω allows the switch to drive loads as low as 50 Ω without significant loss. Current is limited to 5 mA flowing through the 2N5179. This limits the switched signal to 250 mV with a 50-Ω load; 2.5 V with a 500-Ω load. — *Dennis Monticelli, AE6C, Fremont, California*

BATTERY CHARGING AND SOLDERING-IRON CARE

☐ I just purchased a 1984 *Radio Amateur's Handbook* and found something that could cause trouble. Chapter 10, under "Charging Nickel-Cadmium Batteries," recommends a constant-current charging scheme. This is the best charging method, but it can destroy the battery in some cases. A constant-current system attempts to maintain the same charging rate as the battery approaches full charge. To do this, the voltage across the battery must increase. The voltage applied to a NiCd battery should not be allowed to exceed the potential of the fully-charged cells by more than a few percent. With the Handbook charger, the potential could approach 50 V, which is enough to puncture the separators (or burn out a short). A charging system should include *voltage* as well as current regulation. I use a 723 regulator set to approximately 1.4 V/cell and a current control set to the appropriate current. This system starts charging with a constant current and gradually changes to constant voltage. No timing is necessary and the battery may be charged indefinitely without damage. A 723 can pass 100 mA, so a pass transistor is not needed for AA cells. The system is simple, cheap and safe. — *Warren H. Clark, Balboa, California*

☐ A recent article in *QST*, "Build That Kit Painlessly" (Jan. 1984, p. 19), recommends steel wool to clean a soldering iron. That practice stands alongside the use of acid core solder — as a "no-no." Small pieces of steel wool can stick to the iron and then to the soldered joint. With IC pins 0.01 inch apart, a short can, and frequently will, result. A friend of mine who is in the electronics manufacturing business traced a series of bad boards to the use of steel wool as an iron cleaner. It cost him several hundred dollars to replace the boards. (They had plated through holes, which make the ICs almost impossible to remove.) When you have been at this as long as I have (50 years), you learn a few tricks. — *Warren H. Clark, Balboa, California*

[See, "Construction Practices and Data Tables," *Radio Amateur's Handbook* (Newington: 1984) for methods of cleaning soldering-iron tips. — Ed.]

COMMENTS ON THE PS-5

☐ I have some comments regarding Mr. Gerald Hull's, AK4L article, "Introducing the PS-5 — A Dependable, 5-A Portable Power Supply" (June 1983 *QST*). Several errors have crept into Fig. 2 of the article that should be cleared up before some unsuspecting fellow loses a regulator IC. [See also Feedback in April 1984 *QST*. — Ed.] The following information has been garnered from the various semiconductor manufacturers who have published regulator specification/data sheets and power-supply design references. The bypass capacitors (2 µF/25 V) should be connected to pin 4 of the regulator IC with leads no longer than ¼ inch. Dipped, solid tantalum capacitors are recommended: they have extremely low inductance as well as excellent high-frequency characteristics. When placed within ¼ inch of the IC, these capacitors prevent the IC from "seeing" a resonant circuit (up to 100 MHz and higher) with attendant oscillation and destruction of the regulator IC.

The Fairchild *Hybrid Data Book*, 1978 edition, pages 5-16 through 5-19, gives design information for basic regulated power supplies. Values for R1 and R2 can be determined with the formula:

$$V_{out} = \left(\frac{R1 + R2}{R2}\right)V_{control} \qquad \text{(Eq. 4)}$$

When $V_{control}$ is 5 V and the quiescent current is assumed to be 1 mA:

$$R2 = \frac{5}{0.001} = 5\ k\Omega \qquad \text{(Eq. 5)}$$

Substitute this value, along with an output voltage of 13.8, into Eq. 4 and solve for R1. The answer is 8.8 kΩ. A series combination of 6.8 kΩ, 1.8 kΩ and a 1-kΩ potentiometer is shown for R1 in Fig. 4. The 1-kΩ potentiometer provides adequate adjustment and resolution for amateur use.

Last, Mr. Hull's statement that "crow-bar" circuits are slow is somewhat misleading. A fast-blow fuse can carry 125% of the rated current indefinitely; a 500% overload is required to open the fuse within 50 to 200 mS, according to Bussmann and Littelfuse literature. A thermo-mechanical circuit interrupter, such as Mr. Hull uses, achieves the goal of spare-fuse elimination, but it offers little in the way of protection. The crow-bar, when properly executed, requires much less than 20 mS for operation. It is many times better than the common fast-acting fuse or thermo-mechanical circuit breaker.

I suggest that the crow-bar circuit in Fig. 4 be used to provide protection for the PS-5. The basic crow-bar circuit can be speeded by addition of a transistor amplifier to provide the required SCR gate signal.

I must compliment Mr. Hull for the PS-5. He met his design goals and produced a very attractive piece of equipment. — *Leroy Smith, WBØLTV, Hot Springs, SD*

Feedback

☐ William Newkirk, WB9IVR, brings to our attention an error in "Understanding Resistors," (March 1984 *QST*). The output waveform in Fig. 5B (p. 13) should be shown 180° out of phase with the input signal.

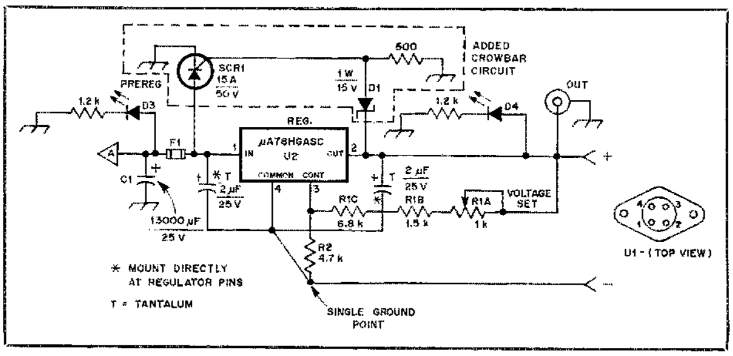

Fig. 4 — A partial schematic of the PS-5 with Smith's suggestions implemented. Resistances are in ohms; k = 1000. F1 is a 5-A, 32-V fuse.

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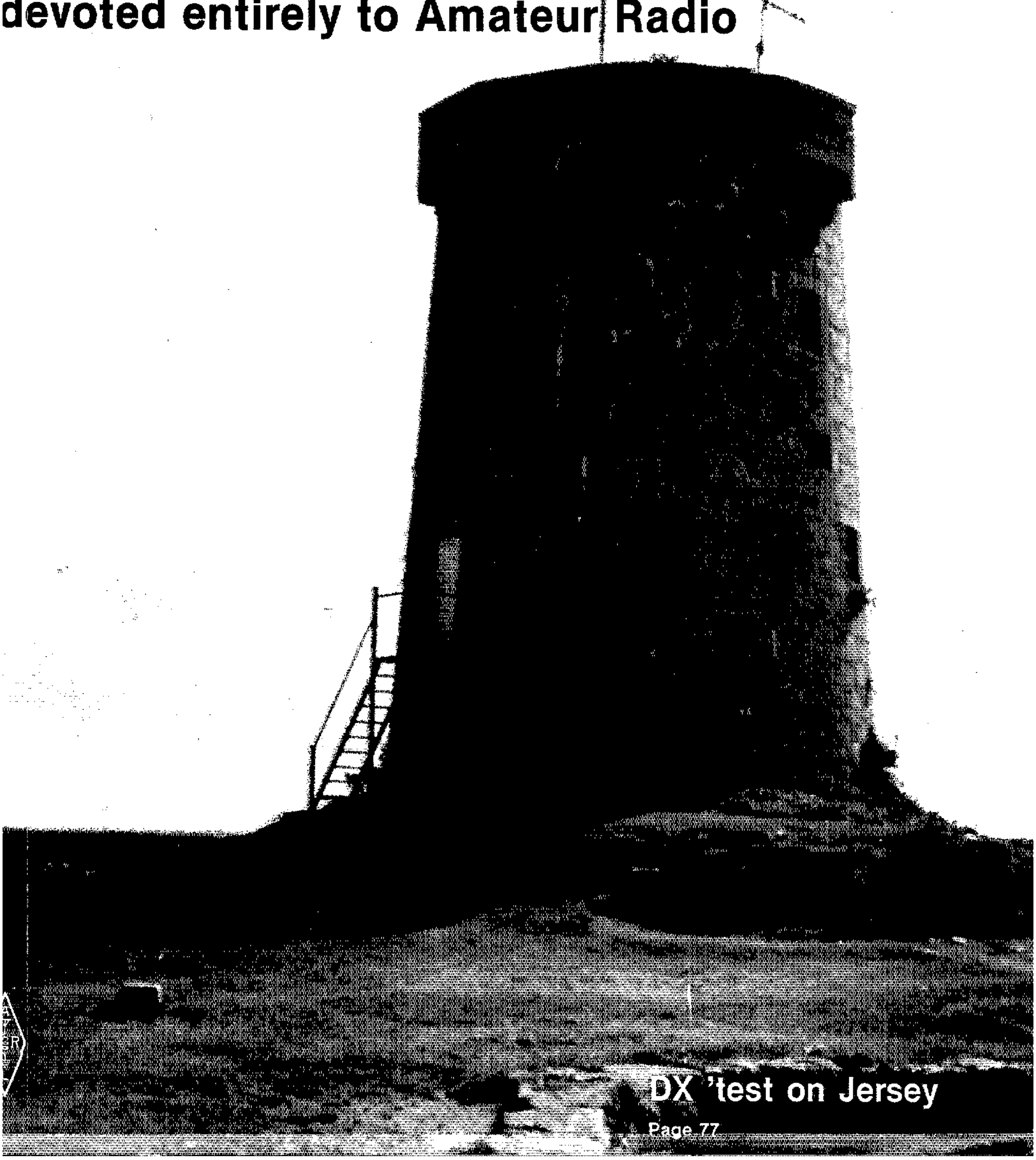

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CONTENTS

OUR COVER
Whether you operated the ARRL DX Contest from a (literal) shack, or, as the Jersey ARS group (GJ3DVC) did, from a 200-year-old tower built to defend the channel island against Napoleon, you'll find your score listed with the DX 'Test recap that begins on page 77.

TECHNICAL

BEGINNER'S BENCH

NEWS AND FEATURES

OPERATING

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A Complete Morse-Code System for the VIC 20™ Computer

If you liked the "Keyboard Keyer and Code-Practice System" in January 1984 *QST*, you'll love this receive program.

By Barry King,* KA7SPU

When I read the January 1984 *QST* article by Dan Whipkey, N3DN, I went out and bought a VIC 20 computer, built the interface and entered his program.[1] It worked exactly as described. I was impressed with the versatility of the VIC 20, and began to wonder if I could add code-reading capability to this already powerful system.

Being able to copy Morse code off the air would complement N3DN's keyboard sender, and the ability to monitor a hand key would round out the code-practice system. Could I do this without investing in the usual peripherals, such as expansion RAM for the computer, a disk drive, a printer, a commercially made interface unit or professionally written software? After several false starts, and lots of trial and error in the development of the machine-language code-reading routine, I found that the answer is "yes!"

My program preserves most of the special functions developed by N3DN. Several additional commands have been added to make full use of the reading program. From the keyboard sending mode, pressing the RETURN key takes you into the reading mode and opens the PTT line on your rig. From the reading mode, pressing S (for send) takes you back to sending.

The "up arrow" key serves as a transmit switch, like the PTT switch on your mike. The switch will stay closed until you open it with SHIFT/R or RETURN. If you're using full- or semi-break-in, you may not need that capability, but it's there just in case.

If you're like me, you'll never be able to remember all those commands, but don't despair! Press the @ key, and a menu appears that lists all of the functions, along with those developed by N3DN (for temperature conversion, frequency tables, screen clearing and sending special concatenated symbols). From the menu, you can continue by pressing the space bar or any of the command keys listed in the menu.

As an optional alternative to N3DN's time printer, I designed a six-digit clock that resides in the cassette-buffer-memory area and runs continuously. Time is displayed in the upper-right-hand corner of the screen without interfering with the sending or receiving programs.

The speed range for reading code is about the same as that of the sending program — 3 to 70 WPM. The reading program can understand all of the characters that can be sent by the sending program, except for $\overline{AR}$, $\overline{SK}$, $\overline{KN}$ and $\overline{BT}$. These appear on the screen as the keys used to send them: comma, semi-colon, equals sign and hyphen. Any invalid character, such as four dashes or six dots, prints as an underlined space. That provision allows for the possibility that it was actually a misunderstood letter, in which case the word will appear with an underlined space where the invalid character occurred. Such an error is easier to read than if the invalid character were left out entirely.

Any seven-element character will display "(ERROR)." That may, in fact, be part of the message, as in cases where the operator you're listening to makes a mistake and sends seven dots to indicate his intention to start over.

Software Logic

To intialize the program and enter the keyboard mode, you need to set the time (if you're using the clock) and desired code speed in response to the program queries. If at any point you want to go back and change the transmitted code-speed, STOP the program and type RUN50. That starts with the code speed question and goes on from there.

When you call the reading program with the RETURN key, the code sending speed currently in use is loaded into the reading-program speed variables. From there, automatic speed-adjustment routines take over. Seven variables are used in character analysis and speed adjustment. Incoming dots and dashes are measured and averaged, as are element spaces and character spaces. From this data, an overall speed variable is continually updated. The results are used as criteria for determining whether subsequent elements are dots or dashes, and whether spaces are element spaces, character spaces or word spaces.

In addition to this code-speed fine tuning, there are routines that watch for symptoms of a grossly off-speed condition, such as consecutive dot characters (E, I, S,

[1]Notes appear on page 16.

*1140 W. 12th, Albany, OR 97321

Table 1

VIC 20 Part 1

```
5 PRINT"PACKING PART 1":POKE55,86:POKE56,27:CLR
10 FORA=6998TO7679:READA$
15 B=ASC(LEFT$(A$,1)):C=ASC(RIGHT$(A$,1))
20 D=-(B>64)*(B-55)*16-(B<65)*(B-48)*16-(C>64)*(C-55)-(C<65)*(C-48)
25 POKEA,D:NEXT
30 CLR:PRINT"LOAD PART 2"
100 DATAAD,FB,03,C9,20,F0,60,C9,2C,90,47,C9,5B,B0,43,AA,BD,97,18,A0,08,84,01,0A
105 DATAC6,01,90,FB,85,02,A5,02,0A,85,02,A0,01,90,02,A0,03,A9,F6,8D,0B,90,A9,01
110 DATA0D,10,91,8D,10,91,20,A9,1B,8C,0B,90,A9,02,2D,10,91,8D,10,91,A0,01,20,A9
115 DATA1B,C6,01,D0,D1,A0,02,20,A9,1B,60,98,0A,0A,A8,A5,00,A2,FA,CA,D0,FD,38,E9
120 DATA01,D0,F6,88,D0,F1,60,A0,04,20,A9,1B,60,73,31,55,32,3F,2F,27,23,21,20,30
125 DATA38,3C,3E,2A,45,80,36,80,4C,80,05,18,1A,0C,02,12,0E,10,04,17,0D,14,07,06
130 DATA0F,16,1D,0A,08,03,09,11,0B,19,1B,1C,68,AA,68,A8,86,03,84,04,E6,03,D0,02
135 DATAE6,04,A0,00,B1,03,C9,FF,F0,06,20,D2,FF,18,90,EC,A6,03,A4,04,98,48,8A,48
140 DATA60,20,F2,1B,28,45,52,52,4F,52,29,FF,A6,8B,9A,E6,21,A2,02,38,E4,21,B0,0E
145 DATA46,8F,A2,00,86,21,E4,8F,D0,04,A2,20,86,8F,A9,00,8D,0B,90,18,90,12,20,F2
150 DATA1B,0D,52,45,41,44,49,4E,47,0D,FF,A9,00,8D,10,91,A5,8F,85,8D,85,8E,4A,85
155 DATAFD,65,8E,85,FE,A5,8D,4A,85,FB,65,8D,85,FC,EA,A5,C5,C9,29,D0,0E,20,F2,1B
160 DATA0D,53,45,4E,44,49,4E,47,0D,FF,60,A9,00,85,8C,A2,00,A0,00,AD,1F,91,29,04
165 DATAF0,28,88,D0,F6,E8,E4,8E,D0,EF,E6,8C,A9,04,C5,8C,D0,E5,18,90,B3,E6,20,A2
170 DATA04,38,E4,20,B0,07,38,26,FE,A2,00,86,20,A9,20,20,D2,FF,18,90,A8,E6,20,A2
175 DATA04,38,E4,20,B0,07,38,26,FE,A2,00,86,20,BA,86,8B,18,90,02,8A,48,A2,00,A0
180 DATA00,A9,F6,8D,0B,90,EA,EA,EA,EA,88,D0,F4,AD,1F,91,29,04,D0,05,E8,EA,18,90
185 DATAE6,8A,48,BA,86,8C,A5,8B,38,E5,8C,C9,0C,90,03,4C,17,1C,A2,00,A0,00,A9,00
190 DATA8D,0B,90,EA,EA,EA,EA,88,D0,F4,AD,1F,91,29,04,F0,BA,E8,E4,8E,D0,E6,A9,00
195 DATA85,8C,A0,08,68,38,C5,8D,66,8C,88,38,C5,8D,B0,08,65,FB,6A,85,FB,18,90,06
200 DATA18,65,FC,6A,85,FC,BA,E4,8B,F0,0A,68,18,65,FD,6A,85,FD,18,90,D7,38,66,8C
205 DATA88,18,66,8C,88,D0,FA,A5,8C,C8,C0,30,F0,0C,D9,C2,1B,D0,F6,98,18,69,2B,18
210 DATA90,02,A9,72,C9,45,F0,13,C9,49,F0,0F,C9,53,F0,0B,C9,48,F0,07,C9,35,F0,03
215 DATA18,90,0A,E6,1D,A2,05,E4,1D,D0,06,46,FC,A2,00,86,1D,C9,54,F0,07,C9,45,F0
220 DATA03,18,90,0B,E6,1F,A2,04,E4,1F,D0,07,38,26,FD,A2,00,86,1F,20,D2,FF,A6,8E
225 DATAA0,00,AD,1F,91,29,04,F0,17,EA,88,D0,F5,84,21,E8,A5,8E,0A,85,8C,E4,8C,D0
230 DATAE9,A5,FD,2A,2A,18,90,07,8A,18,65,FE,6A,85,FE,18,65,FD,6A,85,8E,A5,FB,18
235 DATA65,FC,6A,85,8D,EA,EA,EA,EA,A2,00,A0,00,AD,1F,91,29,04,F0,0B,88,D0,F6,E8
240 DATAE4,8E,D0,F1,4C,A3,1C,4C,C7,1C
```

H or 5), consecutive Ts, seven-element characters and excessive insertion of spaces. In such cases, large adjustments are made to the speed variables in an attempt to bring them under the control of the fine-tuning routines.

All of this is done automatically by the machine-language program. All you will see is the final result printed on the screen. In most cases the program will adjust itself, even to large and abrupt speed changes, without missing more than a word or two. Nevertheless, you may encounter an unusual off-speed condition from which the program does not recover, even after several lines of trying. In that case, toggle to the transmit mode and return immediately to receive. That resets the speed variables and gives the computer another try at self-adjustment. If the problem persists, you may have to go back to transmit, STOP the program and type RUN50 to tell the computer the approximate speed of the code you want it to read. With that much TLC, it can hardly fail!

There are actually two programs required to achieve all this. The first one consists of a few lines of loading instructions followed by 29 long DATA statements that contain the machine-language structure. That program takes up 2383 bytes of memory. The second part contains the entire BASIC language portion of the program. It takes up 2814 bytes. If you already know something about the VIC, you're thinking, "Wait a minute! The VIC has only 3583 bytes free, and besides, it's impossible to use two programs simultaneously!" You're right, but hang on a minute and I'll tell you how to make it work.

Here's what happens. The first program is 2383 bytes long and, like all BASIC programs, it loads into the first 2383 available slots of free memory. This leaves over 1000 unused bytes between the end of the program and the limit of memory. When the program is run, the first thing it does is to reset the computer "memory limit" pointers from the actual memory limit to a new position 682 bytes lower. This creates a block of memory that is off-limits to all BASIC programs, and which is protected against interference and erasure.

The program then takes the two-digit hexadecimal values in the DATA statements and packs them, in order, into the reserved section of memory. There are 682 of them, so they fit neatly in that space. This process takes about 40 seconds. When it's done, the program itself is no longer needed, but the 682-byte machine-language routine it has created is firmly entrenched in the top of free memory space, and will stay there until the power is turned off, even if you load and run another program in the 2901 bytes that remain free. The Part 2 program, then, loads into that remaining memory and calls the machine language program when needed.

Typing in the Program

The complete program listings for the VIC 20 are given in Table 1, and Table 3 has a listing for the C64 computer. Be very careful when entering the DATA statements of Part 1. A single incorrect or misplaced character in that section can make the program fail. (See Table 2 for a short proofreading program to help you check for errors.) Also, be sure to SAVE a copy of your work on tape before attempting to RUN the program. If it does have a mistake, it may crash and be completely lost. Unless you have a copy, your typing time will be wasted.[2]

SAVE Part 1 at the beginning of a new blank cassette with the command SAVE "PART 1". Then enter Part 2 and SAVE it on the section of tape immediately following the end of Part 1. I like to run the tape forward just a bit after the end of Part 1 to make sure there's no overlap.

When you've got these programs on tape, you can LOAD the whole thing by rewinding the tape then holding down the SHIFT key and pressing RUN/STOP twice. The second stroke goes into the keyboard buffer and is read at the appropriate time as the command to LOAD PART 2.

The computer SEARCHes for, LOADs and RUNs Part 1. The tape stops while Part 1 does its machine-language program-

PIN #	TYPE	NOTE
1	JOY0	
2	JOY1	
3	JOY2	
4	JOY3	
5	POT Y	
6	LIGHT PEN	
7	+5 V	MAX 100 mA
8	GND	
9	POT X	

PIN #	TYPE	NOTE	PIN #	TYPE	NOTE
1	GND		A	GND	
2	+5 V	MAX. 100 mA	B	CB1	
3	RESET		C	PB0	
4	JOY0		D	PB1	
5	JOY1		E	PB2	
6	JOY2		F	PB3	
7	LIGHT PEN		H	PB4	
8	CASSETTE SWITCH		J	PB5	
9	SERIAL ATN IN		K	PB6	
10	9V AC	MAX 100 mA	L	PB7	
11	9V AC		M	CB2	
12	GND		N	GND	

Fig. 1 — VIC 20 Game Port and User Port pin identification information. Note that on the User Port, the terminals named with numbers are on the top of the board, and those identified by letters are on the bottom.

Table 1 (continued)

VIC 20 Part 2

```
1 IFPEEK(833)<>47THENOPEN1:CLOSE1:SYS858
2 PRINT"{CLR}{C/DN}{C/DN} CLOCK SET":INPUT" HHMMSS";A$:IFA$=""THEN10
3 A=848:FORB=1TO6:IFB=3ORB=5THENA=A+1
4 C=A+B:POKEC,VAL(MID$(A$,B,1))+48:NEXT
10 PRINT"{CLR}{C/DN}{C/DN}  MORSE CODE PROGRAM":PRINT:PRINT"     BY N3DN  AND":PRINT
20 PRINT"      KA7SPU/TL8CB":PRINT
25 FORA=1TO2500:NEXT:GOSUB780:PRINT"{CLR}{C/DN}{C/DN}"
30 PRINT" KEYBOARD=1":PRINT:PRINT" CODE PRACTICE=2":PRINT:INPUT" YOUR SELECTION";G
40 POKE36878,15:ONGGOTO50,480
50 CLR:PRINT"{CLR}{C/DN}{C/DN} CODE SPEED":INPUT" WPM";S:T=225/S:PRINT:POKE0,T:TC=0:
   POKE37138,255
70 GETB$:IFB$=""THEN70
75 IFB$="£"THENGOSUB780
90 IFB$="*"THEN350
100 IFB$="+"THEN410
110 IFB$="£"THEN470
115 IFASC(B$)=94THEN890
120 IFASC(B$)>132ANDASC(B$)<142THEN210
125 IFASC(B$)=210THEN900
130 IFB$=":"THENPRINT"(AR)";:GOTO190
140 IFB$=";"THENPRINT"(SK)";:GOTO190
150 IFB$="="THENPRINT"(KN)";:GOTO190
160 IFB$="-"THENPRINT"(BT)";:GOTO190
170 IFASC(B$)=13THEN770
180 PRINTB$;
190 POKE1019,ASC(B$):SYS6998:GOTO70
210 N=ASC(B$)-132:ONNGOTO220,230,240,250,260,270,280,290,300
220 AD$=HC$:GOTO310
230 AD$=" DE KA7SPU ":GOTO310
240 AD$=" KA7SPU ":GOTO310
250 AD$=" CQ CQ CQ DE KA7SPU KA7SPU KA7SPU K ":GOTO310"
260 AD$=" R TKS UR RST IS ":GOTO310
270 AD$=" QTH IS ALBANY, OR. ALBANY, OR. ":GOTO310
280 AD$=" NAME IS BARRY BARRY BARRY HW? ":GOTO310
290 AD$=" RIG HERE IS ICOM720-ANT IS DIPOLE ":GOTO310
300 PRINT:CLR:INPUT"HIS CALL";HC$:GOTO70
310 X=1
320 B$=MID$(AD$,X,1):X=X+1
330 IFX=LEN(AD$)+2THEN70
340 PRINTB$;:POKE1019,ASC(B$):SYS6998:GOTO320
350 PRINT"{CLR}":INPUT" FAR-1,CEL-2";H:PRINT
360 ONHGOTO370,390
370 INPUT" DEG. FAR";FA:PRINT:CE=INT((FA-32)*5/9)
380 PRINT" FAR";FA;"= CEL";CE;:PRINT:GOTO70
390 INPUT" DEG. CEL";CE:PRINT:FA=INT(CE*9/5+32)
400 PRINT" CEL";CE;"= FAR";FA:PRINT:GOTO70
410 PRINT"{CLR}":PRINT"FREQ. ALLOC-EXTRA":PRINT
420 PRINT"10 PH.","28500-29700":PRINT"10 CW.","28000-29700"
430 PRINT"15 PH.","21250-21450":PRINT"15 CW.","21000-21450"
440 PRINT"20 PH.","14200-14350":PRINT"20 CW.","14000-14350"
450 PRINT"40 PH."," 7150- 7300":PRINT"40 CW."," 7000- 7300"
460 PRINT"30 CW.","10100-10109":PRINT"AND","10115-10150":GOTO70
470 PRINT"{CLR}":GOTO70
480 PRINT"{CLR}":INPUT" CODE SPEED";CC:PRINT:PRINT:CS=225/CC:POKE0,CS
490 CLR:PRINT" 1=LTRS,NUMS,PUNCT":PRINT
500 PRINT" 2=LTRS,NUMS":PRINT
510 PRINT" 3=LTRS ONLY":PRINT
520 INPUT"YOUR SELECTION";PS:PRINT"{CLR}"
530 CT=1:PRINT:PRINT:PRINT
540 PRINT" 1=RANDOM SPACING":PRINT
550 PRINT" 2=5 CHAR. GROUPS":PRINT
560 INPUT"YOUR SELECTION";SS
570 IFSS=1THENZR=INT(RND(0)*10)
580 IFSS=2THENZR=5
590 FORT=1TOZR
600 ONPSGOTO610,630,650
610 RN=INT((RND(0)*47)+44):IFRN>57ANDRN<63ORRN=64THEN610
620 GOTO660
630 RN=INT((RND(0)*43)+48):IFRN>57ANDRN<65THEN630
640 GOTO660
650 RN=INT((RND(0)*26)+65)
660 PRINTCHR$(RN);:CT=CT+1
670 POKE1019,RN:SYS6998:NEXTT
680 PRINT" ";:RN=32:POKE1019,RN:SYS6998
690 IFCT>200THEN710
700 GOTO570
710 PRINT:PRINT:PRINT" 200 CHARACTERS SENT"
720 PRINT" CHECK YOUR COPY":PRINT
730 PRINT" 1=ANOTHER SESSION":PRINT
740 PRINT" 2=QUIT":PRINT
750 INPUT" YOUR SELECTION";YQ
760 ONYQGOTO480,10
770 POKE143,2*PEEK(0):SYS7236:POKE198,0:GOTO70
780 PRINT"{CLR}{C/DN}"
790 PRINT" THESE SPECIAL KEYS":PRINT" ARE AVAILABLE IN"
800 PRINT" SENDING MODE:":PRINT
810 PRINT"      ↑:RADIO TRANS.":PRINT"SHIFT/R:RADIO REC."
815 PRINT" RETURN:RADIO REC.AND"
820 PRINT"         READING MODE":PRINT
830 PRINT"   *:TEMP CONV.":PRINT"   +:FREQ. TABLE"
840 PRINT"   £:CLEAR SCREEN":PRINT"   @:READ THIS LIST"
850 PRINT"   ::(AR)":PRINT"   ;:(SK)":PRINT"   =:(KN)"
860 PRINT"   -:(BT)":PRINT:PRINT"   (HIT SPACE BAR)"
870 GETB$:IFB$=""THEN870
880 PRINT"{CLR}":RETURN
890 POKE37136,2:GOTO70
900 POKE37136,0:GOTO70
```

Note that characters inside of braces represent keys on the keyboard. {C/DN} is the ⇓ key.

VIC 20 Clock Loader

```
5 PRINT" PACKING CLOCK":FORA=833TO988:READA$
10 B=ASC(LEFT$(A$,1)):C=ASC(RIGHT$(A$,1))
15 D=-(B>64)*(B-55)*16-(B<65)*(B-48)*16-(C>64)*(C-55)-(C<65)*(C-48)
20 POKEA,D:NEXT
25 CLR:FORA=833TO988:A$=A$+CHR$(PEEK(A)):NEXT
30 PRINT" SAVING CLOCK":OPEN1,1,1,A$:CLOSE1
35 PRINT" CLOCK TAPE IS READY"
100 DATA43,4C,4F,43,4B,00,00,00,00,00,00,00,00,00,00,00,30,30,3A,30,30,3A,30,30
105 DATA18,78,A9,74,8D,14,03,A9,03,8D,15,03,58,60,FE,51,03,BD,51,03,60,A9,30,9D
110 DATA51,03,60,48,08,CE,59,03,D0,5D,8A,48,98,48,A9,3C,8D,59,03,A2,07,20,67,03
115 DATAC9,3A,D0,37,20,6E,03,CA,20,67,03,C9,36,D0,2C,20,6E,03,CA,CA,E0,04,F0,E5
120 DATA20,67,03,38,C9,35,90,18,AC,51,03,C0,32,D0,09,CA,20,6E,03,A9,31,8D,52,03
125 DATAC9,3A,D0,07,20,6E,03,CA,20,67,03,A2,08,BD,50,03,9D,0C,1E,A9,06,9D,0C,96
130 DATACA,D0,F2,68,A8,68,AA,28,68,4C,BF,EA
```

packing job, and then hands control back to the computer, which starts the tape again to SEARCH for and LOAD Part 2. That part will eventually come up running. All of this is automatic, but it does take quite a bit of time — over 2½ minutes. You might want to start the loading routine a bit ahead of time so that it will be ready and waiting when you need it. Once it's loaded, there are no further delays or pauses in the program operation.

If you want to try the code-reading program with your hand key before investing time and materials in the radio interface, it's easy enough to do. Use miniature clips, or pin-plug sockets, to attach wires to the JOY Ø and GND pins in the VIC joystick port. (See Fig. 1.) Hook these wires to your hand key. Put the program in reading mode and pound away. You'll hear the code you're sending through the TV audio, and you'll see the computer interpretation on the screen.

Adding The Digital Clock

If you don't want to use the clock, delete lines 1, 2, 3 and 4 from Part 2. If you do want to use it, here's how. After you've entered and SAVEd correct copies of Parts 1 and 2 on tape, clear your computer and enter a copy of the clock-loader program. SAVE it, on a separate cassette. Then reload the cassette containing Parts 1 and 2, and position it at a point on the tape just after the end of Part 2. Now, RUN the clock loader. It will take a few moments to assemble the clock in the cassette buffer, and then the program will instruct you to press RECORD and PLAY on the tape player. When you do this, the clock is stored as a short data file that will be loaded automatically by Part 2 each time you start the program. You'll have no further need of the clock loader, unless you later want to make another clock on a different cassette.

When this is done, you're ready to try loading the whole thing. Rewind your tape of "Part 1," "Part 2" and "Clock." Clear your computer, depress the SHIFT key and push RUN/STOP twice. If you've got it all right, the whole program, including the clock, will come up running in a couple of minutes. You're offered a chance to set the clock every time the program is RUN from the beginning. If you don't need to set it, just ignore the question and push RETURN. The clock can be turned off by typing RUN/STOP and RESTORE, and turned on again by the command SYS 858.

The clock has blue digits and runs on a 24-hour format. The color is controlled by the character 06 in line 125. It can be changed to any number from 00 through 07, yielding any of the VIC's eight colors. The numbers correspond to the order in which the colors appear on the keyboard, i.e., 00 = black and 07 = yellow. You can change colors while the clock is run-

Table 2

Proofreading

Many readers have difficulty correctly entering the machine language section of computer programs. Part 1 of my program will be even more difficult than N3DN's was. Here's a short proofreading program that will help you check your entry of Part 1 for errors.

```
970 A=256*PEEK(44)+PEEK(43): FOR
   B=1TO35:C=PEEK (A+2): D=A
980 A=256*PEEK (A+1) +PEEK (A): FOR
   E=DTOA:F=F+PEEK (E):IF F > 999THEN
   F=F-999
990 NEXT:PRINTSTR$ (C);":";F,:NEXT
```

Type it in after you've finished typing Part 1 and have SAVEd a copy. Type RUN970 and you will get a list of all the BASIC line numbers, along with a number that is derived from the sum of the numerical values of all the characters in the line. A correct copy of Part 1 yields the following list:

5: 424	10: 876
15: 215	20: 184
25: 103	30: 501
100: 615	105: 774
110: 79	115: 422
120: 504	125: 726
130: 910	135: 84
140: 379	145: 549
150: 690	155: 140
160: 560	165: 28
170: 230	175: 572
180: 4	185: 245
190: 788	195: 105
200: 400	205: 807
210: 309	215: 722
220: 55	225: 579
230: 72	235: 426
240: 609	

If any of the numbers on your own list differ from mine, you have an error somewhere in the indicated line number. Look for it, correct it, and try again. When you're done, erase lines 970, 980 and 990 by typing each of the numbers with nothing following it and pressing RETURN. This method will not catch an error in which two correct characters are out of sequence, nor will it catch two or more errors that, by coincidence, exactly offset each other. Fortunately, most errors are not like that, and will be detected. Now you have an exact copy of Part 1 ready to be SAVEd on tape.

ning by POKEing 973 with one of the color code numbers.

The 24-hour format is controlled by the characters 35 and 32 in line 120. For a 12-hour format, change them to 33 and 31, respectively.

Incidentally, this clock should also work with any of your other VIC 20 or C 64 programs. Just add lines 1 through 4 from Part 2 to that program, and use the clock loader program to make a copy of the clock on tape right after the program with which you want to use it.

Remember that the clock will be erased by any subsequent tape operation. It should be turned off before attempting a LOAD or SAVE.

Building the Interface Circuit

Output Keying

I checked the CW key jack of my ICOM IC-720 for open-circuit voltage and short-circuit current, and found it to be within the capabilities of a transistor. I suspect this would probably be true of most rigs. The limits of the 2N2222 are 30 V and 800 mA. I used a single 2N2222 for keying. The emitter is connected to ground, the collector to the positive key line, and the base to the PBØ user-port terminal (pin C) in the computer. See Fig. 1. A disadvantage of this approach, as compared to N3DN's relay, is that it is polarity sensitive and you must make sure the positive line of your key cord is connected to the transistor. If in doubt, turn your rig on, plug in a keying cord, and short the ends of the wires with a diode. It should key in one direction, but not the other. When it keys, you've got the cathode (marked with a stripe) connected to ground. The other wire is positive and should be connected to the switching-transistor collector.[3]

TR Switching

I still had the relay I purchased for N3DN's circuit. I wanted to be able to do TR switching from the computer keyboard, so I decided to use it for that. The current and voltage requirements in this application are much higher than for keying, at least in the ICOM. I bought a mike connector for the radio, found the two pins that activate the PTT circuit, and hooked them up to the relay contact points. N3DN's circuit for driving the relay from computer output works perfectly, and I have duplicated it in my circuit (Fig. 2), except that it connects to User Port pin D (PB1) instead of pin C (PBØ), since that is where the program directs the TR-switching commands.

Audio Input

Now we get to the bulk of the circuit: the audio input section for reading Morse code. It's built around the 741 op amp, which is available from Radio Shack (part no. 276-007). In this configuration, the 741 serves double duty as a voltage amplifier and as an RC active band-pass filter for a specific audio frequency. That means that if you connect the circuit to the terminals of a speaker that's putting out a faint Morse code signal at, say, an 800-Hz tone, you can amplify the code signal while attenuating static and noise.

This circuit has a high input impedance meant to be connected in parallel with a speaker, not to replace the speaker. If the external speaker jack on your radio is the kind that disconnects the internal speaker when you use it, you will need to modify the radio in some way. You could change the jack to the kind that doesn't disconnect

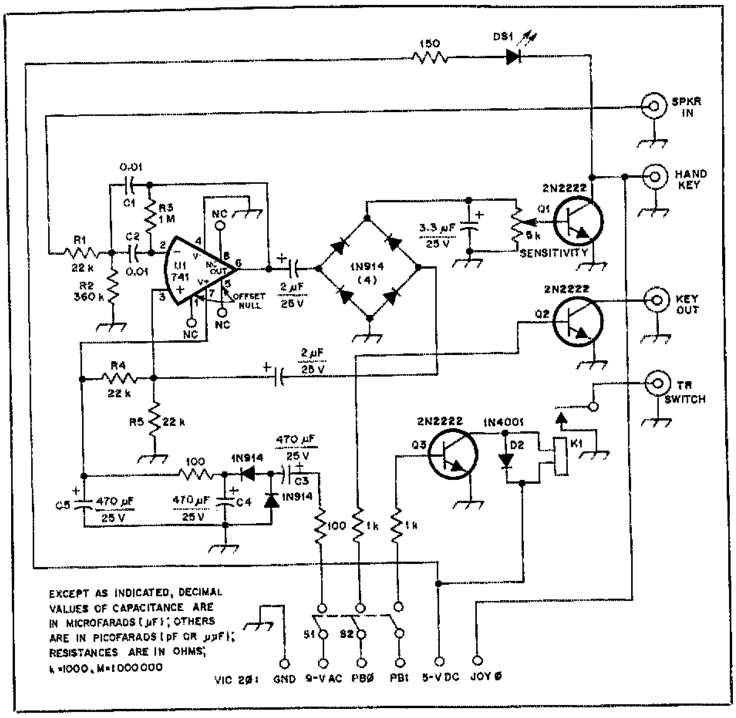


Fig. 2. — Complete schematic diagram of the VIC 20 interface circuit. C1 and C2 along with R1 through R5 produce a band-pass filter centered on 800 Hz. The filter has a gain of 24 and a Q of 27.

K1 — Miniature 5-V relay, Radio Shack part no. 275-240, or equiv.

U1 — 741 op-amp, Radio Shack part no. 276-007, or equiv.

Table 3

C64 Part 1

```
5 PRINT"PACKING PART 1":POKE55,86:POKE56,157:CLR
10 FORA=40278TO40959:READA$
15 B=ASC(LEFT$(A$,1)):C=ASC(RIGHT$(A$,1))
20 D=-(B>64)*(B-55)*16-(B<65)*(B-48)*16-(C>64)*(C-55)-(C<65)*(C-48)
25 POKEA,D:NEXT
30 CLR:PRINT"LOAD PART 2"
100 DATAAD,FB,03,C9,20,F0,60,C9,2C,90,47,C9,5B,B0,43,AA,BD,97,9D,A0,08,84,FB,0A
105 DATAC6,FB,90,FB,85,FC,A5,FC,0A,85,FC,A0,01,90,02,A0,03,A9,11,8D,04,D4,A9,01
110 DATA0D,01,DD,8D,01,DD,20,A9,9D,8C,04,D4,A9,02,2D,01,DD,8D,01,DD,A0,01,20,A9
115 DATA9D,C6,FB,D0,D1,A0,02,20,A9,9D,60,98,0A,0A,A8,A5,02,A2,FA,CA,D0,FD,38,E9
120 DATA01,D0,F6,88,D0,F1,60,A0,04,20,A9,9D,60,73,31,55,32,3F,2F,27,23,21,20,30
125 DATA38,3C,3E,2A,45,80,36,80,4C,80,05,18,1A,0C,02,12,0E,10,04,17,0D,14,07,06
130 DATA0F,16,1D,0A,08,03,09,11,0B,19,1B,1C,68,AA,68,A8,86,03,84,04,E6,03,D0,02
135 DATAE6,04,A0,00,B1,03,C9,FF,F0,06,20,D2,FF,18,90,EC,A6,03,A4,04,98,48,8A,48
140 DATA60,20,F2,9D,28,45,52,52,4F,52,29,FF,A6,8B,9A,E6,21,A2,02,38,E4,21,B0,0E
145 DATA46,8F,A2,00,86,21,E4,8F,D0,04,A2,20,86,8F,A9,00,8D,04,D4,18,90,12,20,F2
150 DATA9D,0D,52,45,41,44,49,4E,47,0D,FF,A9,00,8D,01,DD,A5,8F,85,8D,85,8E,4A,85
155 DATAFD,65,8E,85,FE,A5,8D,4A,85,FB,65,8D,85,FC,EA,A5,C5,C9,0D,D0,0E,20,F2,9D
160 DATA0D,53,45,4E,44,49,4E,47,0D,FF,60,A9,00,85,8C,A2,00,A0,00,AD,00,DC,29,01
165 DATAF0,2B,88,D0,F6,E8,E4,8E,D0,EF,E6,8C,A9,04,C5,8C,D0,E5,18,90,0C,E6,20,A2
170 DATA04,38,E4,20,B0,07,38,26,FE,A2,00,86,20,A9,20,20,D2,FF,18,90,A8,E6,20,A2
175 DATA04,38,E4,20,B0,07,38,26,FE,A2,00,86,20,BA,86,8B,18,90,02,8A,48,A2,00,A0
180 DATA00,A9,11,8D,04,D4,EA,EA,EA,EA,88,D0,F4,AD,00,DC,29,01,D0,05,E8,EA,18,90
185 DATAE6,8A,48,BA,86,8C,A5,8B,38,E5,8C,C9,0C,90,03,4C,17,9E,A2,00,A0,00,A9,00
190 DATA8D,04,D4,EA,EA,EA,EA,88,D0,F4,AD,00,DC,29,01,F0,8A,E8,E4,8E,D0,E6,A9,00
195 DATA85,8C,A0,08,68,38,C5,8D,66,8C,88,38,C5,8D,B0,08,65,FB,6A,85,FB,18,90,06
200 DATA18,65,FC,6A,85,FC,8A,E4,8B,F0,0A,68,18,65,FD,6A,85,FD,18,90,D7,38,66,8C
205 DATA88,18,66,8C,88,D0,FA,A5,8C,C8,C0,30,F0,0C,D9,C2,9D,D0,F6,98,18,69,2B,18
210 DATA90,02,A9,72,C9,45,F0,13,C9,49,F0,0F,C9,53,F0,0B,C9,48,F0,07,C9,35,F0,03
215 DATA18,90,0A,E6,1D,A2,05,E4,1D,D0,06,46,FC,A2,00,86,1D,C9,54,F0,07,C9,45,F0
220 DATA03,18,90,0B,E6,1F,A2,04,E4,1F,D0,07,38,26,FD,A2,00,86,1F,20,D2,FF,A6,8E
225 DATAA0,00,AD,00,DC,29,01,F0,17,EA,88,D0,F5,84,21,E8,A5,8E,0A,85,8C,E4,8C,D0
230 DATAE9,A5,FD,2A,2A,18,90,07,8A,18,65,FE,6A,85,FE,18,65,FD,6A,85,8E,A5,FB,18
235 DATA65,FC,6A,85,8D,EA,EA,EA,EA,A2,00,A0,00,AD,00,DC,29,01,F0,0B,88,D0,F6,E8
240 DATAE4,8E,D0,F1,4C,A3,9E,4C,C7,9E
```

C64 Part 2

Only those lines with changes to the VIC 20 listing are shown.

```
22 PRINT" COMMODORE 64 VERSION"
25 FORA=1TO2000:NEXT:GOSUB780:PRINT"{CLR}{C/DN}{C/DN}"
27 POKE56579,255
29 S=54272:POKES,110:POKES+1,52:POKES+5,16:POKES+6,240:POKES+24,15
40 ONGGOTO50,480
50 CLR:PRINT"{CLR}{C/DN}{C/DN} CODE SPEED":INPUT" WPM";S:T=225/S:PRINT:POKE2,T:TC=0
190 POKE1019,ASC(B$):SYS40278:GOTO70
340 PRINTB$;:POKE1019,ASC(B$):SYS40278:GOTO320
480 PRINT"{CLR}":INPUT" CODE SPEED";CC:PRINT:PRINT:CS=225/CC:POKE2,CS
670 POKE1019,RN:SYS40278:NEXTT
680 PRINT" ";:RN=32:POKE1019,RN:SYS40278
770 POKE143,2*PEEK(2):SYS40516:POKE198,0:GOTO70
890 POKE56577,2:GOTO70
900 POKE56577,0:GOTO70
```

C64 Clock Loader

Only those lines with changes to the VIC 20 listing are shown.

```
105 DATA09,78,A9,74,8D,14,03,A9,03,8D,15,03,58,60,FE,51,03,BD,51,03,60,A9,30,9D
125 DATAC9,3A,D0,07,20,6E,03,CA,20,67,03,A2,08,BD,50,03,9D,1D,04,A9,0E,9D,1D,D8
130 DATACA,D0,F2,68,A8,68,AA,28,68,4C,31,EA
```

the speaker, or fabricate some other way of hooking up to your speaker without disconnecting it. External speaker sockets that disconnect the internal speaker usually have an unused terminal that remains connected to audio output even when a plug is inserted. You can put a jumper from there to the one where the internal speaker is connected, or just connect the internal speaker wire directly to the other terminal.

The amplified and filtered signal can be rectified, filtered again and used to bias a switching transistor, which can then be read by the computer. I originally tried to do this with another miniature relay, but the speed of the machine-language program is such that even the slightest relay-contact bounce was read as a code element of infinitesimal length. The status of the switch is tested tens of thousands of times every second. Although this could probably be corrected with a debouncing circuit, solid-state switching seems to be a better all-around solution.

To provide some control over the switching sensitivity, I applied the dc output of my circuit to one side of a 5-kΩ potentiometer and grounded the other side. The potentiometer becomes a variable voltage divider. The wiper can tap into any dc voltage between ground and the amplifier output, which is determined by the strength of the signal you're reading and the voltage gain of the op amp (more on that later), up to a maximum of 5 or 6 V. The amplifier output may vary with the signal strength and the volume setting on your radio. The voltage needed to bias the switching transistor remains constant, but you will always be able to find a range of positions on the potentiometer where the dc voltage goes over that threshold when a code element is present, and drops below it during the spaces. That's exactly what you need for accurate code reading!

I needed a way to monitor the performance of the switching transistor while setting the pot. An LED (Radio Shack part no. 276-021A) with its anode connected to +5 V, and cathode connected to the transistor collector, does the trick. The light turns on when the transistor is forward biased, and off when it's not. I drilled a hole through the Commodore logo at the top left of the computer and placed the LED there. The potentiometer can be used to adjust switching sensitivity until the blinking light matches the code you want to read. Acceptable performance can be obtained over a wide range of settings. I have achieved the best results by setting the radio volume low and the variable resistor near the high end of its range, but only a little higher than the point where the light first starts to blink. The software is designed to read a connection between the Game I/O or User port pin JOYØ and GND as a code element.

Power Supply

Capacitors C3 to C5 and the other components near them make up the op-amp power supply. They draw a tiny amount of current from the VIC 20 9-V ac supply and put out about 14-V dc for the op amp, with the 470-μF capacitor I used. The 741 normally needs both positive and negative power supplies. R4 and R5 make a voltage divider used to create a pseudoground at a voltage that is half the total. This approach allows us to connect pin 3 of the amplifier to the pseudoground and apply true ground to pin 4 as −7 V and the positive dc supply to pin 7 as +7 V.

Customizing The Audio Frequency

Capacitors C1 and C2 are the key to the circuit filtering performance. Unwanted signals can be attenuated two ways: by keeping them off the input terminal in the first place, or by bringing their result from the output back to the input on the feedback line that goes from pin 6 to the junction of C1 and R3. This works because the 741 is wired as an inverting amp, meaning that the output is opposite in polarity to the input. If an instantaneous voltage at the input was +3 V on a unity-gain op amp, the output would be −3 V. It's clear that a shorted feedback line would cancel everything to zero. A selectively closed feedback line, though, cancels only those signals that are high enough in frequency to get from the output, through C1 and C2, and back to the input. That's the low-pass filtering. C2 and R2 also perform the high-pass filtering by shorting the low-frequency signals to ground before they arrive at the amplifier input.

The center frequencies are high enough to squeeze through the input filtering, but not high enough to develop a lot of self-canceling feedback. In this application, we can get away with using a very high Q (narrow filter bandwidth). No one is listening to the output except the computer, and it doesn't care at all about tone quality, which is usually the limiting factor on the Q of CW audio-filtering circuits.

The voltage gain, center frequency and Q of the circuit are all determined by the relative values of resistors R1 through R5 and capacitors C1 and C2. You can customize the circuit performance by varying these components to achieve the characteristics you want.

You will probably want to read code at the same pitch as the sidetone your radio generates. Match the filter characteristics of your interface to the center frequency of the CW filter in your transceiver. On many rigs that frequency is around 800 Hz.

Formulas for this kind of circuit can be found in *The Radio Amateur's Handbook*, pp. 4-47 and 8-29. The exact values of gain and Q are not really critical. High Q narrows the bandwidth of your filter; low Q broadens it. High gain means your system will work with the radio volume turned down and the SENSITIVITY potentiometer turned down; low gain means the opposite. The more important task is to find any reasonable pair of values for gain and Q that will make a circuit to filter your chosen frequency, and that can be built with standard-value components. Most combinations of gain, Q and center frequency will call for resistances and capacitances that can't be easily achieved when it comes to actually assembling the circuit.

That means using the formulas by trial and error, which would be very time-consuming on a calculator. I know you have a VIC 20, or are going to get one (otherwise you wouldn't be reading all this), so let's use it to do the dirty work. Table 4 lists a short BASIC Program for this task.

Enter your chosen center frequency in line 10 instead of the 800 Hz that I used, and the value of your capacitors if they're different from mine, which are 0.00000001 F, or 0.01 μF. RUN the program, choose a value for gain and another for Q in response to the computer queries, and see what you get. Each complete circuit design takes only a fraction of a second, so you're free to try as many as you like.

I cannibalized an old cassette player for resistors and capacitors. This program discovered a circuit with a gain of 24 and Q of 27, which I could build with the parts I found inside of that unit. Those values are shown on my schematic. You can use my values if you like, but it's easy to design your own, with the help of the VIC.

Once you've customized the circuit to read code at your chosen audio frequency, it's nice to adjust the computer program so it will generate that same tone through the TV audio in keyboard sending, code practice and reading modes. The pitch of the computer-generated code is controlled by the hexadecimal numbers "F6" that appear in lines 105 and 165 of Part 1. F6 is the hexadecimal equivalent of the decimal number 246. These values are packed into memory locations 7075 and 7388. You can check them any time after Part 1 has done its packing, by typing in the commands ?PEEK (7075) and ?PEEK (7388). Both should return the number 246. The first one controls the pitch of the sending program code; the second, that of the reading program. They produce an 800-Hz tone on the TV audio.

Table 3 (continued)
Notes on the C64 Version

The 64 has two sets of joystick switches.

Connect the interface wire marked "Joy Ø" to "Joy BØ" in the 64. All other connections are the same as those on the VIC.

The pitch of the audio tones generated by the 64 can be changed by varying the values POKEd to S and S+1 in line 29 of Part 2.

On some TV screens, the clock may be hidden just off the top right corner of the screen. To move it nearer the center, find the 1D values in line 125 of the (C64) clock loader and change them to a lower number, like 10. The color of the digits is controlled by the 0E in line 125, and may be changed to any of the 16 available colors.

Running the proofreading program (Table 2) with the C64 Part 1 gives the following list:

5: 472	10: 6
15: 342	20: 309
25: 226	30: 622
100: 783	105: 72
110: 505	115: 907
120: 997	125: 218
130: 400	135: 571
140: 874	145: 44
150: 223	155: 689
160: 111	165: 574
170: 774	175: 115
180: 522	185: 771
190: 317	195: 631
200: 924	205: 340
210: 839	215: 251
220: 581	225: 107
230: 597	235: 952
240: 154	

Table 4
Filter-Value Program

```
10 FØ = 8ØØ:WØ=2*3.1416*FØ:C1=.ØØØØØØØ1
20 INPUT "GAIN"; AV: INPUT "Q";Q
3Ø R1=Q/ (AV*WØ*C1)
4Ø R2=Q/((2*(Q^2)-AV) *WØ*C1)
5Ø R3=(2*Q) / (WØ*C1)
6Ø R4=.Ø2*R3
7Ø PRINT"R1=";R1:PRINT"R2=";R2:PRINT
   "R3=";R3:PRINT"R4=";R4:GOTO1Ø
```

To select a higher pitch you need to change 246 to a higher number (up to 255), and vice versa. Change the numbers with the commands POKE 7075,X and POKE 7388,X (X being the new number you want to try). Run the program, listen to the results, compare it to the sidetone from your rig, and change it again as necessary. When you've found the number you want, convert it to hexadecimal. (For an explanation of decimal to hexadecimal conversion, see N3DN's article in January *QST*.) LOAD and LIST Part 1, lines 105 and 165, and type in your new hexadecimal number in place of the F6 values. Be sure to copy over the remainder of these lines when you make the changes. SAVE the modified program in place of the original, and you're all set.

Summary

This Morse code system provides good performance at a very reasonable price — even if you were to buy a new VIC 20 especially for it. It can be used as a starting point for further development, depending on your own interests. Hardware fans might want to add a small audio amp and mike plug so the VIC could actually hear and read the sound of code. Software fans may want to find ways to add screen windows, word-processing functions and the ability to generate hard copy on a printer.

A note to programmers: The program is tailored to the unexpanded VIC 20. It should also work with the 3-kbyte expansion, but any larger expansion will use the area where I put machine language for screen memory. The machine language is not relocatable. Although I kept absolute addresses to a minimum, there are still some there, and these would have to be changed before you could relocate the program.

Enjoy your computerized CW terminal!

Notes

[1]D. Whipkey, "A Keyboard Keyer and Code-Practice System," Jan. 1984 *QST*, pp. 13-16.

[2]The author will supply a copy of the programs to anyone who sends him a blank cassette tape and a self-addressed stamped cassette mailer, along with $3 to cover handling. Be sure to specify whether you want the VIC 20 or C 64 version. The ARRL and *QST* in no way warrant this offer.

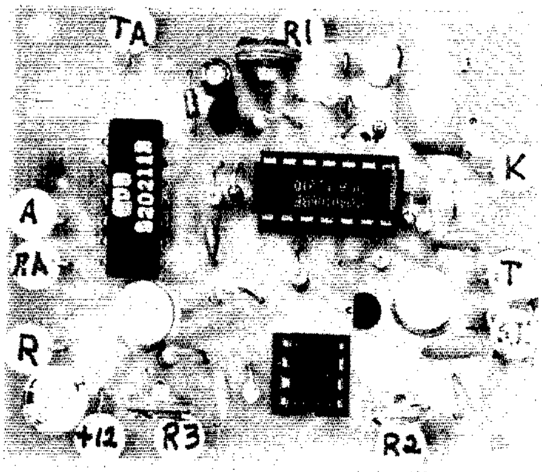
[3]This will work only if your rig requires a connection to ground for keying. If it needs a voltage source for keying, build the circuit shown in the 1984 *Radio Amateur's Handbook*, p. 11-3, Fig. 5. It provides output for both kinds of keying.

Strays

I would like to get in touch with...

☐ anyone with a service manual for a CLEGG FM-DX transceiver. Alan H. Carp, K1HLZ, 4 Post Oak La., Natick, MA 01760.

TR Circuits for Homemade Rigs



The published circuits for many solid-state transmitters of amateur design lack TR or break-in delay circuits. This month's workshop project is a TR module for full QSK or semi break-in.

By Doug DeMaw,* W1FB

Did you build a CW rig from an article, but found that it lacks a TR (transmit-receive) circuit that does not require manual operation? We often find ourselves duplicating solid-state transmitter designs, only to do a bit of head scratching in an effort to come up with a suitable TR type of circuit.

The trend today is toward full break-in (QSK) by CW operators, but few commercial transceivers contain that feature. I think an ideal solution is to have the equipment outfitted for semi or full break-in at the flip of a switch. Traffic handlers and many ragchewers prefer full break-in for expediency in getting from the transmit mode to the receive mode almost instantly. The more casual operator may not care to be so fast on the draw, so he or she may prefer a delay period between transmit and receive — the common feature of most commercial transceivers today.

Whatever your preference, the practical circuit in this article provides the choice between break-in delay or full QSK for low-power transmitters. It also contains a sidetone generator and dc switching for muting the receiver during transmit periods. It is compact and inexpensive to build, and a parts kit is available.[1]

Simple TR Methods

In the early days of Amateur Radio, many of us were satisfied to throw one or more switches to change from transmit to receive. It was not uncommon to throw three or four switches in those days of long transmissions on AM or CW, which surely aided the acquisition of the ARRL Rag Chewers' Club certificate! In my shack, at the start of my amateur experience, I threw two toggle switches and a large knife switch to transfer the transmitter and receiver operating voltages. The knife switch took care of antenna changeover!

Today's operation prohibits such archaic TR techniques, and we can be thankful for that. But, we are still restricted by the delay features contained in the VOX (voice-operated switch) circuits of modern equipment. The drop-out (delay) period can be set by the operator through adjustment of a delay control, but erratic operation will result when we attempt to provide instantaneous break-in with VOX circuits. Furthermore, the relay that switches the antenna will not follow fast CW without the contacts bouncing apart or hanging up during the keying period. We should have no trouble envisioning the kind of CW that would be generated with that anomaly taking place! The reed relay offers the best solution to the problem, up to a specific RF power limit. It switches with minimum contact bounce and is suitable for all but high-speed CW work. Too much current through the contacts, however, will cause arcing and subsequent sticking of the contacts.

Solid-state switching seems to be the best way to go for TR purposes, but the state of the art has not favored high-power TR switching at RF. High-power transistors

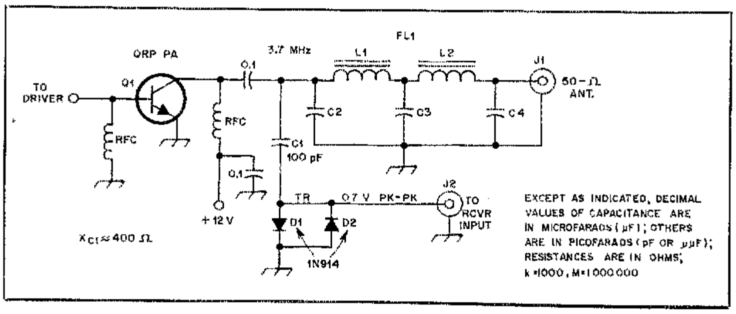


Fig. 1 — Schematic diagram of a simple TR circuit that utilizes a pair of small-signal diodes to shunt the sampled RF energy to ground during transmit periods. This circuit is suitable for low-power operating only, and permits approximately 0.7 V to reach the receiver input circuit.

[1]Notes appear on page 20.

*ARRL Contributing Editor, P.O. Box 250, Luther, MI 49656

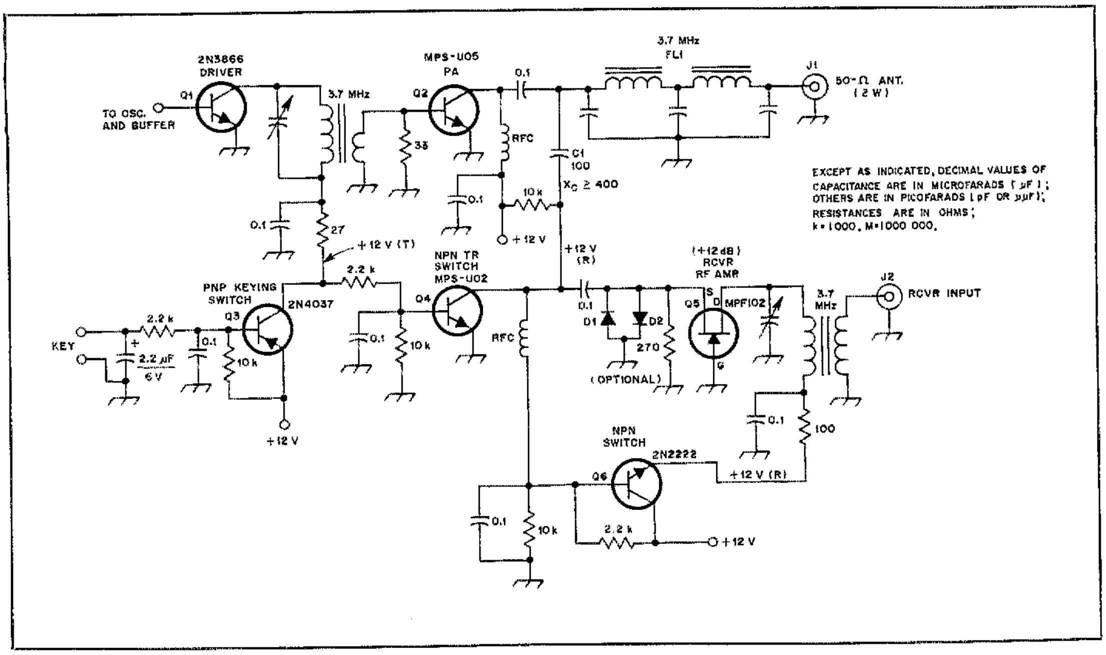


Fig. 2 — A circuit example of a suggested TR circuit for use with low-power transmitters to permit full QSK. The TR logic provides for transmitter keying, antenna switching and receiver RF amplification. An explanation is in the text.

and diodes offer too much leakage from the transmitter to the receiver, and devices that would be well suited to high-power operation would carry a prohibitive price tag. More work needs to be done in this area, especially with regard to PIN diodes. MOS power FETs also offer good promise in this area.

The QRP operator is fortunate with regard to solid-state TR switching, because many diodes and transistors are available for this application at low cost. Let's examine some proven and suggested circuits for low-power solid-state switching of dc and RF. Fig. 1 shows a method used by Wes Hayward, W7ZOI, in some of his QRP transceivers. It suffers a couple of minor shortcomings. These trade-offs often come with simplified circuitry.

Q1 of Fig. 1 represents the last stage of a transmitter. A typical output LC network (C2, C3, C4, L1 and L2) forms a half-wave harmonic filter. The station antenna is connected to J1 of the transmitter. At the Q1 side of the network we attach C1, a sampling capacitor. The value of C1 must be included in the calculation of the value of C2, since the two capacitors are in parallel during key-down periods. During receive, FL1 is between the antenna and the receiver input circuit, thereby adding some low-pass filtering during receive. There will be a slight insertion loss through the filter (unavoidable), however, and the size of C1 will be so small that additional losses will result during the receive period. It is necessary to keep C1 small in value to prevent significant loss to ground via D1 and D2 during transmit. This is one of the trade-offs mentioned earlier. A capacitive reactance (X_C) of 400 ohms is suggested for C1. Do not use a lower value. Assuming the circuit in Fig. 1 was designed for the 80-meter Novice band (3.7 MHz), we would arrive at the recommended capacitance value from

$$C_{\mu F} = \frac{1}{f(\text{MHz}) \times X_c \times 2\pi} \qquad \text{(Eq. 1)}$$

$$C = \frac{1}{3.7 \times 400 \times 6.28} = 0.000107\ \mu F$$

where X_c is in ohms. From this we can see that 107 pF is required. Since 100 pF is the nearest standard value for C1, we shall use it. Thus, when calculating the value for C2, we must include the 100 pF of C1 in the design.

The remaining trade-off for the circuit of Fig. 1 is the barrier voltage of the shunt diodes, D1 and D2. If we use 1N914s or some equivalent silicon diode, they will conduct and clamp the voltage level at roughly 0.7. This amount of RF voltage will not harm the receiver input, but if the receiver has AGC it may lock up the AGC circuit, causing a delay in receiving until the AGC circuit recovers.

The signal loss with this sample TR circuit may reach 10 dB, which on the higher HF bands may be prohibitive in terms of receiver noise figure. I have used this technique successfully in simple gear from 160 through 30 meters. I have a better circuit for these bands and higher — see Fig. 2.

Improved Solid-State QSK

Although the circuit of Fig. 2 may look overly elaborate for a low-power transmitter, it is inexpensive and requires very little space on a circuit board. It illustrates how we might overcome the loss mentioned in our discussion of Fig. 1. Q3 is used as the keying transistor. When the key is closed, Q1 conducts and permits the flow of dc to the driver, Q2. At the same moment it provides forward bias to Q4, which conducts and shorts out the RF energy through C1. Q4 is more effective for this function than are D1 and D2 of Fig. 1. The resultant RF voltage to Q5 is on the order of 100 mV, key down. D1 and D2 of Fig. 2 need not be used unless you are weak of heart. That is, if you fear a failure of Q4, the diodes will afford backup protection of the receiver RF amplifier, Q5.

A grounded-gate FET stage, Q5, serves as an RF amplifier to compensate for the loss through the TR circuit (discussed with regard to Fig. 1). During transmit, the +12 V to Q5 is removed by means of NPN switch Q6. When Q4 is conducting (during transmit), the forward bias to Q6 is removed, thereby turning off Q6. TR switch Q4 also protects the source of Q5 from excessive RF energy when the key is closed.

This circuit is similar to one I have used a number of times. The transistors specified

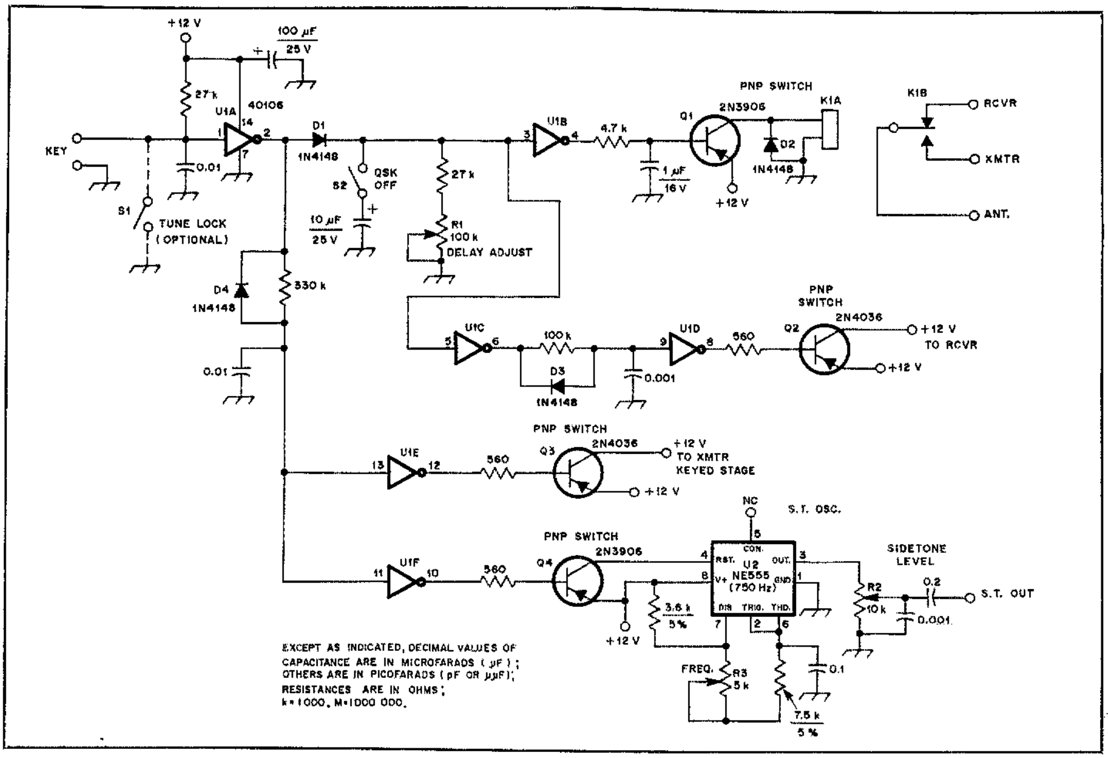


Fig. 3 — Practical circuit for a TR circuit with sidetone generator. Semi-break-in or full QSK is possible with this circuit by means of S2. Capacitors are disc ceramic except those with polarity marked, which are electrolytic or tantalum. Resistors are ¼-W carbon composition. Variable resistors are circuit-board-mount controls. K1 is a reed relay, SPDT, in a 14-pin DIP package, 12 V. S1 and S2 are SPST toggle or slide switches. U1 is an RCA CD40106BE IC. This circuit is not recommended for RF powers in excess of 25 W.

may be replaced by a number of other types, provided they carry similar ratings. The shortcoming of this circuit is that it is suitable for only one band, unless a band-switch is added to change the frequency of the transmitter and RF amplifier Q5. At any rate, it permits full QSK for transmitters up to, say, 5 W. Additional switching transistors can be added to permit receiver muting and sidetone keying during the transmit period. Additional information on solid-state TR circuits can be found in the ARRL book, *Solid State Design for the Radio Amateur.*

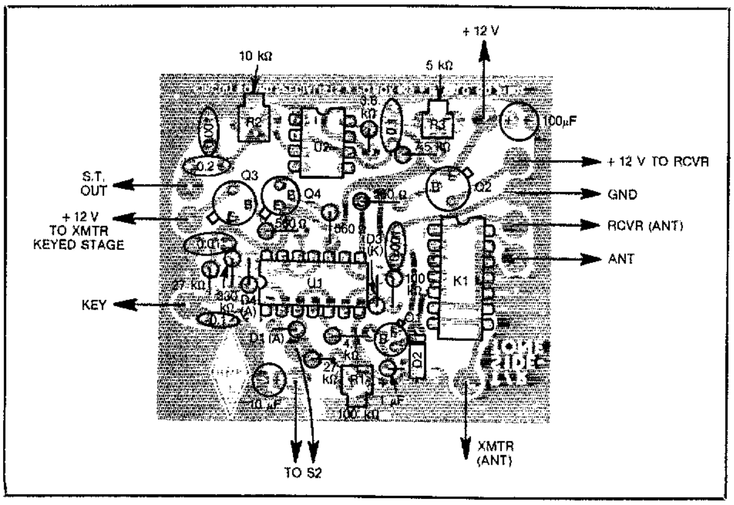


Fig. 4 — Parts-placement guide for the TR module as seen from the component side. Diode anodes and cathodes are shown as (A) and (K), respectively.

A TR Module with Reed Relay

A practical TR circuit is seen in Fig. 3, and it represents our workshop project for this month. The idea was hatched by Bob Shriner (WAØUZO) and me for use in a transceiver that may appear in ARRL literature later on. Bob derived this circuit from a repeater COR (carrier-operated relay) he designed earlier.

All of the U1 gates are inverters. They are contained in an RCA CD40106BE 14-pin DIP IC. This chip is a hex inverter with built-in Schmitt triggers. Bipolar transistors have been added for dc switching of the various lines. An NE555 timer IC serves as the sidetone generator. Output from U2 can be fed to a receiver for monitoring your CW sending.

When S2 is closed, the break-in delay function is activated. The drop-out time for K1 is set by means of R1. When S2 is open, the TR module provides full QSK, consistent with the sending speed the relay can handle. The circuit board is 2¼ by 2¾

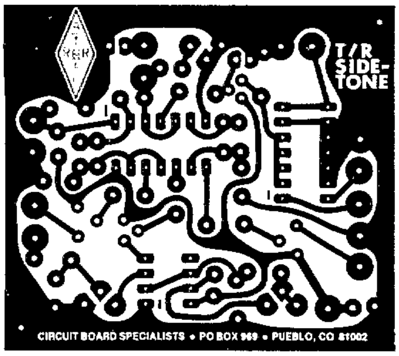


Fig. 5 — Circuit-board etching pattern for the TR module. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil.

inches in size, which makes it easy to tuck it into small equipment cabinets.[2] A parts-placement guide is given in Fig. 4. The circuit-board template is presented in Fig. 5.

In Summary

If there is a bottom line I might offer here, it is that very little added cost and effort are needed to make your low-power transmitter a convenience and joy to operate. If you're into contesting, full break-in will save time for logging and dupe-sheet checking.

If you have not operated a QSK rig before, you may at first be annoyed at hearing noise and QRM each time the key is up. It took me some time to adjust to this distraction. It tended to interrupt my train of thought the first few times I used a QSK CW transceiver. But, there are some advantages to full break-in: For example, other stations can break in without waiting until you stand by. Also, if there is heavy QRM on your operating frequency, you will become aware of it almost immediately! With this knowledge, you may want to ensure that the other station is copying your message before you proceed. If the copy is bad, you can move to a clear frequency and avoid a repeat of your transmission.

Some QRPers may try to convince you that a QRP rig should be ultra simple, with the fewest stages possible, and minus the frills. Balderdash! There is no reason why operating conveniences and advantages should not be included in any transmitter, high-power or not! You may experience a great deal of pride when you complete your transmitter after having included a good break-in circuit (and any other features you deem appropriate). Good luck with your workshop endeavors!

Notes

[1]Circuit boards and parts kits for the QSK module are available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002.
[2]mm = in × 25.4.

New Products

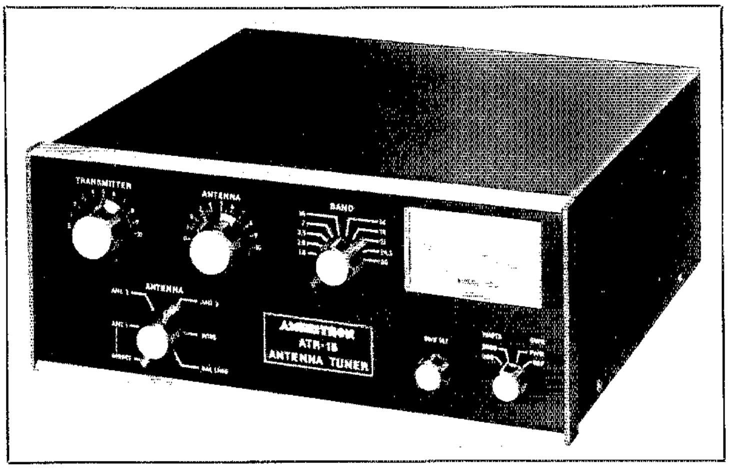
AMERITRON ATR-15 ANTENNA TUNER

☐ The ATR-15 is a T network-type of antenna-matching network that covers the frequency range of 1.8-30 MHz in 10 switch-selected ranges. Sufficient network tuning overlap provides continuous tuning coverage of the ranges. On the 80-10 meter bands, the unit is rated to handle a maximum power input of 1500 W; on 160 meters, 1000 W. The BAND switch is silver-plated and its contacts are rated at 7 A; the air-variable capacitors have 4.5-kV ratings.

An input impedance of 50 ohms is specified for the ATR-15. Output impedances may range from 20 to 800 ohms. For use with balanced feeds, an internal balun is supplied. You may select 1:1 or 4:1 ratios for the balun. Three coaxial, one single-wire and a balanced output are switch selected from the front panel.

A peak-reading wattmeter and an SWR indicator are included. The wattmeter has two ranges: 0-200 and 0-2000 W. Metering functions are still available when the ATR-15 is bypassed. The meter may be illuminated if you supply an external 12-V source to the available rear-panel connector.

Dimensions: 5¼ × 13¼ × 13½ inches (133 × 337 × 343 mm) HWD. Price class: $290. The ATR-15 is available from Ameritron, 9805 Walford Ave., Cleveland, OH 44102. — *Paul K. Pagel, N1FB*



Wire Beam Antennas and the Evolution of the "Double-D"†

Need a compact beam antenna? Try this aerial, developed by one of our neighbors across the pond. Build one for your favorite HF or VHF band.

By Peter Dodd,* G3LDO

During March 1979, I wanted a beam antenna to take further advantage of the sudden improvement in conditions on 28 MHz. It had to be lightweight because of the tall, unguyed mast in use, and a quad was not feasible because of the obstructions encountered when the mast was tilted over. This article describes the development of an antenna that met these requirements.

VHF modeling is a well established technique and is used by many designers as a method of testing HF-antenna design.[1,2] Using this method to design different types of amateur antennas seems to be beneficial and has been used extensively in this project.

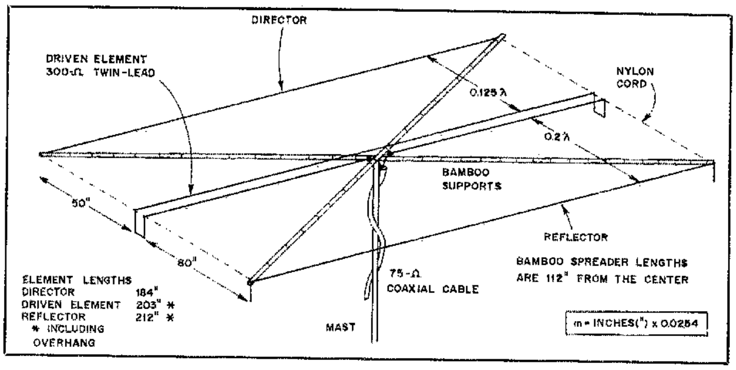


Fig. 1 — Construction details of a 28-MHz wire Yagi.

First Attempt

The first wire Yagi beam was constructed using graphs from *The ARRL Antenna Book* as a guide.[3] The wire elements were laid on a crossed bamboo support as shown in Fig. 1. The support was not quite large enough, and the driven element and the reflector were allowed to dangle over the edge of the support. The elements were pruned for a low SWR and reasonable directivity. The beam proved quite successful, giving an average improvement of two S units when compared with a dipole at the same height.

The only problems encountered were with the dangling ends of the elements, which caused fluctuation in SWR and, presumably, gain, in windy weather. Heavy rain caused an increase in SWR from 1.4:1 to 1.8:1.

Wire Yagi Experiments

To obtain some insight into the performance of the wire Yagi, a VHF model was constructed and measurements performed with test equipment used on previous tests.[4] The elements were pruned for minimum SWR and maximum forward gain, which fortunately occurred at the same element dimensions (Fig. 2). The driven element of the Yagi was not located halfway between the director and the reflector because it would be too close to the metal of the support mast.

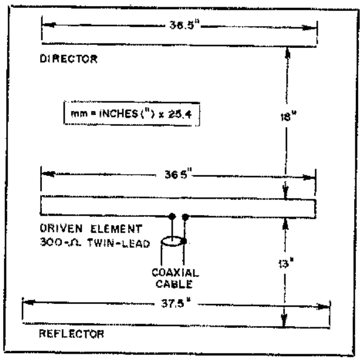


Fig. 2 — Dimensions of a 145-MHz Yagi optimized for maximum gain.

Antenna field strength was compared with a reference dipole whose performance had been optimized. The model performed as well as an all-metal beam at the center of the band, with a comparative directivity pattern shown in Fig. 3.[5]

These models were constructed from no. 18 wire, which gave a length-to-diameter ratio in the range of 10^2:1. When the model is scaled to the HF band, the range will be in the 10^3:1 region. The appropriate factor will have to be applied if the antenna is scaled directly from the VHF model, using the graph in Fig. 4. When an attempt was made to calculate the factors for scaling up, it was obvious something was wrong: On checking the dimensions of the model it was noted that all the elements were nearly 2 inches shorter than normal 144-MHz antennas.[6] The model was rebuilt using insulators at the end of the elements, and the tuning and testing procedure was performed again. The elements finished up slightly longer, but the increase was less than ¼ inch.

When the model was rebuilt a third time, using uncovered wire for the parasitic elements, the measured length returned to "normal" proportions, and it was evident that the insulating material had a loading effect. To determine the loading effect of PVC insulation, a 15-foot length of wire was measured for resonance using a GDO. The measured frequency was 31.1 MHz. This is very close to the theoretical value given by:

$$\ell(\text{ft}) = \frac{468}{f(\text{MHz})} \quad \text{(Eq. 1)}$$

[1]Notes appear on page 23.

†Adapted from an article by the same title in *Radio Communication* (RSGB), June/July 1980, p. 616.

*66 Arundel Rd., Augmering, West Sussex, England

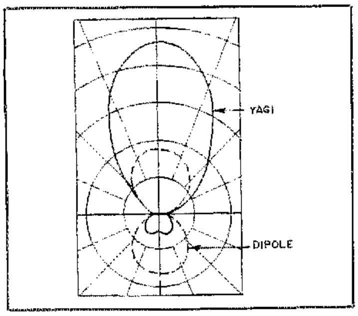


Fig. 3 — Wire Yagi and dipole directive patterns compared.

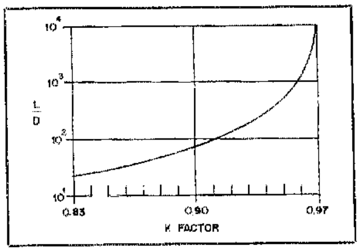


Fig. 4 — Graph of length/diameter correction factors for antenna-element lengths.

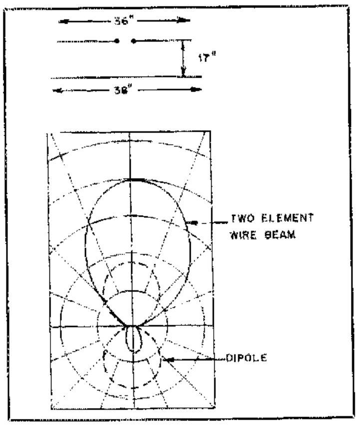


Fig. 5 — Two-element wire beam dimensions are shown at A. At B, the directive pattern is compared with that of a dipole.

Different thicknesses of a 15-ft length of PVC-covered wire were also checked, and were found to vary between 29.9 and 30 MHz. It would seem that the velocity factor of PVC-covered wire is about 0.965.

Two-Element Wire Beam

A two-element model was constructed. The dimensions and radiation pattern are illustrated in Fig. 5. A 28.6-MHz antenna was scaled from this model and fed directly with 75-Ω coaxial cable. The minimum

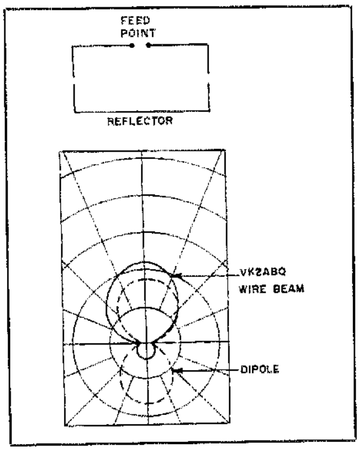


Fig. 6 — The VK2ABQ-antenna configuration is shown at A. At B, the directive pattern of this antenna is compared with that of a dipole.

SWR of 1.5:1 probably results from a driven element center impedance of 50 Ω, so the antenna would perform better if 50-Ω cable were used.

The antenna's performance over a three-month period was comparable to the three-element model previously used. This could be accounted for by the difficulty of adjusting three elements for optimum performance.

Two-Element Wire Beam Derivatives

A number of experiments were performed to investigate methods of making the two-element beam more compact without compromising gain. All theoretical and previously published work on the subject was ignored, and an empirical approach was used in performing the experiments.

A further objective was simplicity. This is necessary because the more complex the array, the more interacting parameters that require adjustment. It is also more difficult to scale and build a complex array. Simplicity means ignoring traps and loading coils, which leaves element bending as the only solution to making a compact antenna. When an element is bent, the resonant frequency appears to rise. A GDO is necessary to determine the exact resonant frequency of a bent element.

What to do with the bent elements is a mechanical problem. One way out of this is to make a VK2ABQ configuration as shown in Fig. 6. This has good directivity, but poor gain compared with the two-element antenna. If the mechanical aspects are ignored and the elements are allowed to droop (like the top half of a quad), the gain returns to that of the two-element antenna (Fig. 5). As this seems to have the same gain as a quad, there appears to be little point

Table 1
Equations for Calculating the Dimensions of an HF-Band Double-D

Dimension	*Length (inches)*†
A and B	$\ell = \frac{3350}{f(MHz)}$
C	$\ell = \frac{2370}{f(MHz)}$
D	$\ell = \frac{700}{f(MHz)}$
E	$\ell = \frac{1336}{f(MHz)}$
Total element length	$\ell = \frac{6022}{f(MHz)}$

†m = inches × 0.0254

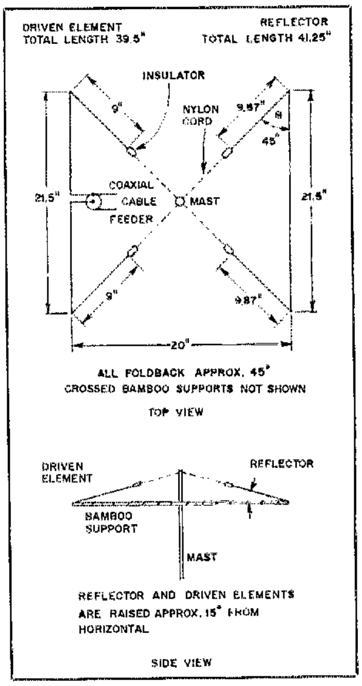


Fig. 7 — A Double-D antenna, showing construction details and dimensions for a 145-MHz model.

in making a full-wavelength loop quad.

The Double-D Configuration

The Double-D was the final result of a number of experiments to overcome the problem of what to do with the folded parts of the elements. A VHF model is shown in Fig. 7, and the HF version in Fig. 8. Dimensions for the HF version can be calculated from the equations given in Table 1. The early HF models were derived by scaling the VHF-model dimensions with the correction factors from the graph in Fig. 4. Results of this approach were disap-

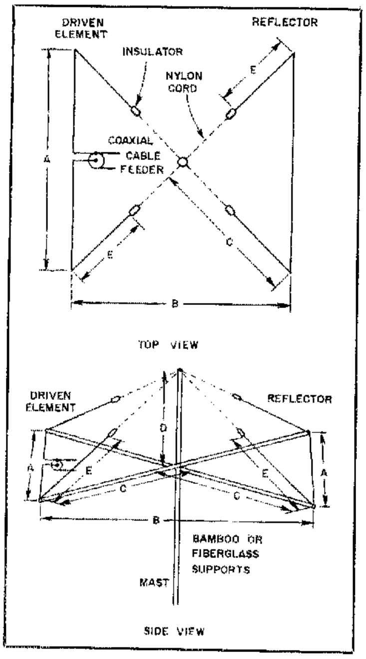


Fig. 8 — General construction details of an HF version of the Double-D. The letters refer to equations given in Table 1 for each section.

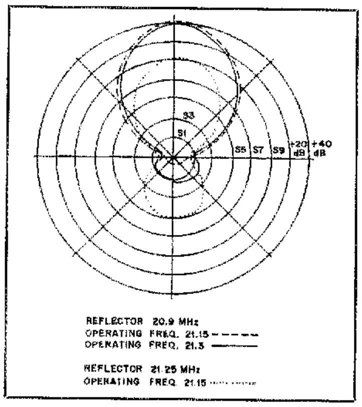


Fig. 9 — Directive-pattern variations, with changes in reflector length and operating frequency for a 21-MHz Double-D.

pointing. The equations given in Table 1 are derived from careful measurements made on a 21-MHz-band model. The most surprising result was that optimum performance occurred when the reflector was approximately the same length as the driven element.

Effects of different reflector lengths relative to the operating frequency are shown in Fig. 9. These diagrams were obtained by placing a modulated signal generator in the apex of the house roof approximately two wavelengths from the

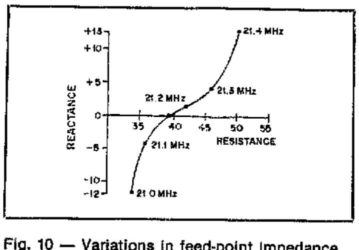


Fig. 10 — Variations in feed-point impedance with frequency changes for a 21-MHz version of the Double-D.

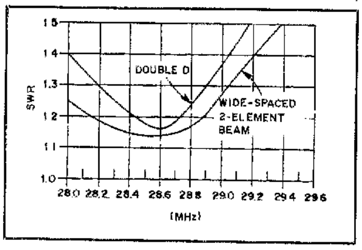


Fig. 11 — Graph comparing the SWR of a Double-D and a wide-spaced, two-element beam antenna.

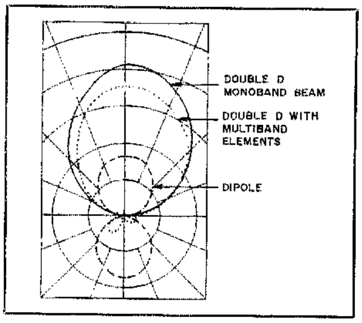


Fig. 12 — Comparative antenna directive patterns for monoband and multiband Double-D beams, along with a dipole for reference.

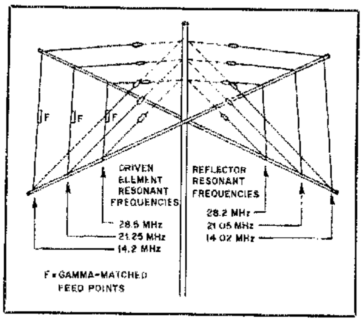


Fig. 13 — Diagram showing a suggested layout for a multiband version of the Double-D.

antenna. Readings were obtained from the transceiver S meter while rotating the antenna, and can only be regarded as comparative.

The radiation-resistance readings of Fig. 10 were obtained via a 3/2-λ section of 75-ohm coaxial cable, using the method described by Doyle Strandlund.[7] Separate noise-bridge measurements and an SWR of 1.5:1 confirm a feed impedance of 35 to 50 ohms. The feed impedance of a driven element without a reflector is about 50 ohms. A previously constructed 28-MHz version had a feed impedance of 50 to 60 ohms, and the VHF model matched very well into 75-ohm coaxial cable. A comparison of SWR for the Double-D and a wide-spaced, two-element beam is shown in Fig. 11.

Experiments with the VHF model showed that it was not detuned by the presence of other-band elements, although the feed impedance and radiation pattern were disturbed (Fig. 12). This seems to suggest that a multiband version is feasible. A possible configuration is shown in Fig. 13.

Construction Details

The spreaders were made by clamping bamboo canes to angle aluminum.[8] Insulators are made from any thin insulating material (such as Plexiglas®). This construction overcomes the problem of not knowing how much wire to allow for attachment to the insulator. Nylon cord rather than wire should be used between the insulator and mast, if detuning effects are to be avoided. The elements are attached to the spreaders with PVC insulating tape.

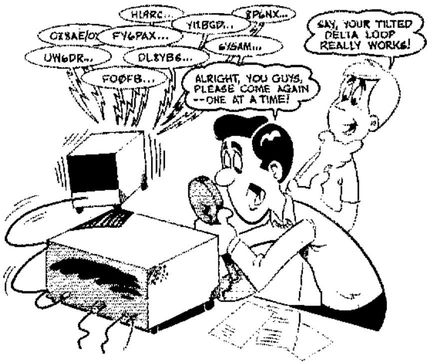
HF-Band Performance

In practice, the performance of the Double-D antenna on 28 MHz appears to be as good as was predicted by the VHF model. The front-to-back ratio, according to local reports, is about four or five S units. When the antenna was used with a QRP 3-W homemade SSB transceiver, QSOs with all continents were made in less than a week of normal operating. Versions of this antenna for 14 and 21 MHz have been tried, and they perform well. An antenna system comprising these two antennas has been mounted on a single support and fed directly with one coaxial feed line. The directional properties of each antenna are unimpaired, but the SWR on the 14-MHz antenna is nearly 2:1.

Notes

[1]P. G. Dodd, "Assessment of HF Aerials Using VHF Aerials" *Radio Communication*, Dec. 1972, p. 809.
[2]M. F. Radford, "Aerial Gain and How It is Measured," *Wireless World*, Oct. 1966.
[3]*The ARRL Antenna Book*, 14th ed. (Newington, CT: American Radio Relay League, 1982), p. 9-5.
[4]See note 1.
[5]The antenna-directivity patterns shown in this article are for comparative purposes only. No scales are shown in the graphs because they do not represent exact measurements.
[6]mm = inches × 25.4; m = feet × 0.3048.
[7]D. Strandlund, W8CGD, "Amateur Measurement of R + jX," *QST*, June 1965, p. 24.
[8]See note 3, p. 9-8.

The Full-Wave Delta Loop at Low Height



You'll be surprised at the results you'll get from a full-wave loop at low heights.

By Doug DeMaw,* W1FB and Lee Aurick,** W1SE

Property size and antenna-support height are ever-present concerns of the urban amateur. Many good antennas are untried because the radio amateur is unable to imagine how a large wire antenna could be squeezed onto a small lot. Certainly, this is typical in the case of full-wave loop antennas. But, there is no rule that dictates using a symmetrical loop. It can be distorted rather severely without spoiling the performance. The same philosophy is appropriate with regard to height above ground and the plane in which the antenna is erected. In most instances, a less-than-optimum full-wave loop will outperform a dipole or inverted-V antenna that is close to the ground in terms of wavelength. It is possible that such a loop will give comparable or better performance than a vertical antenna that is less than 90 degrees (with respect to ground), or one with a substandard ground screen.

We want to discuss the practical considerations of loops that can be supported from low supports on small pieces of property. The results we have obtained are noteworthy with respect to all-around "solid" communications within and outside the USA. Perhaps you will be inspired to unroll some wire and try a loop at your QTH.

Some Loop History

Loops were used first as receiving antennas. While single- and multiturn small loops worked well for receiving, they were not satisfactory for transmitting: They were inefficient in terms of gain, and the feed impedance was generally a fraction of an ohm, making them difficult to match. The losses were significant. But, it was possible to use a compact loop (less than 0.5 wavelength) for receiving in place of a full-size version that could require thousands of feet of conductor. One of us owned a portable broadcast-band receiver in the 1930s. The loop antenna was stored in the lid of the cabinet, and needed to be mounted atop the radio during reception periods! The radio was heavy: It weighed 91 pounds, including the various dry batteries.[1]

Receiving loops continued to be useful for many years in the commercial services, especially for LF and VLF applications. Amateurs also used them (and continue to do so) for improved reception on 160 and 80 meters. The signal-to-noise ratio of receiving loops is markedly better than that of vertical antennas, and they are directional.[2] Many successful 160-meter DXers owe their success to the use of receiving loops with low-noise preamplifiers. Practically, these loops are the next best thing to Beverage antennas.[3]

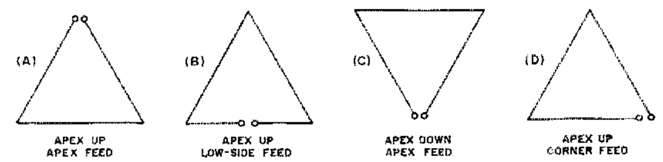
Loop Characteristics

What are some of the advantages of a closed, full-wave loop? Perhaps number 1 on the list is the lack of need for a ground screen. The matter of effective height above ground is still a consideration, but we need not lay a ground-radial system as would be the case with a vertical antenna. Consideration number 2 is that a full-wave loop (depending on the shape) has some gain over a dipole. Number 3 relates to noise factor. A closed loop is a much "quieter" receiving antenna than are most vertical and some horizontal antennas.

To illustrate this point, the 160-meter antenna at W1FB is a 3/8-wavelength inverted-L with twenty 3/8-wave radials. Since this is essentially a vertically polarized antenna, it is noisy (man-made and atmospheric noise). There are times when an S9 signal is unreadable because of the ambient noise being S9 or greater in strength. Upon switching to the 75-meter Delta loop, the same signal will rise above the noise by 1 or 2 S units, while the noise and signal will drop well below S9. For example, the received signal may drop to S6 on the loop, but the noise will decline to S4.

Feed-point selection will permit the choice of vertical or horizontal polarization. Various angles of radiation will result from assorted feed-point selections. The system is rather flexible when we want to maximize close-in or faraway communications (high angle versus low angle). Fig. 1

[1]Notes appear on page 26.



	POLARIZATION	RADIATION ANGLE
A	HORIZONTAL	MODERATELY HIGH
B	HORIZONTAL	HIGH
C	HORIZONTAL	MODERATELY HIGH
D	VERTICAL	LOW

OVERALL LOOP SIZE (FEET) $\approx \frac{1005}{f\,(MHz)}$

FEED IMPEDANCE $\approx 100\ \Omega$

Fig. 1 — Various configurations for a full-wave Delta loop. Radiation angles and polarization are affected by the feed-point placement and location of the apex.

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**Advertising Manager, ARRL

illustrates various configurations that can be used. The arrangement at C is used at W1SE, and the shape at D is being applied at W1FB. Both antennas are cut for 80-meter operation. The bandwidth at resonance is on par with that of a dipole. A Transmatch is used for matching the system to the transmitter in those parts of the band (75 and 80 meters) where the SWR is too high to deal with.

Our loops are not deployed in a vertical plane, owing to the lack of tower height. A 60-foot tower and 50-foot tree support the W1SE antenna. A single 50-foot tower is used at W1FB.[4] Both loops are tilted away from the supports at roughly 45 degrees (Fig. 2). This shows the present W1FB system. The loop is broadside northeast and southwest for maximum radiation in those directions at 80 meters. More on this later.

When these low-to-the-ground experiments began in the summer of 1983, we were joined by Bill Martinek, W8JUY, near Traverse City, Michigan. Bill experimented with various loop configurations so that he and W1FB could make signal comparisons locally and afar. He finally adopted the W1SE format with the apex down (Fig. 1C, with the flat top strung between two 50-foot trees). In order to keep the loop completely vertical (not sloping), he chose a triangle that was not equilateral. The upper side of his triangle is substantially longer than the two downward sides. His signal on 75 meters is consistently 10 to 20 dB stronger than with his inverted V. The point of this discussion is that you need not use an equilateral triangle if it will not fit on your property. Erect whatever you can, then give it a try!

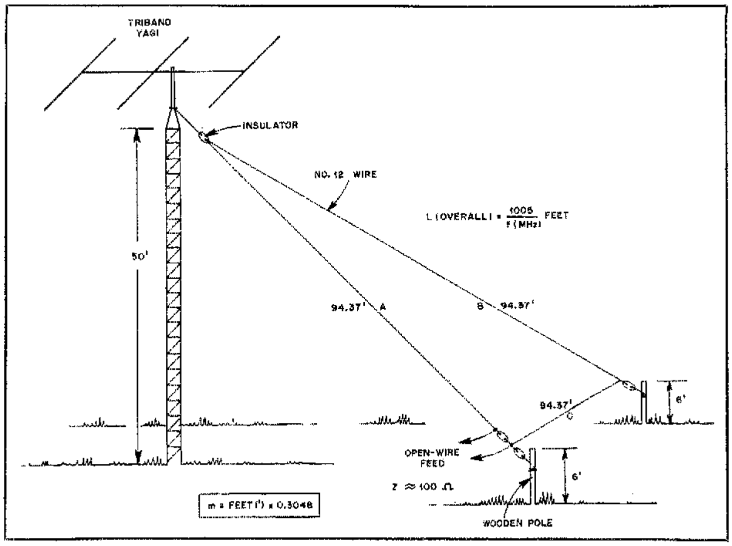


Fig. 2 — A tilted Delta loop for 80 meters is used at W1FB. The tower height is only 50 feet. Homemade open-wire line is used as the feeder to permit multiband use with vertical polarization and a low radiation angle.

Feed Methods

A Q section is used for feeding the W1SE loop. A Q section is a quarter-wavelength line with an impedance that is somewhere between the antenna feed impedance and that of the feed line. Calculation is a simple matter:

$$Z\ (\text{Q section}) = \sqrt{Z1\ Z2}\ \text{ohms} \quad \text{(Eq. 1)}$$

where Z1 is the antenna impedance, and Z2 is the feeder impedance in ohms. In this case, assuming approximately 100 ohms for the antenna feed impedance, we would have $\sqrt{100 \times 50} = 70.7$ ohms for the Q-section impedance. This represents a close match to 52-ohm coaxial cable. The Q-section length (made from RG-59/U) can be determined from L(feet) = 246 V/f(MHz), where V is the velocity factor of the coaxial line for the matching section. (The length should be verified using a dip meter.) For operation at the W1SE-chosen frequency of 3.825 MHz, the calculation calls for a Q section of 42 feet 5 inches (Fig. 3).

Open-wire feed is used at W1FB (Fig. 3B) to permit multiband operation through

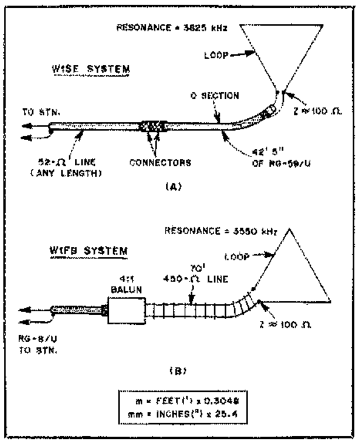


Fig. 3 — At A is the feed method used at W1SE. A coaxial Q section closely matches the 100-ohm feed impedance to a 52-ohm coaxial line. Illustration B shows the W1FB feed arrangement. Open-wire line, a balun transformer and a short length of RG-8/U cable permit multiband use with a Transmatch. Ideally, the open-wire line would continue all the way to the Transmatch, and the balun transformer would be located at the Transmatch.

10 meters. Unfortunately, a short run of RG-8/U was needed to bring the feed line to the ham station — under the driveway. The coaxial cable was buried in the ground for this reason. A homemade 4:1 toroidal balun transformer (two stacked T200-2 Amidon cores and Teflon-insulated no. 14 wire) was enclosed in a weatherproof box and mounted on one of the support poles for the 450-ohm open-wire line. The RG-8/U was run underground from that location (about 25 feet). Ideally, the open-wire line would have been brought into the house, where it would be matched to the station gear with a Transmatch. Fortunately, the SWR at loop resonance is 1.3:1 without the Transmatch in use.

Performance

This is the part of our article that many of you have been waiting to read. Well, the W1FB results have been entirely gratifying. The loop replaced an inverted V with an apex height of 50 feet. This led to a pronounced improvement in all-around communications on 75 and 80 meters out to 500-600 miles. But, the loop proved to be very effective also for DX communications to Europe on 80 meters. The first version was that of Fig. 1B. Although the antenna was outstanding for close-in 75- and 80-meter work, it offered dismal DX performance. The configuration at D of Fig. 1 seems to offer a good compromise in performance for local and DX work. The theoretical launch angle to the horizon at the loop fundamental frequency is 10 degrees, as reported by VE2CV in a letter to W1FB. This assumes that the loop is erected vertically and at a reasonable height above ground.

Harmonic operation of the loop, as depicted in Fig. 1D, is superb. At times it outperforms the trap tribander atop the tower during DX operation to Europe and Africa. The loop shows an average 6-dB signal increase on 20 and 15 meters in the

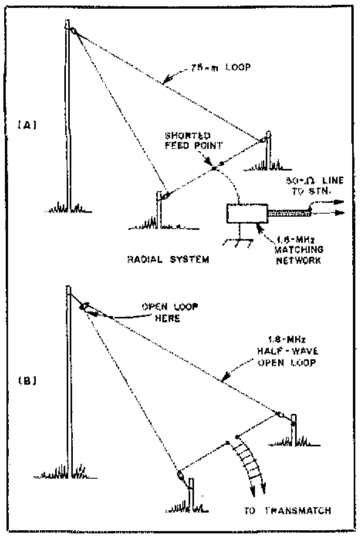


Fig. 4 — Two methods for using a full-wave loop at half frequency. A switching arrangement could be applied at the feed point to change from a closed, full-wave loop to the first configuration seen here. The method at A performs as a ¼-wavelength radiator, but a ground screen is required. Method B is satisfactory as a ½-wavelength open loop for half-frequency use. It requires opening the loop at the electrical point opposite the feed point. A relay could be used for this purpose.

favored direction, owing to the gain and lower radiation angle of the loop. Radiation at the harmonics is in the plane of the loop rather than broadside to it. This makes it ideal for contacts into Africa. It is perhaps the most effective 40-meter DX antenna that has been used at W1FB from northwest lower Michigan. The Transmatch is required on all harmonic frequencies other than 18.111 MHz, where W1FB has been conducting propagation studies with Bill Orr, W6SAI, Prose Walker, W4BW, Bob Haviland, W4MB and Stu Cowan, W2LX, under special experimental/research licenses (KM2XQV). The loop has worked very well on 24.9 MHz as well during these tests. At 18.111 MHz, the SWR is 1.4:1.

The operating results at W1SE also indicate that a tilted loop, close to the ground, functions quite well. With loop resonance at 3825 kHz, the 2:1 SWR points occur at 3734 and 3934 kHz, respectively. This 200-kHz bandwidth spectrum can be shifted up or down the band by lengthening or shortening the loop conductor and Q section accordingly. From the W1SE location in Newington, the loop has delivered impressive performance for local and DX work.

A 40-meter Delta loop was constructed for use at W1SE after noting the fine performance of the 80-meter system. It was cut for resonance at 7016 kHz. This model was erected in a completely vertical format, using 143 feet 3 inches of wire. The Q section is 23 feet 2 inches long. The apex (feed point) is 4 feet above ground. The SWR on 40 meters is less than 2:1 across all of the band. The 80- and 40-meter W1SE loops showed resonance slightly apart from the design frequency, perhaps because of the proximity of the antennas to ground. Resonance on 40 meters was checked as 7050 kHz. Both loops are performing better for local and DX contacts than any of the many antenna types tested at W1SE. We would be even more impressed if we could elevate our Delta loops so the lower portions were a half wavelength or greater above ground.

In Conclusion

There is no rule that dictates the shape of a full-wave loop. The triangular format is convenient for mounting the radiator. If the apex is at the top, only one high support structure is needed. You may have one or more tall trees that can be used as supports. Circular, square or rectangular shapes have been used by many amateurs, and the results were good. Certainly, a loop is an impressive receiving antenna, in terms of noise reduction. In some urban locations, that may be more important than transmitting a "death-ray" signal! There is something to be said about the age-old expression, "If you can't hear 'em, you can't work 'em."

An 80-meter Delta loop can be used on 160 meters by adopting one of two simple methods (Fig. 4). A closed loop does not, however, offer good results when the overall length is a half wavelength. Either of the techniques in Fig. 4 will work, but the method at A requires a ground-radial system for best results.

Notes

[1]kg = lb × 0.454.

[2]D. DeMaw, "Beat the Noise with a Scoop Loop," *QST*, July 1977, and "Maverick Trackdown," *QST*, July 1979.

[3]H. H. Beverage and D. DeMaw, "The Classic Beverage, Revisited," *QST*, Jan. 1982.

[4]m = ft × 0.3048; mm = in × 25.4.

New Products

LAMBDA SEMICONDUCTORS SWITCHING POWER-SUPPLY-CONVERSION KIT

☐ A monolithic switching power-supply-conversion kit is available from Lambda Semiconductors. When operated from 25-V dc, this "Cooler" kit will deliver 5 V at 5 A, with 77% efficiency. Total noise and ripple is limited to 30 mV P-P.

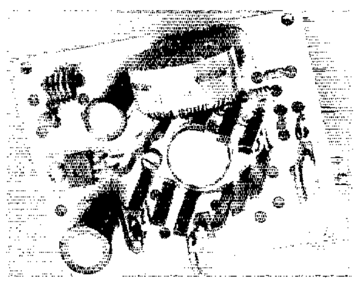
The heart of the design is an LAS 6301 monolithic switching regulator in a hermetically sealed 8-pin TO-3 case. This contains a temperature-compensated voltage reference, sawtooth oscillator with over-current frequency shift, linear trailing-edge pulse width modulator and double-pulse suppression logic, error amplifier and a 5-A, current-limited output transistor.

The kit contains a double-sided, silk-screened PC board, a hefty heat sink for the LAS 6301, and all necessary components and mounting hardware. Assembly is a snap. A pictorial board view and detailed photograph of the assembled unit help to identify parts and determine correct component polarities.

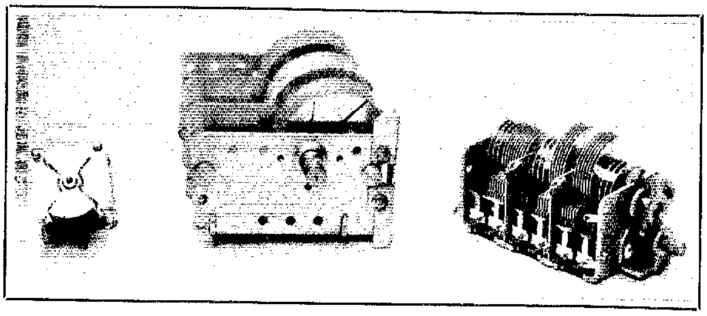
Alignment and testing are straightforward. A VOM is the only required test instrument, although photographs of oscilloscope waveforms are also provided by the manufacturer. These show circuit operation under various loading conditions, and may prove useful for troubleshooting. Assembly and testing take less than 2 hours.

The LAS 6301 is capable of output powers in excess of 100 W, but can be destroyed if the critical 25-V-input requirement is not met. Also, a reasonably constant output load should be maintained. (Sudden open- or short-circuited conditions cause severe electrical stress to switching-type dc-dc converters.) Properly operated, however, this kit provides higher conversion efficiency than linear-type converters, and is smaller and lighter.

Further information on the "Cooler" kit or the LAS 6301 can be obtained from Lambda Semiconductors, 121 International Dr., Corpus Christi, TX 78410, tel. 800-255-9606. — *Greg Bonaguide, WA1VUG*



Shapes of Variable Capacitor Plates



Ever wondered why variable capacitors have such a variety of shapes? Or why that new VFO you built tunes faster at one end of the tuning range? This article describes the development of variable capacitors from a historical viewpoint.

By Joe Rice,* W4RHZ

Every once in a while I read a construction article, or hear some amateurs talking, about a project that indicates to me that they do not understand the fundamentals of variable-capacitor-plate shapes. These hams lament the fact that when they try to calibrate a dial it does not turn out to be linear with respect to frequency. They have not taken into account why there are certain shapes to the rotor and stator plates of any variable capacitor. The shape of these plates control whether the tuning will be linear with respect to frequency, wavelength or capacitance. There is a definite shape to produce each tuning characteristic, and selecting just any junk-box capacitor for a project can lead to unexpected results.

There are three basic types of capacitor-plate shapes, though dozens of different ones have evolved over the years. These are called straight-line capacitance (SLC), straight-line wavelength (SLW) and straight-line frequency (SLF). For some reason, the information about these capacitor-plate shapes has not appeared in any Amateur Radio literature over the years (at least to my knowledge). I have become familiar with the capacitors as they were developed because I serviced radios as early as 1934.

In the early days, a radio dial would be marked from 0 to 100 or 100 to 0 depending on whether the variable capacitor increased capacitance with clockwise or counterclockwise rotation. Around 1928 dials were marked in wavelengths because the broadcasting station licenses used the term "wavelength" to define the station operating point.

By the early 1930s, all American radios had dials marked in frequency. It wasn't until after 1934 that the FCC granted licenses to commercial broadcasters using frequency to define the operating point.

One goal of the design engineers was always to provide a linear tuning rate for each of these different dial-marking methods. It takes a different shape of variable capacitor to provide a linear frequency change per rotation than it does to produce a linear wavelength change.

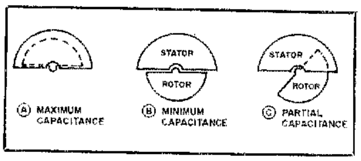


Fig. 1 — The capacitance of an air-dielectric variable capacitor is changed by moving the rotor plates so they mesh more or less with the stator plates. When the plates mesh completely, the capacitance is at a maximum.

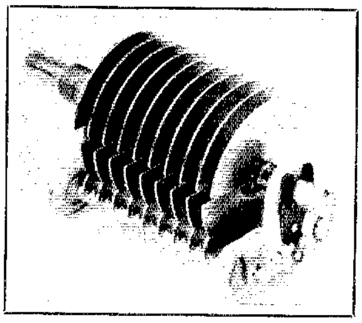


Fig. 2 — A straight-line-capacitance variable capacitor. Notice the semicircular plate shape and the central axis of rotation.

Variable Capacitors

Capacitors having an air dielectric find their greatest use in the tuned RF circuits of radio receivers and transmitters. They are commonly made variable; that is their effective capacitance may be changed while the capacitor is being used in the circuit. These units consist of a group of stationary plates called the *stator,* and a set of rotating plates called the *rotor.* The capacitance of these units is varied by moving the rotor plates so they fit between the stator plates. The more the plates mesh, the greater the capacitance. When they mesh completely, the capacitance is at a maximum (Fig. 1). The size of the plates and the spacing between them determines the maximum capacitance and voltage rating of the capacitor.

Straight-Line-Capacitance Variables

A capacitor with semicircular plates and the axis of rotation in the center will have a linear capacitance curve. This means that as the shaft is rotated the capacitance changes in direct proportion to the amount of rotation. (Equal capacitance changes for equal dial rotations throughout the tuning range of the capacitor.) This type of capacitor is shown in Fig. 2.

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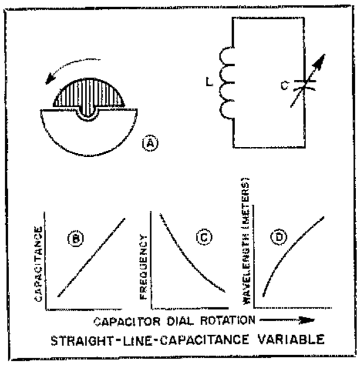
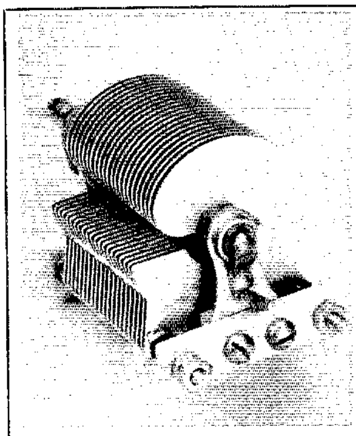


Fig. 3 — The value of a variable capacitor may be made to vary directly with the angle of rotation by using semicircular rotor and stator plates, as shown at A. B shows the relationship between dial rotation angle and capacitance. A graph of frequency versus dial rotation is shown at C, and that for wavelength versus rotation is shown at D.



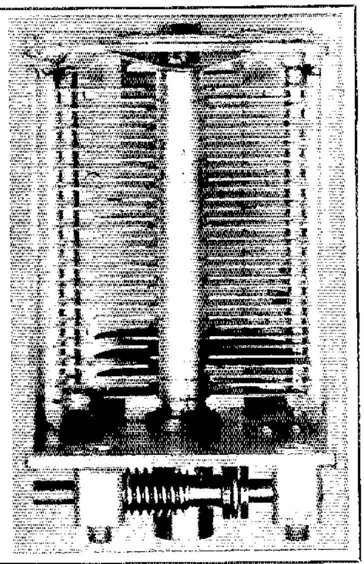


Fig. 4 — A straight-line-wavelength variable capacitor. Notice that the axis of rotation is centered in the stator section, but the leading edge of the rotor plates is tapered.

At first glance, you might think a capacitor that has a linear capacitance change per degree of dial rotation would be ideal. But if you want the frequency or wavelength to change linearly with dial rotation, this capacitor will not do it. We can see this by studying the formula for resonant frequency:

$$f_R = \frac{1}{2\pi\sqrt{LC}} \qquad \text{(Eq. 1)}$$

where

f = frequency in hertz, L = inductance in henrys and C = capacitance in farads. This is a basic formula, even though we normally use smaller values of L and C, such as microhenrys and picofarads.

Since the 2π is a constant and L is also a constant for most tuned circuits, they can be disregarded so we can determine what kind of curve this mathematical formula represents. If we simplify it this way, we can write

$$f_R \propto \frac{1}{\sqrt{C}} \qquad \text{(Eq. 2)}$$

This shows that the frequency will vary as the inverse square root of the capacitance. Since wavelength is the reciprocal of frequency, the wavelength will vary as the square root of the capacitance varies. Fig. 3 shows the tuning curves of the SLC capacitor.

If this type of capacitor is connected in parallel with a fixed tuning coil, the resonant frequency of the circuit can be changed by rotating the capacitor knob. The graph of resonant frequency versus dial settings shown in Fig. 3 indicates that the curve becomes steeper at the smaller-capacitance end of the scale. This means that a given dial rotation near this end produces a much greater change in the frequency of the circuit than an equal rotation at the upper end of the scale.

If a tuning capacitor having semicircular plates is employed in a radio receiver, many stations will be received over a small, crowded portion of the dial. At the high-frequency end of the scale, you must set the capacitor with a high degree of accuracy in order to receive only a single station at a time.

Straight-Line-Wavelength Variables

Many years ago, a type of capacitor having a plate shape such that equal angles of rotation produced equal changes in the *wavelength* of the tuned circuit was used extensively in wavemeters. These were designed to measure the wavelength of a transmitted signal. This type of variable capacitor was convenient for the purpose, since the dial could be calibrated directly in wavelengths and equal divisions would represent equal changes in wavelength. Designers found they could obtain this response by tapering the advancing edge of the rotor on the variable capacitors. Fig. 4 shows such a capacitor.

Straight-line-wavelength variable capacitors were used in receivers in an attempt to reduce the crowding of stations at the low-wavelength end of the tuning range. Fig. 5 shows the capacitance, frequency and wavelength versus shaft rotation curves for this type of capacitor. It might seem that this would be the ideal capacitor for tuning a radio receiver;

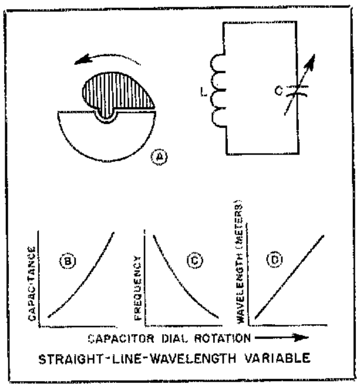


Fig. 5 — The basic shape of the plates for an SLW variable capacitor is shown at A. Graphs of capacitance, frequency and wavelength changes with capacitor rotation are shown at B, C and D, respectively.

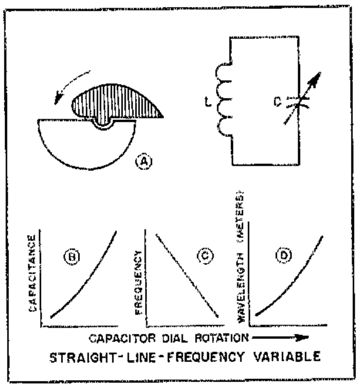


Fig. 6 — By proper shaping of the capacitor plates, as shown at A, we can obtain the capacitance, frequency and wavelength variations with shaft rotation shown at B, C and D, respectively.

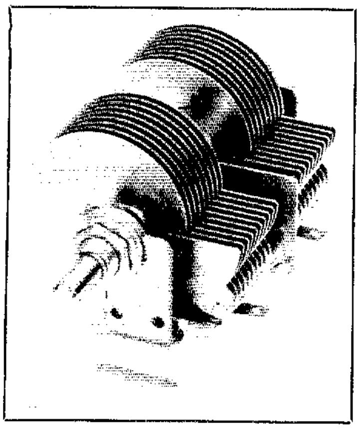


Fig. 7 — A Centraline variable capacitor. The plate shapes are semicircular, but the axis of rotation is off center for both sets of plates.

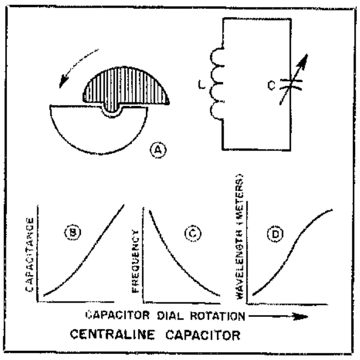


Fig. 8 — Compromise tuning curves can be obtained by varying the shape of the capacitor plates from the three basic types. Here the capacitance, frequency and wavelength changes with dial rotation for a Centraline capacitor are shown.

however, the operating wavelength (or frequency) of broadcast stations is not determined by equal wavelength changes. So even with this type of capacitor, the stations at the low-wavelength (high-frequency) end of the scale are crowded. There is a decided improvement over the SLC capacitor. Stations at the upper wavelengths are also crowded somewhat, but the separation of stations in the middle of the tuning range is just about perfect.

Straight-Line-Frequency Variable Capacitors

The straight-line-frequency variable capacitor is designed with a plate shape that makes the rotation of the dial proportional to the resonant frequency of the tuned circuit in which it is used. Fig. 6 shows the plate shapes for this type of capacitor. SLF capacitors are useful in oscillators and in wavemeters calibrated in frequency, where it is desirable to have equal dial divisions to indicate equal frequency changes.

With this type of capacitor, stations separated by an equal 10 kHz spacing, such as on the standard broadcast band, can be tuned with equal dial rotations from one station to the next. There may still be some problems if the high-power stations in a certain area tend to be concentrated at one end of the dial.

For most Amateur Radio work, we are dealing with relatively small tuning ratios, such as from 7.0 to 7.4 MHz. In this narrow band, it is possible to make your own SLF capacitor by selecting a semicircular-plate capacitor. You can use this capacitor for a bandspread circuit. By setting the coarse-tuning adjustment with another capacitor, you may only need one or two rotor plates on your bandspread capacitor. Draw the general shape of an SLF capacitor plate onto the rotor and stator plates of your capacitor. Then, carefully cut or file the plates to shape. In this manner it is not too difficult to shape a capacitor that will meet your needs.

Other Tuning Curves

Capacitors having rotor- and stator-plate shapes designed to produce certain compromises in their tuning curves have also been developed. Some designers may choose a customized capacitor to obtain desired tuning characteristics. Capacitors designed to produce a composite tuning curve, such as is shown in Figs. 7 and 8 are commonly known as Centraline or Midline capacitors. These desirable tuning characteristics can be obtained by irregular shaping of the rotor plates, the stator plates, or both.

Making Ganged Variables Track Properly

Most radios use a superhetrodyne circuit similar to the one shown in Fig. 9. The first RF stage must tune from 540 to 1600 kHz for a standard broadcast receiver. The local oscillator in this radio must tune from 996 to 2056 kHz to maintain the constant 456-kHz IF. The local oscillator is set to the high-frequency side of the incoming signal, so $C1_B$ must have a smaller plate surface area than $C1_A$. But the two capacitors must track properly so that both tuned circuits change frequency at the same rate. These capacitors are ganged on a common shaft, and the plate shape for the two sections must be designed properly. The one set of plates may be smaller in size, one section may have fewer plates, and many times the plates are constructed with serrated or slotted plates. In that case, individual sections can be bent slightly to provide a customized tuning curve.

Conclusion

It is evident that the effect of all these capacitor-plate shapes is to produce a gradual change in the capacitance as the rotor shaft is turned. The same result can be accomplished with a slow-motion vernier dial constructed to vary its reduction ratio automatically at various points in the rotation. Shaping the plates to produce the desired result is a much simpler and more economical method of producing the different tuning curves. After the proper punching dies have been made, it costs no more to make capacitor plates with special shapes than it does to make semicircular ones.

Today, we can overcome many of the tuning problems described by using varactor diodes. Varying the voltage across these devices causes them to exhibit the characteristics of variable capacitors. By studying the charts of different variable resistors we can produce any desired tuning curve.

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Ghirardi. *A Radio Physics Course*. New York: Technical Publishing Co., 1933.

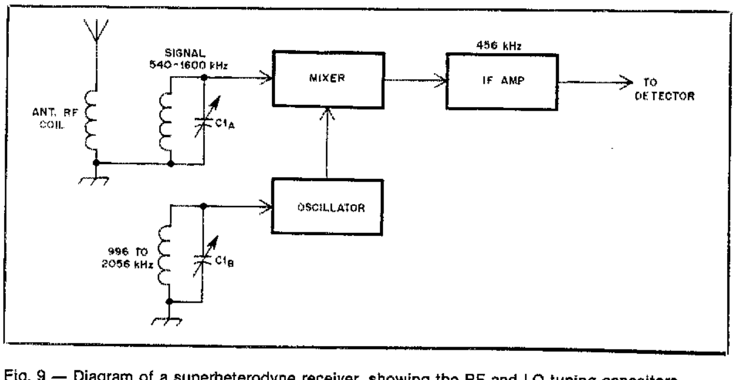
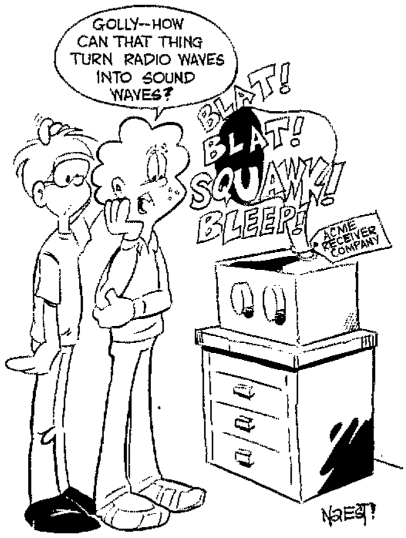


Fig. 9 — Diagram of a superheterodyne receiver, showing the RF and LO tuning capacitors ganged on one shaft. These capacitors must track properly for the radio to work.

• *First Steps In Radio*

How Receivers Work



Part 10: The antennas we discussed last month are of little use until we connect a receiver or transmitter to them. Understanding how receivers operate is a basic part of learning to be a radio amateur. Let's see what makes them tick.

By Doug DeMaw,* W1FB

Some hams lovingly call their receivers "hearing aids." Despite the misnomer being technically incorrect, the term does tell us what a receiver in an amateur station does: It aids us in hearing the other station's message. But, simply hearing signals does not mean we can dicipher them — at least without a good receiver (and some experience and operator skill). After all, many ham bands contain a jumble of radio signals that wax and wane, cover one another up and rattle our earphones or loudspeakers.

A good receiver is not necessarily one that costs $500 or more. Many simple, homemade receivers are capable of good performance if we are willing to do without countless knobs and features that are not essential to separating and copying signals. I think all beginners owe themselves the education and thrill of building at least one receiver. Many a new ham has been known to shout in excitement when that first distant station was pulled in on a homemade receiver. Words can't convey the feeling that goes with that experience. But, in order to pass your Novice exam or build a simple receiver, it is important to understand some fundamentals about receiver circuits.

There are many routes to follow in choosing a station receiver — store bought or made by hand. Let's take a look at some receiver concepts and follow briefly the evolution of the communications receiver.

At the Beginning

You may not be old enough to have heard about the "crystal set." Old-time amateurs still have nostalgic conversations about those early receivers. They consisted of a large coil on a readily available coil form, such as a toilet-tissue roll, oatmeal box or other cylindrical insulating form. The other vital element was a crystal and cat's whisker combination, which was used to detect the incoming signal. Earphones completed the package, apart from the antenna and earth ground. The circuit for such a radio is found in Fig. 1. I would like to suggest that you build one of these broadcast-band receivers for the experience. They are not suitable for reception of amateur signals, since they are incompatible with CW, SSB and FM transmissions.

Remembering that by today's standards these radios are very crude, we must accept limitations in performance. They do not separate strong signals very well, they require long antennas if one is not near a broadcast station, and the sound level in the earphones may be low on the weaker stations. But, the detected signal will be crisp and clear — more so than on some expensive receivers. The fidelity of a crystal set is amazing!

The early-day crystal radios used a galena crystal to detect the signal (Fig. 2), and adjustment of the cat's whisker was a tedious task, indeed. The experimenter had to move the metal whisker about on the surface of the crystal until a "hot spot" was located. The mere act of bumping the table would require readjustment of the whisker, and the really good hot spots were seldom found a second time! The combination crystal and whisker functioned as a modern point-contact diode, which of course has no adjustment (thank goodness!). Tuning capacitors were generally not used. Instead, the insulation along one side of the main coil was bared, and a conductive slider was moved across the exposed turns to change the coil inductance, and hence alter the tuned frequency of the receiver. Other crystal sets had many coil taps that could be selected by means of a tap switch, eliminating the slider mechanism. Enough about the "dark ages." Let's learn what makes so simple a receiver operate before moving to newer things.

The signal is collected by the antenna and flows to ground through coil, L2. The combination of L2 and C1 provides resonance at the desired radio frequency (your favorite station) when you tune C1. The energy flows from the tap on L2, and as it passes through the detector diode it is rectified. This converts the radio energy (RF) from ac to pulsating dc. This dc then flows through the headphones at an audible rate, permitting us to hear the signal.

The process is not unlike that of an ac power supply that uses no filtering after the rectifier. A link winding (L1) is used over L2 when the antenna is long. Were we to

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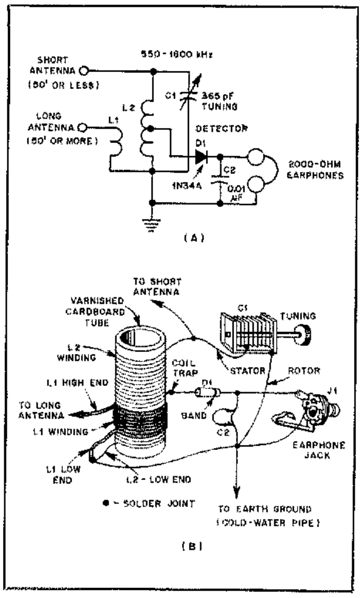

Fig. 1 — The schematic diagram at A shows the simplicity of the first radios, known as crystal sets. C1 was used to tune the stations of the standard AM broadcast band. The pictorial diagram at B illustrates how to connect the component parts of the crystal set. The radio can be built on a piece of wood or Masonite®. C1 is a 365-pF tuning capacitor. The small transistor-radio tuning capacitors are suitable for use at C1 if they have 365 to 400 pF of maximum capacitance. C2 is a disc-ceramic or tubular capacitor. D1 may be a small-signal diode, such as a 1N34A or Schottky diode of the type sold by Radio Shack. J1 is an earphone jack that matches your headphones, which should be 2 kΩ or greater in impedance. Alternatively, you may plug the output of this receiver into the input of your hi-fi amplifier. If so, insert a 0.01-µF capacitor between D1 and J1. L2 can be wound on a toilet-tissue tube. L2 should be about 220 µH in inductance. Use 150 turns of no. 26 enamel wire, close wound. Tap at 50 turns above the ground end. L1 may consist of 40 turns of no. 26 enamel wire, close wound, over the ground end of L2.

connect it directly to the top of L2, it would make the receiver tune very broadly and all of the stations would tend to come in at one setting of C1. In other words, the loading effect of the long antenna would ruin the selectivity of the receiver. The short antenna will not have a serious effect on the performance.

Enter the Vacuum Tube

The vacuum tube came along to help make reception more dramatic and practical. It permitted amplification of the radio signals *before* they were detected. This improved the receiver *sensitivity* immeasurably. Also, tubes could then be used to amplify the audio frequency (AF) after detection. This made loudspeakers practical, and several persons could listen to a radio at the same time. Radios of this class were known as tuned-radio-frequency (TRF) units. They are still used by hi-fi enthusiasts, but contain modern transistors and integrated circuits (IC).

Fig. 3 shows a typical circuit for a TRF radio. Additional RF-amplifier and audio-amplifier stages are used. They greatly increase the level of both the radio-frequency and audio signals, which enables the user to hear weak stations at comfortable volume. A shorter antenna will work reasonably well when the additional amplification is included.

Another popular amateur receiver that came along when vacuum tubes first appeared was known as the *regenerative circuit*. Exceptional sensitivity and selectivity for that era were possible with very few tubes or stages. The detector operated somewhat as an oscillator (just on the brink of oscillation). Part of the oscillator output energy was routed to the input circuit of the state and adjusted to bring the detector to the edge of self-oscillation. This action was called regeneration. It made the detector very sensitive and also aided the selectivity so that stations could be separated easily.

A typical circuit is shown in Fig. 4. The tubes (VT1 and VT2) were, depending on the era, O1As, 6C5s, 6C4s or dual triodes, such as the 6SN7 and 12AT7. Field-effect transistors, such as the MPF102, could be used today for this style of circuit. This kind of radio had a couple of problems. The detector, since it was a self-oscillating stage (like a small transistor), would permit energy to be radiated by the antenna (at the frequency to which the set was tuned). This would cause interference to nearby receivers that were tuned to the same frequency. Also, if the antenna would swing about in the wind, the radio would change frequency, causing the listener to keep his or her hand on the dial to compensate for the slight shift in frequency.

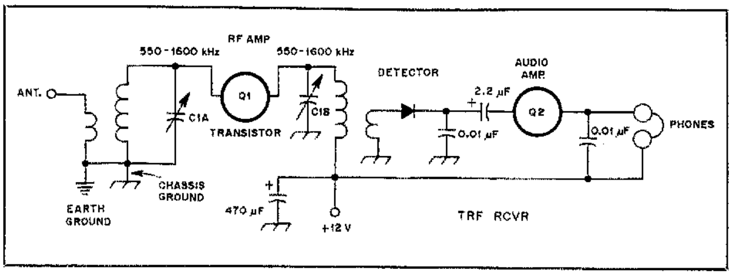

Fig. 3 — Block diagram showing how a TRF radio was set up (see text).

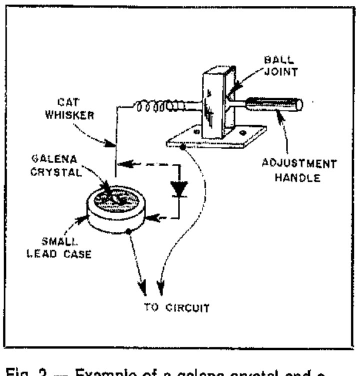

Fig. 2 — Example of a galena crystal and a cat's whisker, as used for detecting signals during the crystal-set era.

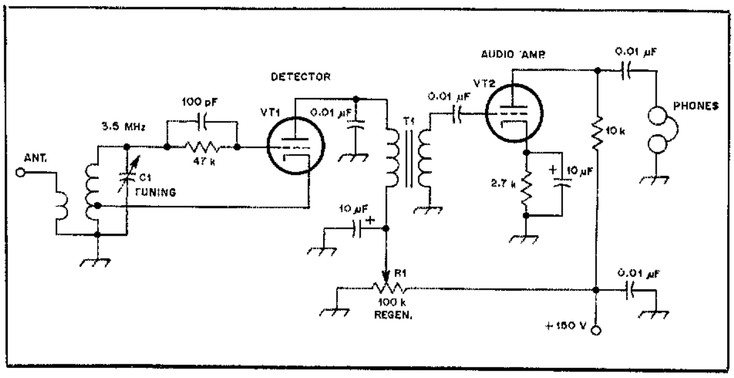

Fig. 4 — A regenerative receiver circuit. C1 was adjusted to the desired listening frequency, and R1 was set so the detector was on the verge of self-oscillation.

Clearly, something better was needed for reliable reception.

The Superheterodyne Receiver

It is not my intent to saturate you with nostalgia, for as the saying goes, "What is past is past." But, the evolution of the radio is important in terms of background if we are to understand how our present-day receivers operate.

About five decades ago, we were blessed by the invention of the superheterodyne receiver concept. Strangely, it has remained the standard circuit ever since, but with improvements and frills. Many of the circuits found in early receivers are common to today's circuits. The primary advancement is the use of semiconductors in place of vacuum tubes. The solid-state parts are, in general, more efficient: They operate cooler and last longer.

What is a superheterodyne radio (often called a "superhet")? The general scheme of the critter is shown in Fig. 5. At the left, we find an RF amplifier. It builds up the signal level from the antenna and helps to separate the stations by way of *selectivity* of the tuned circuits. If the receiver includes an RF gain control (R1), it is used to vary the gain of Q1. Next, the signal, say, 3.7 MHz, is routed to the mixer, Q2. The signal from Q1 is *mixed* with the one from our local oscillator, Q7. The output from the mixer can be either the sum of the two frequencies (9 MHz) or the difference (1.6 MHz). For reasons beyond this discussion we have chosen the higher intermediate frequency (IF). The local oscillator can be thought of as a tunable low-power transmitter that creates a CW carrier. In reality, it is not a signal unless intelligence is contained on it — at least by definition. If we were to be precise in describing the local-oscillator output energy, we would call it RF voltage.

Now that we have mixed our two frequencies in Q2, we have a 9-MHz IF. To ensure that this energy is pure and free of other frequencies (including the difference IF of 1.6 MHz), we have included FL1. This filter contains four or more quartz crystals that permit the passage of the desired frequency (9 MHz) while greatly attenuating or rejecting frequencies above and below 9 MHz. Depending on the design goals for the filter, it may pass only a narrow band of CW frequencies (250 Hz), or it may be wide enough to permit SSB or AM signals to pass (2 to 3 kHz). An FM filter will pass a much wider band of frequencies (15 kHz for many modern amateur FM transceivers).

There is always some signal loss (insertion loss) through a filter, for in order for it to be a filter it must have that characteristic. The typical loss through a filter will range from 5 to 10 decibels (dB). If the station to which we are listening is running 100 W of power, a 10-dB filter loss would be equivalent to that station reducing its power to only 10 W. Therefore, we must build up the IF signal by means of IF amplifiers (Q3 and Q4).

Our ability to separate the signals has come through the selectivity of the RF amplifier stage and the filter, FL1. Therefore, the IF amplifiers do not need to have a high degree of selectivity, since the job has already been done. In fact, if we chose to use no tuned circuits between the IF amplifiers, we could design our circuit that way. Most IF tuned circuits are used to provide an impedance match between stages, rather than to increase the selectivity.

Now that we have increased the signal level from FL1, we are ready to detect or *demodulate* it. This brings us to the product detector, Q5, of Fig. 5. Generally speaking, it functions as does the mixer, Q2. The major difference is that the IF of this stage is at audio frequency rather than at RF. Therefore, the local oscillator (BFO Q6) is offset in frequency by an audio amount. For CW reception it is usually between 700 and 1000 Hz, depending on the designer's philosophy. Thus, our BFO crystal can be 700 Hz above or below the 9-MHz IF for CW reception. The offset is about 1.5 kHz for SSB reception. No BFO is needed for AM or FM reception, but special detectors are required. A product detector can be used for AM reception, however, if the AM signal is tuned in as one might tune in an SSB signal (tuned until no whistle from the AM carrier is heard). A wider IF filter is desirable for AM reception so that better fidelity will result.

Now that we have detected the signal, all that remains is to build it up (at audio frequency) until it is strong enough to operate headphones or a speaker. An audio-gain control (R3) is included for setting the level for comfortable listening. Some receivers use an IF-gain control (R2) for varying the IF gain.

The circuit of Fig. 5 is that of a single-conversion superheterodyne receiver. Double- and triple-conversion receivers are common as well. They offer some advan-

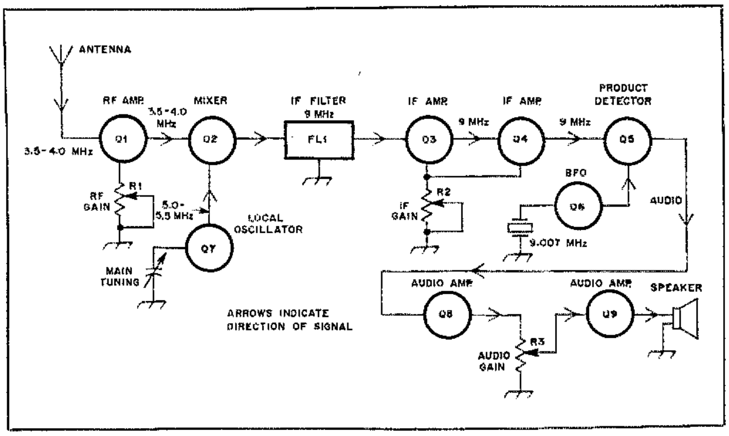

Fig. 5 — Block diagram that shows the lineup of a single-conversion superheterodyne receiver. The function of the stages is treated in the text.

Glossary

AGC — automatic gain control. An electronic circuit that lowers the receiver gain as the incoming signal becomes stronger.

BFO — beat-frequency oscillator. It generates an RF voltage that is beat or mixed with the IF signal to produce an audible voltage or signal.

decibel — (dB) — a unit of relative power measurement.

demodulate — the process of removing signal energy from an RF or IF signal and changing it to an audio frequency.

filter — a circuit used to pass desired frequencies while rejecting unwanted frequencies.

IF — intermediate frequency, as related to superheterodyne circuits.

local oscillator — generally considered the circuit in a radio receiver or transmitter that controls the operating frequency. It is adjustable by the operator from the front panel of the equipment.

regeneration — a state that exists when the output energy from a stage (amplifier) is routed to the stage input, intentionally or otherwise. It causes the stage to self-oscillate.

selectivity — the ability of a circuit to select the desired frequency while rejecting other frequencies.

sensitivity — the ability of a receiver to extract weak signals from the internal noise of a receiver to make them discernible or readable. Based on the ratio of the inherent receiver noise to the level of a received signal.

S meter — a panel instrument on a receiver that provides visual observation of received signal levels on a relative basis.

TRF radio — a nonsuperheterodyne receiver that has tuned RF amplifiers, a detector and audio amplifiers.

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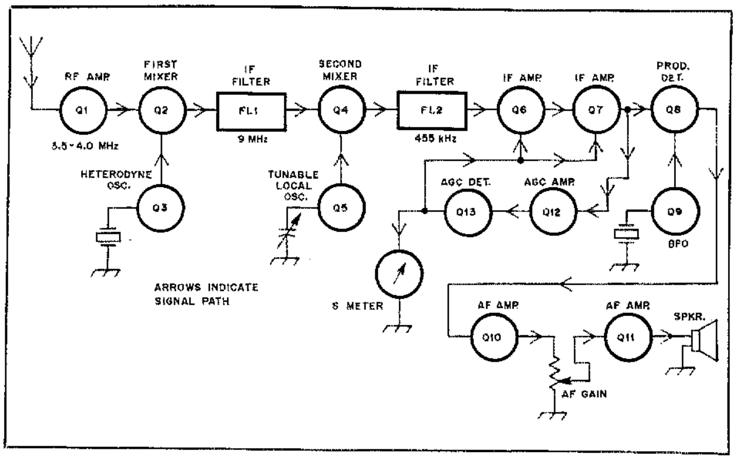

Fig. 6 — Block diagram of a double-conversion superheterodyne receiver. The function of the circuit, plus the addition of AGC and an S meter, are discussed in the text.

tages that we won't get involved with here, but Fig. 6 shows how they differ from a single-conversion receiver.

Practically, we have two receivers in series. There are two local oscillators (Q3 and Q5), two mixers (Q2 and Q4) and two IF filters (FL1 and FL2). What we are doing is converting the signal frequency from our antenna to 9 MHz, then converting it again to a lower frequency (455 kHz). The lower frequency is known as the second IF, while the 9-MHz frequency is the first IF. A triple-conversion receiver would have three local oscillators, three mixers and perhaps another IF filter. Fig. 6 shows the most fundamental method for realizing a double-conversion receiver. Modern receivers are substantially more esoteric than the example we have examined.

AGC and S Meters

Today's radios have automatic gain control (AGC) and relative signal-strength indicators (S meters). The technique for obtaining these features can be seen in simple form by returning to Fig. 6. Some IF energy is sampled at the output of the last IF amplifier, routed to an AGC amplifier (just another IF amplifier, actually), which is Q12 in our circuit, then it is rectified at Q13. The resultant dc voltage is sent back to the two IF amplifiers (Q6, Q7) for the purpose of changing their gain as the incoming signal from the antenna changes in amplitude.

The stronger the received signal, the greater the AGC voltage, and hence the lower the IF amplifier gain. This helps to keep the signal at the speaker from changing in volume, even though the received signal may vary considerably in strength. Some of the rectified AGC voltage may be used to operate an S meter, which gives us a visual indication of the relative strength of the received signal.

Today's receivers feature many additional frills, such as digital frequency readout, passband tuning, notch filters (for removing interference) fast and slow AGC response and frequency memories. But, the basic circuit is of the type shown in Figs. 5 and 6.

What Have We Learned?

If we are to summarize this lesson about receivers, we can say that the superheterodyne receiver is the common circuit today. It grew from the simple crystal detector of yesterday through a long period of evolution that brought performance landmarks step by step. A knowledge of how our receivers function is important if we are to pass the FCC license examination. It is vital also if we are to service our equipment or experience the thrill of designing and building a homemade receiver. If you wish to learn more about receivers I suggest you obtain a copy of *Understanding Amateur Radio.* There is an additional wealth of information on this subject in *The Radio Amateur's Handbook,* also available from the ARRL.

Strays

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☐ Wonder what you've been missing by not subscribing to *QEX,* the ARRL newsletter for experimenters? Among the features in the September issue were:

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- "Tips For Using Ribbon Cable," a reprint from the journal of the South African Radio League
- A review of a new book, *Land Mobile Communications Engineering*

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Next Month in QST

Among the fall collection of technical articles in November *QST* will be

- one showing how to build a waveform shaper that will make your CW signal the envy of your friends.
- one that will help with that all-too-common complaint — "where do I find parts for construction projects?"
- one that explains, in easy-to-understand language, how transmitters work — another in the First Steps in Radio series.

Happenings will bring you up to date on the brewing 220-MHz battle, and How's DX? will explore the rarefied world occupied by members of the DXCC Honor Roll.

Whatever your ham radio interests may be, you'll find lots of fascinating reading in November *QST.*

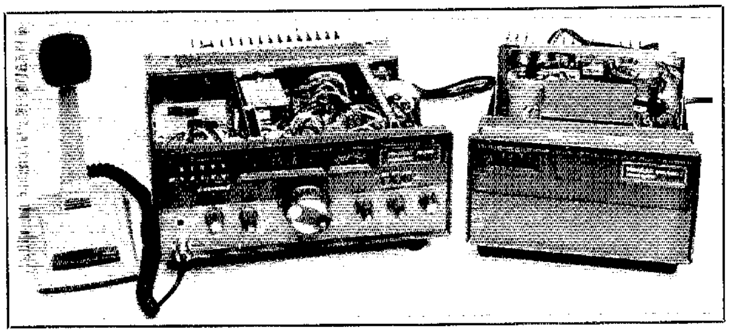
Product Review

Conducted By Paul K. Pagel,* N1FB

Heath HW-5400 HF Transceiver

My excitement ran high that Christmas of 1967. I had recently passed my Novice exam, and my parents had bought me a Knight-Kit T-60 crystal-controlled AM and CW transmitter. I spent most of my Christmas vacation assembling the kit. I got a lot of soldering experience, I learned how the pieces of my transmitter fit together (so that later, when repairs were necessary, I was willing to dive right in and locate the faulty components), and my parents saved about 40% of the cost of an assembled, comparable rig.

There was a lot of excitement around my house for the Christmas of 1983, too. This time most of the excitement was generated by my three harmonics, but I also had a new radio kit to build. I had been asked to complete the construction and review the Heath HW-5400 transceiver. This rig has many features I wish I could add to my Tempo 2020, so I quickly accepted the challenge.



A former ARRL Hq. staffer had started the project in April 1983. Three boxes were returned to Headquarters by mid-December: one for the radio, one for the power supply, and the heaviest and smallest one of all for the power transformer. The review unit also included the optional SSB filter unit, the push-button frequency-entry keypad and the HDP-242 desk microphone.

Luckily, the original reviewer had followed the most important instruction of all when he began the project: *Do not remove any bag or parts from the shipping carton until it is called for in the instructions.* There are 14 circuit boards in this kit, and the components for each one are found in one or two small paper bags. Heath has even included a map to show you where each bag of components is located in the carton.

My first step was to transfer all of the corrections on the enclosed addendum into the construction manual (a large, three-ring notebook). One point of confusion here was that I had two sets of addendum sheets, and at one or two points they made different changes to the same assembly step! Which change is correct? A call to Heath helped me determine which sheet to follow in those cases.

Most of the small hook-up wires are supplied in a 30-inch length of 25-conductor ribbon cable.[1] One of the first steps is to cut this cable into various length strands and multi-conductor cables. I found that it is very easy to ruin this wire. If you try to cut the full length of the cable with a knife, you are sure to nick the insulation in many places. When you perform this operation, do not attempt to cut all the way along the length of cable. Use a very sharp knife to start the cut, then zip the wires apart by hand. I called Heath and explained why I needed a new length of ribbon cable and a few other parts that had not survived the change in hands for the project. In the meantime, I had all of this work to do, and a deadline for the review that was only about a month away.

That was when I decided to start on a fresh project — the power supply. Actually, I recommend that anyone building this kit start with the power supply. It is a small project that goes together quickly. My total assembly time, including circuit checkout and a minor modification (more on this later), was just over 13 hours. Besides, when you have completed the '5400 assembly, you will want to power it up right away, so it helps to have a power supply ready and waiting.

The HWA-5400-1 complements the transceiver nicely. It supplies 13.8 V at up to 20 A to power the rig. It also supplies a 13.8-V memory keep-alive voltage so the transceiver will remember the frequencies stored in memory and the last operating frequency even when the power is switched off. The main supply transformer is activated with the HW-5400 power ON/OFF switch. It features a remote voltage-sensing circuit for the regulator transistors. This circuit monitors the voltage being supplied at the rig, and feeds control information back to the transistors. The power supply includes a remote speaker, and it even has a digital-display clock! What more could you ask for?

A small transformer is used to power the clock and memory keep-alive circuit. This transformer is on as long as the supply is plugged in. The main power-transformer primary circuit is closed by means of a relay that is activated when the power switch is turned on.

At construction time, you must decide if you will use the supply on 117- or 234-V mains. There are separate steps in the procedure to guide you through the installation of the proper fuses and jumpers. I decided to wire my supply for use on 117-V circuits. Even though a 234-V supply is more efficient, it is easier to find a 117-V outlet to plug into! Heath provides a standard 117-V, 15-A plug on the line cord. If you decide to go with 234-V operation, you are instructed to cut the plug off the cord and install the proper one.

When you wire the clock circuit board, you must select 50- or 60-Hz operation, depending on the line frequency you have, and you also select 12- or 24-hour display format. I chose the 24-hour format.

The only problem I had while constructing the power supply occurred when I tinned a couple of the larger-diameter wires, as instructed. They would not fit through the circuit-board holes provided. Then I had to clip off the tinned end and use a clean end to solder the wire to the PC board. The wire lengths provided seem adequate in most cases, so making the wire ½-inch shorter did not present any problems. As expected, the instruction manual is detailed and well written.

After completing the power supply and checking the operation, I was shocked to realize that this beautiful station clock provided no way to synchronize the seconds with a WWV time signal! The only way to come close is to plug the power cord in right on the BEEP. I found I could get the clock within 5 or 6 seconds of the correct time this way. But wait! If the only radio I will have in my station to receive WWV signals is the '5400, and it needs the power supply to operate, how can I listen for the tone to plug my supply in? It just won't work! What a disappointment.

Inspection of the clock chip revealed it to be an MM53113N IC. Checking the specifications on this chip in the back of the instruction book proved that it is indeed a full-featured clock chip, capable of alarm functions and much more. Grounding pin 32 (by means of a switch) displays a single minute digit, along with seconds. Now the fast-set switch holds the seconds and the slow-set switch resets them to zero. It didn't take me more than a few minutes to drill a small hole on the bottom of the cabinet, near the front, and to epoxy a small toggle switch to the main chassis

[1] mm = in × 25.4; m = ft × 0.3048.

*Assistant Technical Editor

so the handle just fits through the hole. One word of caution here. Since Heath's warranty does not cover modified kits, I would recommend you build the radio and power supply without modification. After you are sure everything is operating as it should be, then go back and start making your modifications. You might even want to wait for the warranty to expire.

To set the clock, you must use some device to reach through a small hole in the front panel. A plastic tube about 1 inch long, which is a molded part of the front panel, guides the tool to the contact switch. Heath suggests use of a toothpick, but it did not work for me. A flat toothpick flares too much to fit all the way through the tube, and when I shaved one down so it would fit, it lacked the necessary strength. The perfect instrument proved to be a paper clip, with one end straightened. The remaining bends in the clip form a nice handle, the metal is thin enough to fit through the tube, and it has the required strength.

On with the Construction

The replacement parts arrived before I had completed assembling the power supply, so I was ready to get on with the radio by now! After I got into "virgin territory," things went smoothly with the kit assembly. The 259-page assembly manual is complete and detailed (so what else is new?). The instructions for each circuit board direct you the parts-box map to locate the correct bag and circuit board. Then you do a quick parts inventory for that section, and begin stuffing the board. Some of the boards are rather densely packed, but not so much that you can't work on them. The parts are installed in an orderly fashion, usually starting with the small resistors, diodes and capacitors, and then on to the larger components, such as electrolytic capacitors. You are instructed to move around the board, adding components section by section. A pair of small needle-nose pliers and a close-cut dikes are handy tools for this project.

Chuck Hutchinson, K8CH, showed me a nifty trick for installing the components. Even though the instructions are to mount the small components flush against the PC board, Chuck likes to mount them a little above it. His reasoning is that when a component burns or explodes, it is not as likely to char the PC-board markings. This can be important when you try to identify the part number and value to replace the damaged part. A piece of scrap PC-board material can be cut to a width about equal to the length of a ¼-W resistor body, and several inches long. This "spacer" can be held under the component being installed and the leads flared slightly to hold it in place while you solder them to the board. This provides a uniform spacing for the components above the board, and makes a very professional-looking job when the circuit board is done.

After each circuit board is completed, you are directed to make a series of visual checks on your work. It is much easier to double-check each component location and orientation at this time than after the boards are installed in the chassis! Also be sure to check every solder connection for cold-soldered joints or excess lead lengths that could short against another circuit trace or the chassis.

Most of the check-out procedures include a few resistance measurements. Heath recommends use of a high-input-impedance VOM. My meter has an input impedance of 20 kΩ/V. Heath also cautions that the negative ohmmeter lead must be connected to the ground foil unless you are told to do otherwise. Most hams will be aware that the red (+) lead on most VOMs is negative in the ohmmeter positions. Be sure to check your meter with a second voltmeter. You will get erroneous results on many of the measurements if the leads are reverse connected. My VOM gave results that did not agree with the expected measurements in a number of instances. I tried a VTVM from the ARRL lab to double-check those results. In most cases, the results were in the range of acceptable values when I used the VTVM. I would recommend the use of an FETVM or VTVM if at all possible.

Even with the VTVM, some measurements indicated problems with certain components. On the audio board, I found one troublesome measurement that indicated a faulty capacitor. When I tried to locate that part on the board, I discovered that it had been replaced with a jumper wire in the installation step! This illustrates the fact that a kit as complex as an HF transceiver is a dynamic project. The engineers at Heath are constantly working to improve the radio, but the documentation may not always keep up with the changes. (Of course, the same is also true for fully assembled rigs, but you would not be as aware of the changes. Many of the schematic diagrams supplied with those rigs do not match the actual circuitry inside the box.) There are markings and mounting holes on several boards for components no longer used. I used a felt-tip pen to mark off those areas, just so I wouldn't wonder if I had left out an important component later on.

There were a few other minor snags in doing these resistance checks. On the HI and LOW VCO boards you are instructed to check for shorts on the feedthrough capacitors, using your ohmmeter set to the × 1-kΩ range. The +12 V leads on both these boards have a 600-Ω resistor to ground on this capacitor, which looks like a dead short on the recommended range. It can be rather confusing until you start tracing the circuit wiring and schematic diagram.

On the controller circuit board, I installed a set of wires in holes I, G and O. A few steps later, I was again instructed to solder wires to holes I, G and O. That was when I discovered two sets of holes on the board with the same labels! Of course, I had seen the wrong set first. So I had to unsolder the wires and move them. Why label two sets of holes with the same letters on one board? Beats me!

Well, I finally had all of the boards built after spending about 70 hours working on the radio. Approximately another 10 hours of putting the circuit boards on the chassis, and I was ready to begin the alignment procedure. It has been very time-consuming, but fun. I am intimately familiar with every piece of my radio, and how it all fits together.

Then came the snag! While adjusting the USB oscillator on the BFO board, I found that I could not set the frequency to 8.83145 MHz. In fact, I could not adjust it higher than 8.827 MHz. Heath suggests a couple of diodes, an inductor or a transistor as possible culprits, so I lifted them off the board to check. All seemed normal. After many hours searching the circuit board for a bad solder joint and studying the schematic diagram for other possibilities, I came to realize that there was plenty of tuning adjustment, and everything was working. The trimmer capacitor was set to minimum value when the oscillator was tuned to the highest frequency possible. I just couldn't tune high enough — too much capacitance in the circuit! Then I noticed that the manual originally called for a 7.7-pF NP0 capacitor in the circuit, but that value had been changed to a 27-pF NP0 unit. I tried replacing the capacitor with the original one supplied with the kit. Now the frequency was too high, and would not adjust low enough! Well, try some values in between. After several hours of changing capacitors and checking the resonant frequency, I managed to hit on a combination that worked. Now I was able to adjust the frequency properly.

I spent some time on the phone with the Heath technicians on this one! They suggested a faulty capacitor or an incorrect inductor in the circuit. I received prompt, courteous service every time I called (even without identifying myself as an ARRL employee!), and within a few days I had some replacement parts to install. These did not seem to cure my problem, so I put my previous capacitor combination back into the circuit.

Toward the end of the alignment procedure, I hit another snag. To adjust the HI VCO circuit on 12 meters, you are instructed how to set the controls, and then directed to adjust a trimmer capacitor for a reading of +4 V at a test point. I found that by changing the trimmer setting, I could set the voltage to +1.6 or +11, but nothing in between! More calls to Heath. This is a complicated piece of equipment, and troubleshooting over the telephone is next to impossible, but the hams on the technical assistance line really know their stuff. The two or three gentlemen I talked to always had some suggestions or ideas about what could be causing my problems. We finally decided that I had a defective band-switch wafer, causing improper voltages to be switched to the HI VCO board. The band-switch wafers mount on the RF circuit board. A plastic shaft goes through three wafers on this PC board, and connects the front-panel knob and a wafer mounted to it with the sections mounted on the filter circuit board. There seems to be quite a bit of play in this system, and if one of the plastic-capsule wafers is a bit loose (as one of mine was), I don't see any way the whole thing can track properly. I replaced the band-switch wafers on the RF board and a few other components suggested by the Heath technicians. The problem just would not go away!

Heath Solves the Problem

I concluded that I was spending an unreasonable amount of time trying to solve this problem, while Heath could probably swap one or two circuit boards to locate the faulty one, and then it would be much easier to pinpoint the problem component. So I completed the final assembly without doing the rest of the alignment. Then I packed the radio up and shipped it back to Heath, along with a detailed letter explaining the problem I was having. The unit was sent out in early April, but by early June I still had not even received an acknowledgment that it had arrived at the service center! After several phone calls to the Advertising Manager, we did locate the radio. It appears to have had been repaired since early May, but it had been misplaced. I was promised that it would be returned that day, and a week later I had my '5400. I believe this is a case in which a regular customer would have received faster service. Apparently, there was some confusion about how to handle a repair for the ARRL!

Heath returned a copy of the service technician's report and all of the components they replaced. One small coil on the HI VCO board was open. That apparently caused all of

Table 1
Heath HW-5400 HF Transceiver, Serial No. 01-47504

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency Coverage: 3.450-4.050 MHz, 6.950-7.350 MHz, 10.000-10.200 MHz, 13.950-14.400 MHz, 18.018-18.218 MHz, 20.950-21.500 MHz, 24.840-25.040 MHz, 28.000-29.750 MHz.	As specified.
Modes of operation: CW-W, CW-N, LSB, USB.	As specified.
Tuning rate: 50 Hz/step, 1.25 kHz/turn 1 kHz/step, 25 kHz/turn with touch sensor.	As specified. Backlash nil.
Frequency display: 7 digit, vacuum-fluorescent green.	5/16-inch-high digits.
S-meter sensitivity (μV for S9): Not specified.	80 m: 46; 40 m: 43; 30 m: 85; 20 m: 65; 17 m: 82; 15 m: 160; 12 m: 180; 10 m: 94
Transmitter power input: 100 W minimum, except 80 W minimum on 10 m.	117 W maximum on 12 m, 94 W minimum on 10 m.
Harmonic suppression: −50 dB min., referenced to 100-W output.	−58 dB worst case, except −48 dB on 17 m.
Spurious suppression: −60 dB min., referenced to 100-W output.	See Fig. 1.
Third-order IMD: −30 dB min., referenced to 100-W output.	As specified.
Receiver sensitivity: less than 0.35 μV for 10 dB S+N/N.	Receiver dynamics measured with narrow (250-Hz) CW filter:

	80 m	*20 m*
Noise floor (MDS) dBm:	−135	−133
Blocking DR (dB):	110	112
Two-tone, 3rd-order IMD DR (dB):	82	90
Third-order intercept (dBm):	−12	+2

Receiver audio output at 10% THD: 2 W min. into 4 Ω.	2.2 W.
IF shift tuning: ±600 Hz (receive only).	Not measured.
RIT tuning: ±350 Hz.	+400, −700 Hz.
Operating temperature range: 0 to 40° C.	Not measured.
Size (HWD): 5 × 11½ × 14 in (12.7 × 29.2 × 35.6 cm).	5½ × 11½ × 15 in (14 × 29.2 × 38.1 cm), with raised front feet and clearance for heat sink and knobs.
Weight: 24 lb (10.9 kg).	

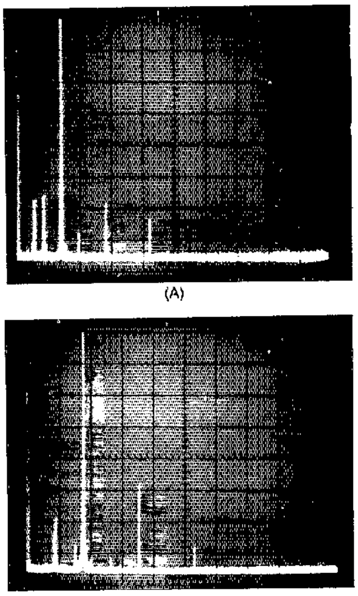


Fig. 1 — Worst-case spectral output of the HW-5400. At A, the rig was operated at 100 W on the 20-meter band. At B, the power output was 109 W on the 17-meter band. For both photos, the vertical scale is 10 dB/division and the horizontal scale is 10 MHz/division. The spectrum analyzer bandwidth was 100 kHz. The transceiver meets the manufacturer's specifications and current FCC spectral-purity requirements.

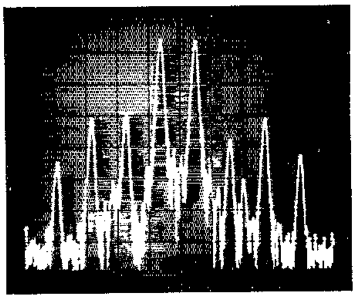


Fig. 2 — Results of the two-tone transmitter test. Third-order products are down approximately 30 dB. The transmitter was being operated at 100-W PEP output on the 20-meter band. The horizontal scale is 1 kHz/division, and the vertical scale is 10 dB/division. The spectrum analyzer bandwidth was 100 kHz.

the difficulty I had with the alignment. I believe I did also have a defective band-switch wafer, but it is hard to be sure. Several other components had to be replaced as a result of improper voltages being applied, either as I had tried to set the band switch to track properly or because of the defective wafer. The technician had even replaced my two 7.7-pF parallel capacitors on the BFO board with the original 27-pf value, and the USB BFO circuit adjusts to the proper frequency now. All of the remaining alignment steps had been completed.

After testing the rig in the ARRL lab (see Figs. 1, 2 and 3 and Table 1), I was ready to take it home for some on-the-air operating. Field Day weekend was fast approaching, and I planned to to use that contest to really see how good the receiver is.

Circuit Description

The main signal flow follows the pattern of most modern transceivers. I will describe only those features that are unique or specific to the HW-5400. Two voltage-controlled oscillators (VCOs) provide the LO signals for the transceiver. One operates on 80, 40 and 30 meters, while the other functions on the higher-frequency bands. Incoming signals are converted to the 8.83-MHz IF before being routed to the audio circuit board. With the HWA-5400-2 2.1-kHz, four-pole SSB crystal filter installed, the signal is filtered before being amplified. After the first IF amplifier, the signal goes through a six-pole filter and three more stages of amplification before being passed to the audio board. The wide and narrow CW filters are active audio stages. The narrow CW filter has a 250-Hz bandwidth, centered on 700 Hz.

At the heart of this radio is a microprocessor. Some of the functions it performs are: refresh the frequency display line; receive input from the shaft encoder or the frequency-entry keypad; program the frequency synthesizer for the desired frequency; poll the front-panel switches for the desired band and modes of operation; ensure that the PLL circuits are locked and the frequency is within certain limits before allowing the transmitter to operate; store the display and memory frequencies for each band, even when the transceiver is turned off (provided the memory-keep-alive voltage is present); and perform diagnostics on the transceiver when it is first powered up.

This last feature can be helpful if some problems develop with your radio. The controller displays certain information to help you track down the problem. If you see PLL on the display when you turn the transceiver on, for example, you will know that one or more of the PLL circuits has not locked. The information is rather limited, but it could prove helpful.

BCD information from the CONTROLLER board is routed to the display circuit board to provide a frequency readout. The vacuum-fluorescent display includes seven digits, a comma, a decimal point and several special display symbols. A small U, L or C to the left of the digits indicates USB, LSB or CW operation. A one-segment bar above this letter indicates that the unit is in the transmit mode. If you tune above or below either amateur-segment band edge, a left-pointing arrow near the left edge of the display will warn you that you are out of band. When you select split-frequency operation, a bar will light under the arrow position; and if you choose to display the memory frequency (which is the transmit frequency during split-mode operation), a bright M will light.

The main-tuning method is quite interesting. The knob contains a metal insert connected to a capacitive-touch circuit. If you place a finger into this indentation, the microprocessor changes from a 50-Hz tuning rate to a 1-kHz rate! Behind the front panel is a plastic disc that has alternate clear and black radial stripes. When you rotate the tuning knob, these stripes pass between two pair of optical encoders. Signals from these encoders enable the microprocessor to determine which way you are turning the knob, and then decide to increase or decrease the operating frequency. During alignment, I discovered that if a bright light shines on the encoder, the frequency will not change! This could lead to a simple "dial lock" modification for the radio!

Most modern transceivers use PLL frequency-synthesis circuits. One problem with these circuits is that the time required to make a frequency step is inversely proportional to the loop filter bandwidth. This filter must have a bandwidth that is narrow enough to attenuate the reference-frequency signal to an acceptable level, and yet wide enough to allow a fast response to frequency changes. For a single-loop synthesizer, the minimum step size is equal to the reference frequency. If the filter bandwidth is left wide enough to provide small frequency steps, then more reference-frequency-oscillator noise will get through to the audio stage, or appear in the transmitted output.

A dual PLL synthesizer is employed in the Heath HW-5400. Loop one has a 10.05-kHz reference frequency, while loop two has a 10-kHz reference. Thus, the loop filters can have a fairly wide bandwidth and still provide good attenuation of the reference frequency. Each loop uses a VCO, whose output varies depending on the band and operating frequency. The VCO signals are combined with the PLL reference oscillators through a divide-by-N counter on the synthesizer board to provide 50-Hz frequency steps. The output from this synthesizer does not suffer from severe phase-noise problems, as has been common with many synthesized rigs. Evidence of this is shown in Table 1. We were able to measure the blocking dynamic range. Many rigs have a "noise limited" entry in that position!

The power amplifier uses three push-pull amplifier stages to produce 100 W of RF output. The final-amplifier transistors are a matched pair of Motorola SRF3351P power transistors. These devices are thermally protected by a pair of diodes mounted in contact with them. As the diodes heat up, they turn off a bias transistor, reducing the bias on the finals. While the transmitter should only be operated into a 50-ohm load, this type of protection does prevent the transistors from being damaged by a mismatched condition. When rigs with transistor final amplifiers first came out, they were prone to destruction of the output transistors if the SWR on the feed line was allowed to go too high. Many hams still seem to believe that this is a problem, but protection schemes such as are employed in the Heath HW-5400, have virtually eliminated this effect.

An Uncluttered Front Panel Means Easy Operating

One of the first things I noticed about the '5400 was that the pictures show a minimum of control knobs on the front panel. Does that mean the radio lacks some of the features of the other manufacturers' newest offerings? You may have noticed that some manufacturers seem to be competing to see how many controls they can squeeze onto the front panel of their radios. Well the HW-5400 may not have *all* of the features, but it does seem to have the important ones!

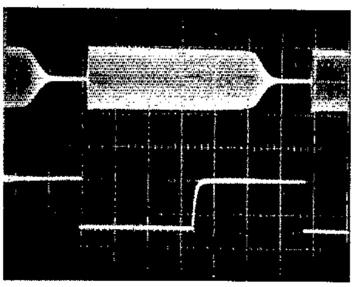


Fig. 3 — Display of the original keyed CW output waveform. The top trace is the RF output envelope, and the bottom trace is actual key closure and opening. Each horizontal scope division is 10 ms. Notice that it takes approximately 20 ms after the key contacts open before the output wave begins to decay. This delay appears to be independent of keying speed, and tends to eliminate the interelement spacing at speeds much above 20 WPM. This should be considered unacceptable for high-speed CW operation.

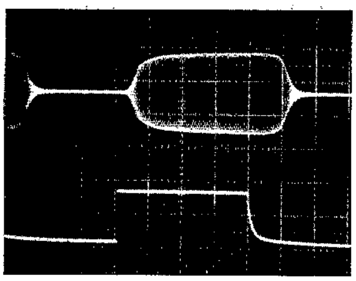


Fig. 4 — CW output waveform of the HW-5400 after I performed Heath's suggested modification. Each horizontal division is only 5 ms on this photo. The rise and fall times are much better, but most important, it only takes about 5 ms for the radio to begin to turn off the carrier after the key contacts are opened.

There is a grand total of six knobs on the front panel. Three of them are concentric, dual controls, however. Single knobs control the main tuning, and select the band and operating mode. The dual controls are for MIC/CW GAIN on transmit, AF/RF GAIN on receive and RIT/IF SHIFT. There are also six, small push-button switches to select other operating features, such as FAST or SLOW AGC action, PTT or VOX operation, TUNE, SPLIT transmit/receive operation, swapping memory and display frequencies or writing the display frequency to memory. With the optional frequency-entry keypad (for the price, I don't understand why anyone would choose to be without this), add 11 more buttons in the top-left corner. Hidden under the name label at the top right are the VOX controls and the sidetone-level adjustment. While you will need a small-bladed screwdriver to turn these controls, it sure beats hiding them under the top cover, where they end up being virtually inaccessible in many cases. Rounding out the front panel are the S meter, a PHONE jack and a MIC connector.

The rear panel is equally simple. A large heat sink for the power amplifier circuit board takes up most of the space. On one side of the heat sink is an SO-239 coaxial connector, a ground lug and phono jacks for a power amplifier ALC voltage and a set of relay contacts that close when the transmitter is activated. On the other side is a six-pin accessory connector, which provides a speaker output, memory-keep-alive voltage input and an output for the voltage-sensing circuitry of the HWA-5400-1 power supply. There is a phono jack for a positive CW keying line and a switch to turn the relay on or off. The largest connector on this side is for the four-conductor power-cord.

Operating Impressions

Lab testing of the receiver section showed it to be a fine performer. The characteristics listed in Table 1 will compare favorably with most receivers on the market today. The two-tone output spectrum and the CW keyed waveform gave me reason for concern about the transmitter portion of the radio, however. The two-tone output does meet Heath's specifications for the radio in terms of the third-order products, but normally we expect the fifth-order products to be reduced below that level. Fig. 2 indicates that the transmitted audio may be distorted somewhat. This is not a major problem, but something that could be improved. Actual operating experience brought no complaints of distorted audio.

My main concern was for the CW waveform. When you look at Fig. 3, you will notice a rather sharp turn-on characteristic, but the real problem is what happens when you let the key up. It takes 20 ms for the radio to realize it is supposed to turn off the carrier, and then about 6 ms more to accomplish this task. For the dot shown here, the transmitted dot length is almost twice the keyed dot length.

Notice what happens to the interelement spacing. For speeds much above 20 WPM, the space almost goes away completely. At Novice speeds, the rig will probably work fine, but for a high-speed CW operator, this waveform would be totally unacceptable. I called Heath for help with this problem. Their engineers looked at the waveform from a '5400 they had, and discovered that it was not what they had intended. I received a phone call a few days later, with a suggested modification to the keying circuit. I was assured that this simple change is being incorporated immediately. If you own an early version of the kit, contact Heath for the information. Any new kits purchased should include the changes on the RF board. Fig. 4 shows the keyed waveform after I made the changes. Quite an improvement!

I made a few contacts prior to the start of Field Day to become familiar with the operation of the rig. This radio is easy to operate, and the controls are placed so that large fingers can use them. The concentric controls have a full-sized knob next to the front panel, with a thin extension through the center. I do not feel like I must carefully reach around the center control to reach the rear one, as I do with many rigs that use this type of control.

I was anxious to try the IF SHIFT feature. I found several CW and SSB signals that had rather severe interference on them during Field Day. By turning this knob to the + or − side, I could usually find a setting that would allow copy of the original station. I find this feature to be very effective!

Since it was such a nice day, I decided to take the rig out to my picnic table for some Field Day fun. After about a half hour of sitting in the direct sunlight, I was getting warm, but not ready to quit yet. The '5400 felt differently about it, though. The brown cabinet and black heat sink were soaking up more heat than I was, and the radio decided to "go north" for a while! After I took it back inside and let it cool off a bit, everything was back to normal.

Switching between the memory and display frequency is an effective way to make a few more contest exchanges while listening to a particular station, waiting for a chance to work it. A single front-panel button makes this change quick and easy.

Fast break-in CW operation is achieved by setting the VOX DELAY to a minimum. It takes a little practice to get used to hearing the active receiver between code letters. But there is no better way to keep track of what is happening on your transmit frequency. More than once I completed a transmission with a non-QSK rig, only to find that the contact was broken because of a strong interfering signal. It is much easier to pick up the pieces when you are aware of the interference right away.

The HW-5400 selects the "normal" sideband on each amateur band. You have the option of choosing the reverse sideband if you have some reason to do so. There are two active audio filters that are selectable for CW operation. The narrow filter has a 250-Hz bandwidth. If you wish to operate other modes, you will have to adapt the radio to suit your needs. To get on RTTY, for example, you will have to wire an extra microphone connector to your modem for AFSK operation.

The S meter has the normal 0-to-9 signal-strength markings, plus marks for 20, 40 and 60 dB over S9. During transmit, the meter doubles as a relative power output meter. There is a block marked ALC on the meter face. It is important that you keep the needle within this block on voice peaks while transmitting SSB. Otherwise, you will overdrive the final amplifier, causing a distorted signal. Adjust the MIC GAIN control while talking into the microphone. For CW operation, you press the TUNE push button and adjust the CW GAIN control for the desired output.

I obtained an extra power cable from Heath so I could connect the transceiver in my car during the review period. The '5400 is small and lightweight, making it be a nice mobile rig. It may present some problems if you want to find space under the dash of a compact car, however. You will have to find some means for connecting a speaker for mobile operation. This could be through the front-panel PHONE jack or by means of a mating connector for the accessory jack. If you want the radio to remember your favorite frequencies between operating periods, you will also have to provide a battery connection to the memory-keep-alive pins.

What has been left out of the HW-5400? It has no noise-blanker circuit, no RF attenuator and no crystal-calibrator or marker-generator circuit. Neither is there any means to disable the AGC operation. There is no provision for auxiliary microphone input or audio output. These features would make it easier to connect an RTTY modem to the radio.

Tuning the receiver without an antenna connected revealed numerous weak "birdies" and other "growlies." The receiver has some odd-sounding noises on the 80-meter band. These seem to be coming from the controller circuit, because when I entered numbers on the keypad while tuned to some of these frequencies, the noise would change. The loudest birdies occur at 4.02112 MHz, 7.0362 MHz, 28.13850 MHz and 28.96365 MHz. These signals just barely move the S meter. I found one stronger signal by tuning to 10.000 MHz and then turning the RIT control as low in frequency as possible. When I also move the IF SHIFT control to the low-frequency side, the S meter moves nearly half an S unit. I did not find any of these spurious signals to be a problem during normal operation, even after I knew where to look for them.

Conclusions

At the beginning of this review I mentioned my first transmitter, a Knight-Kit T-60. There were many reasons for buying a kit then, the greatest of which was the fact that it was possible to save as much as 40% of the cost of a comparable rig. Other reasons were the claims that the builder would learn a lot about electronics in the process, gain knowledge of the radio itself and the sheer pleasure associated with being able to say, "I built it myself!" Were these claims valid then, and are they still valid today? Well, there are probably many different opinions about this.

I never did believe a person could learn electronics by building a kit. You certainly gain a lot of soldering experience, but there is more to electronics than being able to solder properly. There is a potential to learn some electronics, however, if you want to take the time to learn the function of each component as you install it. By tracing the schematic diagram as you go, you can certainly begin to understand the general flow of signals through the radio. While my T-60 was an excellent first-time kit for a high-school-aged Novice, I don't think I could recommend the HW-5400 as a first project under the same circumstances!

Dollar for dollar, can you get a better-performing rig today by building it from a kit than if you bought one already built? Probably not. The price of a fully equipped HW-5400 may be a little less than the price of a comparable transceiver already assembled, but you must be willing to spend on the order of 100 hours to complete this transceiver. Certainly not a weekend project!

So why buy a kit radio? Well, it is certainly true that you will be intimately familiar with the component layout. And I am sure that I will be better able to dig into my '5400 to correct any problems. Heath includes a detailed troubleshooting section with the manual. Complete realignment instructions are also included. To get similar information about another brand of transceiver, you would have to purchase a service manual. Even that may not contain as much material as Heath supplies.

All of this familiarity with the radio also leads to ease of modification. While I was building my kit I thought of several features I might add at some point. I like having a stereo phone jack for my headphones. I have purchased a pair of the lightweight headphones that go with the popular portable FM stereo radios. These 'phones are ideal for long hours of operating, because they are light and comfortable. Also, with a stereo jack, it is possible to insert the plug half way, and have audio in the speaker and the headphones. I've found this to be handy under a variety of circumstances. It might also be nice to have an auxiliary audio output and mic input for use with a radioteletype modem or phonepatch. These and many other modifications will be easy to add.

Finally, there is definitely a great satisfaction to be gained by operating a radio that you have built yourself. This sense of pride is all the greater when the result of your work is a nice-looking, functional transceiver like the HW-5400.

Yes, there are many valid reasons for building a project like this. I hope you'll enjoy it as much as I did. The HW-5400 and accessories are available from Heath Company, Benton Harbor, MI 49022, tel. 616-982-3411. Price classes: HW-5400, $500; HWA-5400-1 (power supply), $200; HWA-5400-2 (SSB crystal filter), $60; HWA-5400-3 (frequency-entry keypad), $60. — *Larry Wolfgang, WA3VIL, ARRL Hq.*

New Products

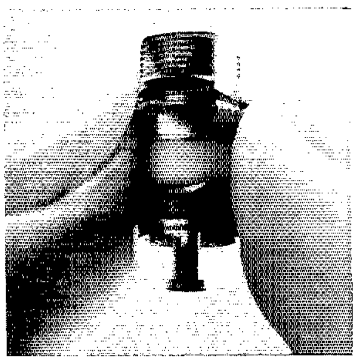
TRIM-TRONICS AIR-VARIABLE CAPACITORS

☐ Trim-Tronics, Inc., offers a line of air-variable capacitors designed with a self-resonant frequency greater than 5 GHz. They are suitable for sensitive telecommunications applications such as satellite, microwave, two-way radio and test instrumentation, where very precise tolerances are required. Typical applications include uses with RF amplifiers and oscillators, and for crystal tuning, coupling, impedance matching and filter tuning.

A unique design produces a high-Q factor (greater than 5000 at 200 MHz), allowing the capacitor to operate at microwave frequencies. The vertical slotted rotor mechanism of the capacitor results in complete surface area contact, producing uniform torque and a contact resistance of less than 1 milliohm.

Available in several mounting styles, the Trim-Tronics air-variable capacitor has a temperature coefficient of ± 15 parts per million over a wide temperature range. The capacitor has a voltage rating of 250-V dc.

Trim-Tronics manufactures air plate and tubular capacitor lines. The company is a member of the Trush Group, Inc., and is affiliated with Alfred Tronser GMBH of Germany. For more information concerning their capacitor lines, contact Mr. James E. Dowd, Trim-Tronics, Inc., 67 Albany St., Cazenovia, NY 13035; tel. 315-655-9528. — *Paul K. Pagel, N1FB*



Conducted By Larry D. Wolfgang,* WA3VIL

HAIRPIN MATCH FOR THE COLLINEAR-COAXIAL ARRAY

☐ I have built several collinear-coaxial-array antennas over the years. A 2-meter version of this antenna is described in *The ARRL Antenna Book*, 13th edition, pp. 247-249. I could not adjust the SWR below 1.7:1. After talking with other hams who built antennas like this, I found that 1.7:1 is about normal for a minimum SWR value.

After many hours of experimentation, I devised a hairpin match that achieved a 1:1 SWR. Dimensions for the antenna and details of the hairpin are shown in Fig. 1. Fig. 2 illustrates the method of connecting the coaxial-cable sections together.

I suggest that you make an antenna using three ½-λ elements to start. Use solid-dielectric cable, which has a velocity factor of 0.66. If the resonant frequency of the antenna is off by more than about 1 MHz, you will have to trim the elements a bit. If it is only off by 0.5 MHz or so, then you can add extra elements at an adjusted length to fine-tune the resonant frequency. Add ½-λ elements in pairs, always maintaining an odd number of ½-λ sections.

I built a collinear-coaxial array for a local repeater. The antenna has nine ½-λ elements, and it seems to provide a reasonable amount of gain. — *Barry Boothe, W9UCW, Chanahon, Illinois*

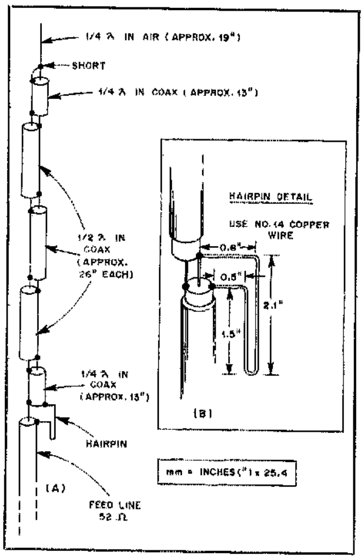


Fig. 1 — Approximate dimensions for the construction of a collinear-coaxial-array antenna are shown at A. B shows the details of a hairpin match used to obtain a 1:1 SWR.

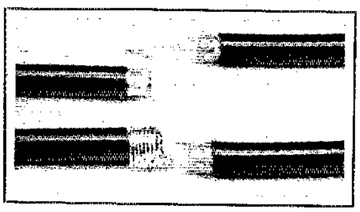


Fig. 2 — Prepared ends of the coaxial cable and the method of soldering them together.

DRILLING IC-PIN HOLES IN CIRCUIT BOARDS

☐ There are many different methods and ideas for producing circuit boards for projects. One step that has given most hams a problem is drilling the holes for a DIP IC. Here is a method I use to make circuit boards for construction projects.

Use rubber cement to attach a blank piece of circuit-board material to a block of wood. Place a copy of the board layout over the PC material and tape it to the wood. Now, drill the indicated holes, but when you come to an IC, drill two holes at diagonally opposite ends of the IC. Then, use two brads to hold a Radio Shack IC board (part no. 276-024) over the appropriate position. Use this predrilled board as a template to drill the other holes. (A piece of perforated board with the proper hole spacing or other template could also be used.)

After drilling all holes, slip a piece of carbon paper under the board-layout pattern and trace the wiring. Finally, remove the carbon paper and pattern and go over the lines with an etch-resist pen or enamel. Make pads around the drilled holes, even putting resist in the holes. The board is now ready to etch.

This system also works for projects with no published PC-board pattern. Carefully plan the layout to conserve as much space as possible. Avoid crossovers and keep the traces from coming so close together that they touch. — *Edson B. Snow, W2UN, Pompano Beach, Florida*

COPPER-FOIL TAPE CIRCUITS

☐ When my wife and I enrolled in a class to learn stained-glass techniques, I made a wonderful discovery for my Amateur Radio projects.[1] Strips of copper tape applied to pieces of stained glass allow the project to be soldered together. This tape is inexpensive and is sold at any hobby shop that has stained-glass supplies. It is available in 5/32, 3/16, 7/32, 1/4-inch and wider rolls.[2] The adhesive on the tape is designed to withstand soldering heat.

The possibilities for this tape seem endless. It is great for making circuit traces for PC projects. If the 5/32-inch width is too great, narrower strips can be cut with scissors or a razor blade. The wider rolls of tape can be used to make round pads with a paper punch, or to cut curved traces. The adhesive is nonconducting, but I would not trust it to insulate the circuit traces. Build the pattern on an insulating material. Crossover traces can be insulated from one another by a piece of paper or other thin, insulating material. Where overlapping traces must be connected electrically, you simply solder them together. The tape is easy to solder to, but I recommend that you keep it in an airtight plastic bag to prevent the copper from oxidizing.

The tape is 0.0015 inch thick (1.5 mils). The cross-sectional area of the 3/16-inch tape is 281.25 square mils, which is equivalent to 358 circular mils. A no. 25 wire has an area of 320 circular mils. The tape should be able to handle 500 mA with no problems.

This copper tape can be used to wind coils on a cylindrical form. Such coils are ideal for a Transmatch because they exhibit low distributed capacitance. Fig. 3 shows why the tape coil has less capacitance than one made from wire.

The March 28, 1983 issue of *Design News* contains an article titled "Foil Tape Converts Reed Switch to Switchable Coaxial Conductor." This article describes how the CATV industry is using 4.2-mil-thick copper tape to make coaxial switches.[3] Fig. 4A illustrates the basic operation of a reed switch (relay) and Fig. 4B shows how a foil-wrapped switch can be soldered into a coaxial line. If the foil is wrapped in a spiral around the switch, the overlap edges should be soldered to form a cylindrical conductor around the glass.

Apparently, the relays and foil being used in

[2]mm = in x 25.4.
[3]Scotch 1245 tape; available from 3M Company, St. Paul, MN.

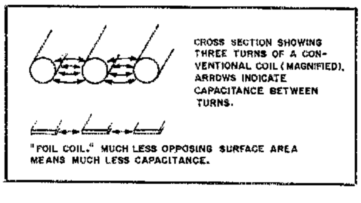


Fig. 3 — The cross-sectional area and distributed capacitance between turns of a wire coil and a foil-tape coil are shown.

*Assistant Technical Editor

[1]This article is adapted from the June 1983 Ozaukee Radio Club Newsletter, P.O. Box 13, Port Washington, WI 53092.

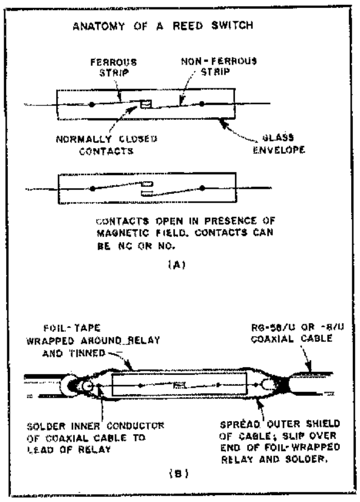


Fig. 4 — The parts of a typical reed switch are shown at A. B shows the construction of a coaxial reed relay.

the CATV industry produce a 75-Ω impedance. Amateurs may have to experiment with relay dimensions and foil thicknesses to obtain the best impedance match for their systems. There are certainly some interesting applications for this idea. The insertion loss is claimed to be less than 0.2 dB, with good isolation. You can use two or more relays in series to increase the isolation if needed.

I am sure there are other uses for this versatile tape. Someone will probably even try building a transmitter in a bottle! Actually, building circuits on a curved surface is no problem at all with this material. — *Stan Kaplan, WB9RQR, Mequon, Wisconsin*

HIGH-VOLTAGE POWER-SUPPLY SAFETY

☐ We all know that a 3000-V power supply with a large filter capacitor is a lethal device. Even with the transformer primary circuit open, the charge stored in the capacitor can be deadly.

While testing some transmitting tubes under actual operating conditions, I was running the amplifier with the safety cover off. I was being extra careful, but as it turned out, not careful enough. Preparing to change tubes, I turned off the power and was reaching for a screwdriver when the telephone rang. As I picked up the phone, I heard my wife come on the line. Since the call was for her, I hung up my phone and went back to my testing.

That is when I made the almost fatal mistake. Instead of picking up the screwdriver to short the filter capacitor, I reached for the tube plate clip. This time I "only" got a slight burn and a severe jolting, jarring, electric shock. Luckily, I was standing on a layer of plywood on the floor, and had only reached with one hand! The shock path was through my fingers to my forearm, which I had rested on the edge of the front panel. Had the shock path been through my chest cavity, I might have been killed! After I regained my composure, I decided to do something to reduce the risk of such a sequence of events recurring.

There is no need for voltage to be applied to the plate line when the tubes are not working. A relay could serve as a safety disconnect to isolate the lethally charged capacitor from the plate line. I looked through my relay collection and found several that would be able to handle the required voltage and current. My final choice was a Leach type 1127 relay with a 117-V ac coil. I cut away part of the mounting bracket near the high-voltage terminals to be sure of sufficient clearance.

I mounted the relay near the hot lead on the filter capacitor. Zip cord is used to wire the relay coil. You should find a spot that has voltage applied to it when the high-voltage supply is energized, and choose a relay that operates on the appropriate voltage. A piece of RG-8/U with the shield braid removed is good for wiring the high-voltage leads. Use the normally open relay contacts in the high-voltage line. I wired the two sets of relay contacts in series for extra isolation.

When I was sure all of the leads were properly soldered and nothing was shorted, I put the unit back in service. It seemed to work fine, but after a couple of weeks a slight corona leak developed between the switching contacts and the grounded frame. Remounting the relay on a piece of plastic spaced away from the chassis cured this problem.

The safety disconnect worked so well that I decided to install a similar relay in my other high-voltage power supplies. My homemade 30-meter transmitter has a 1000-V supply, is wired breadboard style, and has only a front panel. Putting a safety disconnect in this circuit was very worthwhile!

This technique does not render the high-voltage supply harmless, but it does reduce the chance of accidental contact with dangerous voltages. Seeing the high-voltage meter on the tube plate snap back to zero when I open the PTT line sure gives me a reassuring feeling. Adding a safety disconnect is so easy and effective that everyone should put one in the high-voltage-supply line of their transmitter or amplifier. — *John Labaj, W2YW, Elsmere, New York*

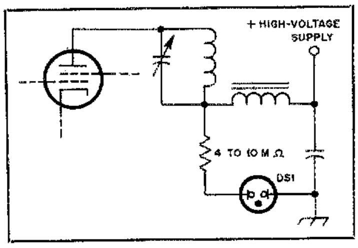


Fig. 5 — Partial schematic diagram showing how KA6UXR adds a visual indicator to warn of the presence of dangerous high voltages in his tube-type equipment.

☐ We should all protect outselves against electric shock by following good workshop practice — such things as unplugging the power supply before working on equipment, using bleeder resistors on filter capacitors and installing safety switches on enclosures. There is still the risk, however, of human and mechanical failures. Moreover, there are numerous occasions when tube transmitter plate circuits must be accessible when high voltage is applied.

I make it a practice to attach a 4- to 10-MΩ resistor and a small neon lamp to the hot end of the plate choke, or in some other conspicuous place in the plate-circuit compartment (see Fig. 5). This gives a visual warning when the circuit is live, either because the power is on or the filter capacitors have not yet bled down to a safe voltage.

With power transistors carrying large low-voltage currents, it is not a bad idea to do the same thing in a solid-state rig. Use a small resistor and an LED, preferably a flasher type. Massive short circuits can be avoided simply by the extra reminder not to let your tuning tool slip. — *Alex Comfort, M.D., KA6UXR, Santa Barbara, California*

BROADCAST ANTENNA FOR 2-METER MOBILE OPERATION

☐ Here is a simple system that permits simultaneous use of a car-radio antenna for broadcast reception and 2-meter operation. It is one way around the complications of drilling holes in your new car to mount an antenna, or of having an extra element to advertise the radio equipment inside the vehicle. There may be a slight signal loss on 2 meters, but little or no loss on the AM broadcast band.

The diplexer is shown in Fig. 6. It consists of two Motorola jacks for the antenna and car radio, plus a third coaxial connector for the line to the 2-meter rig. A parallel-resonant trap for 2 meters connects between the antenna and the car radio to isolate the BC receiver from the 2-meter signals.

The most common length for nontelescoping car antennas is probably 31 inches. I placed a 5- to 25-pF trimmer capacitor between the antenna jack and the 2-meter jack. This is used to tune out the inductive reactance of the antenna.

The whole diplexer fits into a 2 × 2 × 2-inch aluminum box. The trap frequency should be adjusted by means of a GDO before it is connected into the circuit. 5 pF and 0.2 µH are typical values. I used a slug-tuned coil form. The ceramic trimmer capacitor is adjusted for maximum received signal or maximum field strength before installing the cover on the box. The enclosure must be completely RF tight to prevent ignition-noise pickup. Do not use a plastic box! I use 73-ohm coaxial cable for the feed line to my 2-meter transceiver. — *William Skeen, W6WR, Hornbrook, California*

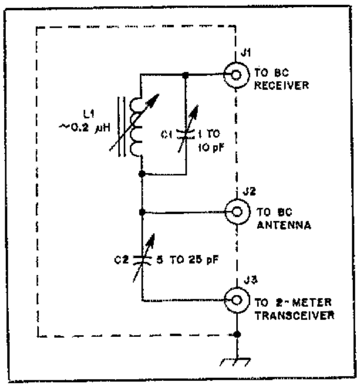


Fig. 6 — Schematic diagram of a 2-meter/AM broadcast diplexer. This circuit allows the use of an AM car-radio antenna for 2-meter operation.

Technical Correspondence

Conducted By
Bob Schetgen,* KU7G

The publishers of QST assume no responsibility for statements made herein by correspondents.

A HIGH-GAIN MONOBAND DIRECTIONAL ANTENNA

☐ The X-ray antenna system was developed for the purpose of obtaining a simplified, high-gain antenna system with directional characteristics that can be changed quickly by remote control. This system provides:

- 6.5-dBd main-lobe gain
- broad bandwidth
- simple coaxial-cable feed
- instantaneous remote beam control
- low-angle DX capability
- modest height and space requirements

Essentially, the X-ray antenna consists of a pair of back-to-back, parallel connected, 1.25-λ V arrays. It could be described as an "inside-out" rhombic. This arrangement requires five supports, including a central support that is at least 0.5 λ high. The remaining four supports, however, can be significantly shorter because a 22° to 35° tilt is applied to all four antenna elements. The basic 1.25-λ V antenna presents an impedance of approximately 100 Ω at the feed point. Therefore, two of them connected in parallel result in an impedance that is near 50 Ω. This offers an extremely convenient point to apply coaxial-cable feed to the system. A 1:1 balun transformer preserves antenna balance. Also, a relatively broadband effect results from the wide-band balance and combined terminal impedances of both Vs.

The tilt angle, α, applied to each element provides a lower vertical-lobe angle. This favors long-range communication paths although it also produces quasi-elliptical polarization. Angle α, as shown in Fig. 1, may be anywhere between 68° and 55° with respect to the central support. Fig. 1 shows a plan and elevation view of the X-ray system. Fig. 2 illustrates the method employed for relay control of directional characteristics, and Fig. 3 shows the relay enclosure mounted on the central mast.

The relay box contains a DPDT relay and a 1:1 balun transformer. Appropriate chassis connectors are mounted at the bottom of the box for remote relay control and coaxial cable to the station. The box should be waterproofed by covering any openings or seams with RTV (General Electric or Dow) sealant. Four 5/8- to 1-inch-diameter holes are provided at four corners of the enclosure and covered by square pieces of Lucite™ or Plexiglas® sheet bolted to the box.[1] Flexible wire leads, from the relay contacts, are brought out through small holes in the insulating sheets and connect to the antenna elements, as shown in Fig. 3.

Table 1 provides the antenna element lengths and the minimum recommended central-mast height for each operating band. The element-length formula is:

$$L = \frac{1230}{f} \quad \text{(Eq. 1)}$$

where
L = length in feet
f = frequency in megahertz

[1]mm = in × 25.4; m = ft × 0.3048
*Technical Editorial Assistant

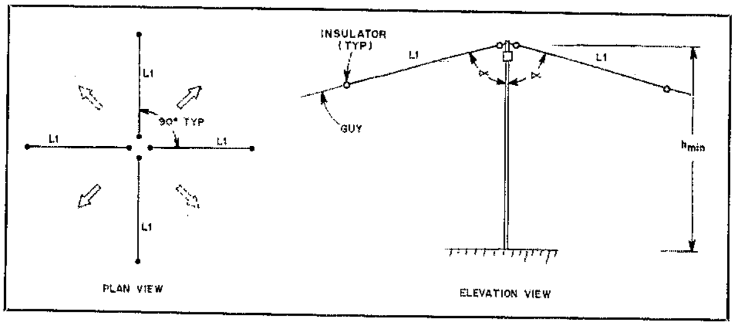


Fig. 1 — Plan View and Elevation of the X-ray antenna array. Minimum center mast height, h, is given in Table 1.

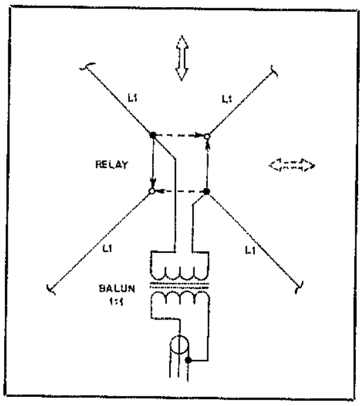


Fig. 2 — Schematic diagram of antenna array and switching system. The arrows indicate main-lobe orientation.

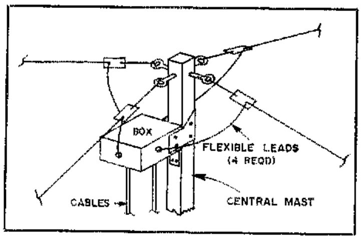


Fig. 3 — Arrangement of antenna and switching box at the top of the center mast.

The system completely covers all but the 10-m band, where it should be limited to any one 0.5-MHz segment. Cut the antenna elements for the center of any band shown in Table 1. Performance should be satisfactory, as long as all elements, including the leads to the relay and balun, are the same length. — *Richard R. Schellenbach, W1JF, Reading, Massachusetts*

Table 1
Element and Mast Dimensions

Band	*Element Length*	*Center Mast*
40 m	172 ft	67 ft
30 m	122 ft	46 ft
20 m	87 ft	34 ft
15 m	58 ft	22 ft
10 m (28.0-28.5 MHz)	43 ft 6 in	17 ft
10 m (28.5-29.0 MHz)	42 ft 9 in	
10 m (29.0-29.5 MHz)	42 ft	

TRANSMATCHES

☐ There seems to be mass confusion about what a Transmatch is and where it should be used. A Transmatch in the shack can, in fact, present a better load to the transmitter or amplifier than exists at the transmission-line input. In the presentation of this "corrected" load, however, only feed-line tuning is accomplished. That is, the transmitter is matched to the feed line, rather than the feed line to the antenna. At different frequencies and line lengths, the item that actually takes power (feed line or antenna) is determined by factors other than the Transmatch setting.

A Transmatch increases performance of the antenna system only when used at the antenna feed point. Consider a typical amateur installation. Coaxial cable has a fixed characteristic impedance. When attached to a mismatched load, however, the cable acts as a transformer. Input impedance may range from zero to infinity (if line losses are ignored) depending on the load impedance and cable length. Cable input impedance varies as a result of the difference between the load and cable characteristic impedances. Any matching is better done at the load, than the line input.

Transmatches are wonderful devices and I use one often as I need to load a random-length wire onboard ship. I keep in mind, however, that I am only providing a proper load for the transmitter — not improving antenna system efficiency. — *Clifford R. Ward, WA5LVG, Spring, Texas*

CURRENT DISTRIBUTION ON DIPOLE ANTENNAS

☐ Dick Rollema, PA0SE, has pointed out an incorrect statement and diagram in my article, "The Effect of Supporting Structures on Simple Wire Antennas" (Dec. 1982 *QST*). On page 32, under the heading, "The λ/2 Inverted V," I stated, "The current elements (*Idℓ*) on each arm of the dipole will be opposite in phase, so the currents that each induces on the tower will cancel." This statement is not correct, since the current on a λ/2 dipole is in phase over almost the entire length of the antenna.

Dick asks: 1) How does this affect the conclusions reached, and 2) Why is the current in all elements of a half-wave dipole in phase, when the magnitude varies cosinusoidally with position on the radiator?

Rollema is correct: The currents on the two arms of a dipole are in phase, but the spatial relationship of each arm current to the feed point is different. That is, if current is traveling toward the feed point on one side of the dipole, it is traveling away from the feed point on the other side.

Hence, for the inverted-V configuration, current is traveling "up" one sloping arm and "down" the other. The vertical components of these current vectors are opposite in phase, and the currents induced on a conductive center support (or the sheath of the coax, if a nonconductive mast is used) are opposite in phase and cancel. This is true only if a balanced feed is employed. More often than not, the inverted V is shown with unbalanced feed (see DeMaw, Jan. 1984 *QST*, p. 31). I cannot say what the radiation pattern would be with such a feed, but it is clear that the vertically polarized fields off the ends of an inverted V are very sensitive to unbalance (see my Technical Correspondence item in June 1982 *QST*).

Rollema points out that a similar wrong statement is made about the current phase on horizontal dipoles (page 33 of my December article). This does not affect the conclusions reached, however: Even for in-phase currents, the support towers are not symmetrical with respect to each arm of the dipole. The induced currents do not cancel.

Now let me address the second question: Why are the current elements on dipoles in phase, while the magnitude varies cosinusoidally with position on the radiator? This is a characteristic property of resonant antennas that is easy to explain for a half-wave dipole.

Consider a current element traveling from a center feed point along one arm of a dipole. As the current travels there is little change in amplitude, but phase changes with distance traveled, until current lags by 90° at the end of the antenna (Fig. 4). At the end of the antenna, where total reflection occurs, there is an abrupt phase change of 180° (associated with a change in the direction of travel) and the current elements travel back toward the feed point. The current on the antenna (amplitude and phase) is the sum of current elements that are traveling in opposite directions on each arm. At the ends of the dipole arms, the current is the sum of two vectors that are equal in amplitude and opposite in phase, and hence, the resultant current is zero.

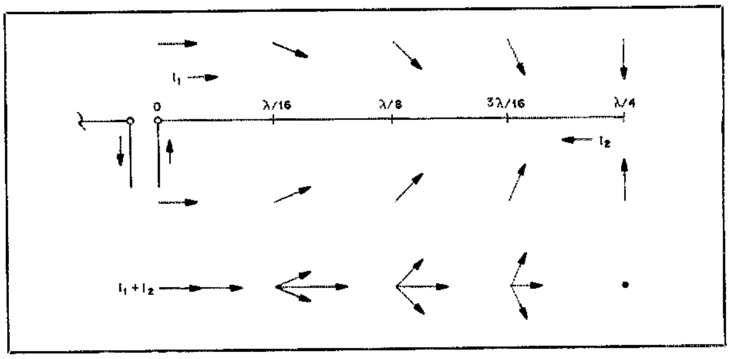


Fig. 4 — A resonant half-wave antenna with unit vectors showing the phase angles of current as it travels from feed point to end (I_1), then from end to feed point (I_2). The lower illustration ($I_1 + I_2$) shows the vectors and their sum, the resultant current, at various points on the antenna.

At the feed point, the currents are in phase, and the total current is maximum. For all in-between distances along the dipole arms the two vectors add, resulting in a total current that decreases cosinusoidally with distance along the arm, but the phase is constant, except at the ends of the dipole, where a phase discontinuity occurs as the amplitude of the current approaches zero (Fig. 4).

If the dipole is extended on one or both ends by a half wavelength, the current standing waves on opposite sides of a current node are 180° out of phase (see *The ARRL Antenna Book*, p. 2-7). Current distribution on nonresonant antennas depends on the method of feed, but the starting point in sketching the distribution is the fact that the current is zero at the ends of the conductor.

This discussion assumes a pure standing wave, whereas in reality, the antenna radiates, and the amplitude of a current element decreases as it travels from the feed point to the end of the antenna. The constancy of the current phase along most of the length of a dipole is, however, rather astonishing, as confirmed by rigorous calculation (Max Royer, private communication), and by measurement. This phase relationship is a property of resonant antennas that carry a standing wave of current, and it is fundamental to the explanation of how an antenna radiates. — *John S. Belrose, VE2CV, Aylmer, Quebec*

CHORDAL-HOP PROPAGATION

☐ In "Theory For Long-Range Propagation" (Technical Correspondence, May 1982 *QST*), K8IRY rediscovers a propagation "theory" that has been proven by others over the past 30 years.

In the early 1950s, Hans Albrecht, VK3AHH/DL3EC, proved that the low path losses and unpredicted times of openings on many HF amateur signals arriving in Australia from Western Europe could be explained only by: "rays propagated in geometrically inscribed hops along the layer but not necessarily with all the ground reflection points required by multihop theory." On his return to Europe, Albrecht further developed this theory and carried out more experimental work. He named the mode "Chordal Hop."

Since the original work by VK3AHH, much more work confirming the mode has been done. Notable in their efforts are Les Moxon; G6XN, K. J. Hortenbach and F. Rogler of the German external broadcasting service and Garry Bold of the Radio Research Centre University of Auckland (New Zealand) and many others (see references).

This work resulted in CCIR Report 250-1 of 1966 whereby communication engineers formally admitted the existence of long-distance ionospheric propagation modes without intermediate ground reflection. — *T. A. Dineen, VK2SV, Port Macquarie, Australia*

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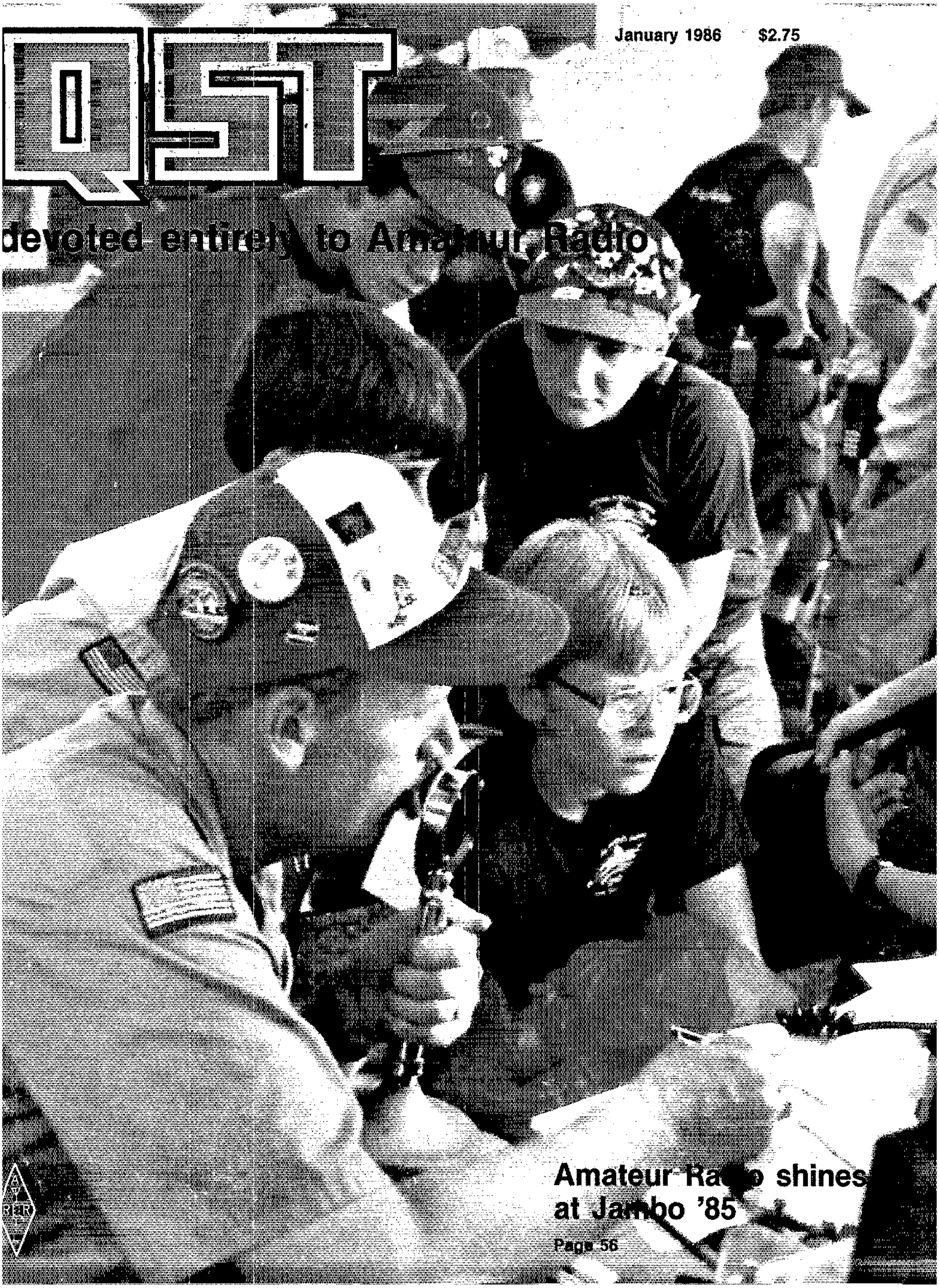
Feedback

☐ Author DeMaw informs us of an error in "Some Basics of VHF Layout and Design," August 1984 *QST*. In Fig. 9, on page 22, the ground connection of Q1 is missing. The emitter of Q1, and all components connected to it, should be grounded.

☐ In "Setting Up Your Station" (July 1984 *QST*, the diameter of the coils used in the "brute-force" line filter is omitted. The coils may be anywhere from 1 to 1½ inches in diameter.

☐ Some people have had trouble winding the transformer for Wayne Cooper's one-transistor RF amplifier, described in the Hints and Kinks column for August 1984 *QST*. The toroid secondary winding (the first one on the core in this case) should cover only about 70% of the core. Do not space it out to fill the entire toroid. The one-turn primary is wound over the top of the secondary winding, near the lead that connects to the transistor.

Also, this circuit should terminate in 50 Ω. If your application requires different input and output impedances, you may need to add impedance-matching components to achieve optimum performance.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CONTENTS

OUR COVER

What do you get when you bring 30,000 Scouts and leaders together to celebrate 75 years of Scouting? A wonderful opportunity for learning about an activity whose benefits last a lifetime! That's Bill, W3FTG, showing a couple of Scouts how it's done. *(photo by Mike Brown, WB2JWD)*

TECHNICAL

NEWS AND FEATURES

OPERATING

DEPARTMENTS

Meteor-Scatter Communications

It takes patience and skill, but bouncing signals off meteor trails is an exciting and rewarding means of communication!

By Clarke Greene, K1JX
92B2 Cynthia La, Middletown, CT 06457

Amateurs who inhabit the VHF bands operate in a different world, propagationwise, from those on HF. The F-layer propagation that makes the HF bands so exciting for long-haul communications visits 6 meters only briefly during peak sunspot years. Above 6 meters, it is nonexistent. For contacts outside the local area—200 to 500 miles, depending on station capabilities—VHFers turn to some pretty exotic propagation modes. One of the more reliable ways to work VHF DX is to reflect signals from meteor trails. To the uninitiated, meteor-scatter communications may seem impossible! This article will take some of the mystery out of this exciting facet of Amateur Radio.

How Do Meteors Make Propagation Possible?

The ionized trail of a meteor (see sidebar) can refract a radio signal. The ability of an ionized area to refract a radio wave is dependent on the electron density. A low electron density will have only a moderate index of refraction, while a high electron density will have a large index of refraction.

The effect is also dependent on the frequency of the radio wave. The electron density in a meteor trail is such that radio waves between 25 and 60 MHz are significantly affected. Since the meteor's size and velocity determine the trail size and hence the ion density, it stands to reason that some meteors have more effect than others. A small percentage of meteors create enough ionization to refract 144-MHz signals, an even smaller percentage can refract 220-MHz signals, while a very few can propagate 432-MHz signals.

The signals refracted by a meteor trail propagate just as they would for any other form of ionospheric propagation. The ionization takes place in the E-layer, so the distance covered by meteor-propagated radio waves is similar to that found in E-layer propagation—normally 1400 miles (or less).

The duration of the meteor-produced ionization is also a function of the electron density. Large, fast meteors ionize a lot of air molecules and create relatively dense ionization. The time required for all the ionized air molecules to contact electrons and recombine is much longer than it would be if only a few ions had to combine with electrons. When the meteor first burns up, the ionization is at its greatest. As time passes, more and more free electrons and ions combine, reducing the ion density, until the density finally becomes virtually zero. At that point, no propagation is possible.

How Does Meteor-Trail Propagation Work?

Enough of that technical stuff! What's it all mean? As illustrations, let's examine two different meteors.

A relatively large meteor, perhaps the size of a peanut, has a chance to encounter Earth in its respective trips around the sun. While passing close to Earth, the meteor finds itself attracted by Earth's gravity, a force stronger than the sun's gravitational pull (since the meteor is much closer to Earth than to the sun). Upon being drawn in at a high rate, perhaps 40 miles per second, the meteor begins to vaporize (burn), stripping electrons from the vaporized gas.

As meteor ionization goes, the ionized trail is very dense. So dense in fact, that a 220-MHz signal from K1WHS in Maine is reflected and received by W5RCI in Mississippi (they just happen to be listening and transmitting on the same frequency; more on that later). The ion density is so great that the index of refraction is high enough for total reflection of K1WHS's signal. A meteor trail capable of total reflection of a signal at a given frequency is known as an "over dense" trail. The ion density is great enough that signals can't penetrate and be refracted; they're reflected. Of course, frequencies below 220 MHz are similarly affected by this meteor; the index of refraction improves for a given ion density as the signal wavelength gets longer.

W5RCI hears K1WHS for maybe 12 seconds at S8 on his receiver. The signal then starts to fade gradually over the next four or five seconds, until it disappears. No more 220-MHz propagation between Maine and Mississippi until the next meteor.

At the same time all this happened, W1YTW in Maine just happened to be scheduling K5BMG in Louisiana on 144 MHz. The signal from Louisiana rose from nothing to S9 for 20 seconds before fading down over the next 20 seconds into noise. Lower ion density is required on 144 MHz than on 220 MHz for propagation, and the ion density from this particular meteor stayed above the threshold on 220 for only a few seconds. The minimum ion density required for 2-meter propagation could be maintained for a much longer period of time than the higher 220-MHz minimum density level.

A lot happens in Maine. While these two Maine VHFers are working unusual meteor-scatter DX, K1UO is operating the ARRL 10-Meter Contest. In response to a CQ, a collection of W4s, 5s and 9s call K1UO. They're all audible at S7 for a couple of minutes before they gradually fade into the noise. Again, the ionization density in the meteor was sufficient for propagating 10-meter signals for several minutes because the required density level is even lower than at VHF.

Meteors like that in the first example are few and far between. Our second example is more the norm.

Time passes for K1WHS. He hears nothing from W5RCI for 20 minutes. 'Tis a lonely life, that of the 220-meteor jockey.

W1YTW has heard little for the past few minutes. Then he hears just above the noise, "TW from K5B." At least the meteors didn't go the way of the passenger pigeon. The particular meteor that propagated that small bit of information was about the size of a grain of sand. The ion density in its trail wasn't great enough for any type of propagation at 220 MHz; it wasn't even sufficient for reflection at 144 MHz. It was dense enough, however, to refract for a brief moment K5BMG's signal from Louisiana. Only a portion of K5BMG's signal was refracted toward Maine, hence the low signal level. The ion density was low enough that in a short time it dissipated below the level necessary to refract two meteor signals. A meteor trail of this type is known as "under dense."

What of K1UO on 10 meters? He heard a loud, 20-second-long burst from W9RE, with a few more seconds of weak signal.

Earth encounters billions of meteors each day. These billions of meteors are spread over the entire Earth, but meteors appropriately placed for communications between a given set of stations are relatively rare. Of these, only a fraction will be large enough to create an ionized trail adequate for propagation at 2 meters; most of the time this propagation will allow a single letter to be received. Even at 10 meters the duration may be but a few seconds. There will be longer propagation "bursts" of course, but these comprise but a few of the meteors.

Table 1
Major Meteor Showers

Shower	*Date(s)*	*Hourly Rate*
Quadrantids	Jan 3-5	45
Lyrids	Apr 19-23	12
Eta Aquarids	May 1-6	12
Arietids	Jun 2-14	70
Delta Aquarids	Jul 26-31	22
Perseids	Jul 27-Aug 14	50
Orionids	Oct 18-23	30
Taurids	Oct 26-Nov 16	16
Leonids	Nov 14-18	60
Geminids	Dec 10-14	70
Ursids	Dec 22	13

Just What Are Meteors?

Meteors are chunks of material usually associated with the debris from a comet. They travel in highly elliptical orbits about the sun. Every day, Earth encounters billions of these meteors. When the meteor's orbit crosses paths with Earth's orbit, the meteor is drawn by Earth's gravitational field into the atmosphere at speeds of about 22,000 to 220,000 miles per hour!

Any object moving at that high speed is bound to have an effect when it collides with an innocent bystander, such as an atmospheric air molecule. The large amount of kinetic energy possessed by the meteor is converted to heat from the friction of entry into the atmosphere. Atoms on the surface of the meteor are vaporized because of the high temperature. These vaporized atoms are contained by the air molecules. The interaction between air molecules and high-temperature atoms ionizes the air molecules and strips electrons from the vaporized meteor atoms.

A trail of free electrons and positively charged ions is left behind the meteor as it races through the sky. This ionized trail is parabolic in shape, with the burning meteor at the head. The size of the meteor and its velocity determine the size of the trail. A typical meteor is about 1 millimeter in diameter, about the size of a grain of sand. A particle of this size creates a trail head of about three feet in diameter and a trail length of between 12 and 40 miles, depending on speed.

When Are My Chances Best for a Meteor-Scatter QSO?

The earth encounters meteors that will support communications every day of the year. There are particular times, however, when the number of meteors increases dramatically. Swarms of meteors, probably the remnants of old comet trails, orbit the sun, and Earth passes through these swarms yearly. These swarms cause "meteor showers."

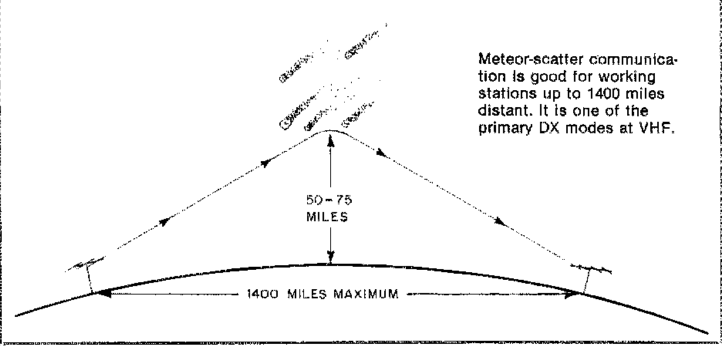
Only a very small percentage of meteors will provide communications between any two points on Earth. Observers use the term "meteor count" to describe the number of meteors that will provide chances for communications between any two points during the course of an hour. The rate depends on the time of day, shower intensity and, of course, radio frequency. During meteor showers, meteor counts of over 60 per hour are quite common on 2 meters, while the count on 10 meters will be greater.

Table 1 shows the yearly meteor showers that are of interest to amateurs. The two largest meteor showers of the year occur in August and December. The Perseids (so named because they appear to emanate from the constellation Perseus) are usually the most productive, followed by the Geminids (emanating from Gemini). Hourly meteor counts on 2 meters of up to 70 and more are quite likely at the peak hours; rates of well over 100 per hour will be seen on 10 meters. Meteor-scatter QSOs are likely, however, during any of the meteor showers listed in the table.

The optimum time of day for meteors is usually in the morning, often around dawn. As Earth revolves around the sun, the "leading edge" encounters meteors first where they are attracted by gravity. As Earth travels further in its orbit, the segments of the planet not in the leading edge are exposed to areas of space that have been "swept clean" of meteors. Only meteors newly arrived to the orbital track can be attracted by gravity for descent to Earth. Consequently, only meteors that have caught up with Earth in its orbit enter the atmosphere.

Burst duration is also greatest around dawn. As Earth revolves around the sun, it has an orbital velocity of its own. At the leading edge of Earth, our planet's orbital velocity is added to the velocity of any meteor attracted toward Earth (much like two cars in a head-on collision; the impact is that much more violent). Burst duration is related to meteor velocity, so the relative velocity improvement found at Earth's leading edge offers an improvement in burst duration.

Some meteor-scatter communication takes place outside of the major meteor showers. Hard-core 6-meter enthusiasts are active most weekend mornings, trying to



Meteor-scatter communication is good for working stations up to 1400 miles distant. It is one of the primary DX modes at VHF.

work new grid squares or just working random stations for the challenge of it. Savvy VHF-contest operators often use random meteor activity to increase multiplier counts dramatically. Most activity takes place on 6 meters between midnight and dawn. The bigger stations routinely work as many as 100 stations and 40 to 50 grid squares via meteors that they would otherwise miss. Meteor-scatter QSOs are possible on 2 meters most mornings, especially during the summer months. More and more stations are scheduling 2-meter meteor QSOs during VHF contests to work additional multipliers.

Where Can I Use Meteor Scatter Propagation?

Meteor-burst propagation can be quite useful for both the VHFer and the amateur operating the ARRL 10-Meter Contest (which usually occurs during the Geminids). For the 10-meter enthusiast, those predawn (preionospheric opening) hours (between midnight and seven local time) can be very productive. Contacts can be made out to about 1400 miles. Rather than waiting to work those relatively close-in stations on backscatter (when the long haul is loud) or on a fluke short-skip opening, they can be worked via meteor propagation.

On 6 meters, which is blessed with quality sporadic-E openings each summer and F-layer propagation at the sunspot peak, meteor scatter is widely used. Bursts can be heard on 6 meters every morning of the year. Although most of these bursts are caused by random meteors, they are usually just called "scatter." Even during non-shower periods, bursts last more than a minute—easily long enough to make contact.

On the higher VHF bands, meteor-burst communication is one of the most reliable long-distance propagation modes available. Sporadic-E propagation on 2 meters allows communications over the same paths as meteors do, but sporadic-E on 2 meters occurs infrequently (perhaps a half dozen times a year) and is only vaguely predictable. Auroral propagation is limited primarily to northern latitudes, and tropospheric ducting is a rare event. Moonbounce provides the most consistent communications link, but it requires above-average station sophistication. Meteor-burst communication is the prime propagation mode for 144- and 220-MHz DX hunters. On 432 MHz, at least three contacts have been made; meteor-burst propagation certainly presents a challenge to the 70-cm operator when bursts are weak and are infrequent.

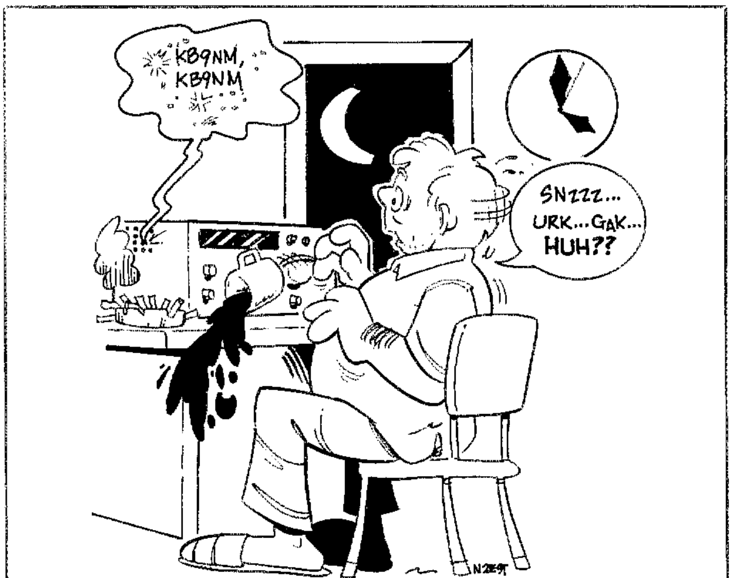
How Do I Make Contact?

Generally, meteor-scatter QSOs are made on SSB. Some operators prefer high-speed CW, and there is some experimentation with packet radio. Although techniques vary from band to band, there is one basic guideline for making meteor-burst contacts: Keep all transmissions as short as possible. Burst duration may be as long as a few minutes or as short as a few seconds. The "opening" time is limited, so time efficiency is very important. The critical aspect is to get call signs and report through—it is easy to make the mistake of talking right through the opening.

Much of the activity on 10 and 6 meters is done randomly. That is, people who enjoy meteor-scatter contacts call CQ or listen for others calling. A good approach for calling CQ on these bands is to call a single CQ, followed by your call sign, repeated two or three times. In that way, even short bursts will convey the information: CQ FROM K1JX. When answering such a CQ, it is usually best to give the other station's call and your own in phonetics once: K1JX FROM W9 ROMEO ECHO. The best response K1JX could give would be W9RE 59 CONNECTICUT and stop. Then immediately W9RE should say ROGER, 59 INDIANA. Upon receipt of W9RE's information, K1JX could say ROGER, QRZ FROM K1JX.

An entire QSO from CQ to QRZ, with complete reports, call signs and acknowledgment (the necessary components for a legitimate QSO) can be completed in about 12 seconds. Usually, a single meteor can sustain ionization for an adequate period of time to complete a contact on 10 meters. Occasionally, multiple bursts are required for both parties to complete the contact. Again, the key is to keep transmissions short and concise. Repeating information unnecessarily is a waste of time, and time is propagation!

Six-meter meteor-scatter operation is similar to that on 10 meters. Since bursts are shorter, it may take several tries to convey all of the information needed to complete



DON'T GIVE UP TOO EASILY!

a QSO.

The story is different on 144 and 220 MHz, however. Because bursts are short and infrequent, most 144-MHz and virtually all 220-MHz meteor-burst contacts are made by schedule or at least through some standardized operating sequence. Schedule frequencies are coordinated in advance down to the kilohertz, as are transmission and reception times. The need for listening and transmitting on the right frequency is obvious. Standardized and agreed-upon-in-advance transmitting and receiving periods keep both stations from simultaneously transmitting or receiving and thereby wasting a possible meteor burst.

Throughout the United States there is a simple accepted standard for transmission timing. Each minute is broken up into four 15-second periods. The station at the eastern end of a potential contact transmits during the second and fourth 15-second period of each minute, and the western station transmits during the first and third period of each minute.

A VHF meteor-scatter QSO may not be completed on a single burst. In fact, since it may take an hour or more for a burst to occur that is good enough to complete a QSO, standards have evolved to judge the validity of a contact. There are three necessary contact components for a contact to be valid. The first is identification of call signs—complete identification. Each station must hear his call sign and that of the other station. The second part is exchange of some sort of information, both ways. The last is acknowledgment, in both directions, of receipt of exchanged information. The integrity of a contact can be considered honored only by strict adherence to this standard. There are those who will try to convince you that something less than this is acceptable. Consider this: Does this person want to really make a contact or does he only want a QSL card? Is the satisfaction in the cardboard or in the accomplishment of a difficult contact?

At the beginning of a schedule, each operator sends calls for the entire 15-second transmit period. The station being called is sent first, followed by the calling station, like this: W9RE K1JX, W9RE K1JX, W9RE K1JX. Some of the most experienced operators "break" about halfway through the 15-second transmission in case a meteor burst is taking place. By doing this, even short bursts can be used successfully.

Once an operator hears a complete set of call signs, he can send the unknown information along with calls. A common system used for years is the S report. A report from S0 to S5 is given based on the burst duration. Unfortunately, the standard for what the different S numbers mean in terms of burst duration have become muddled over the years. As a result of this, the Central States VHF Society, a group of serious VHFers throughout the United States, has advocated the exchange of state or province name in place of an S report. Each system has its merits, but the important thing is for scheduling stations to agree on a particular system. (Random contact seekers don't have that luxury. It adds to the challenge.) In any event, the 15-second transmit period would sound something like this: K5YY K1JX S2, K5YY K1JX S2.

Call signs must be sent continually until you copy the signal report from the other station. You know that the other station has received your call signs when you begin to hear a signal report. A signal report can only be sent upon receipt of complete call signs. Except for an occasional call-sign announcement to satisfy FCC identification requirements, calls needn't be sent from this point on; they only waste burst time.

When you receive a signal report, you can start to send the acknowledgment. This is simply sent in the form of ROGER on voice or R on CW. You must continue to send signal reports until you receive acknowledgment. Then, only the acknowledgments are required. The process is continued until the acknowledgments are received in both directions. The contact is then complete.

Description of the contact sequence may make the process seem difficult and complicated. In practice, it isn't. Since an example is worth something less than a thousand words, here is how a typical schedule between K1JX and KØALL might go. In this case, K1JX receives during the first and third 15-second sequences (00 to 15 seconds and 30 to 45 seconds after the minute) and transmits during the second and fourth.

(As heard at K1JX)

(RX) 0900 (00)-0900 (15)—"Hiss . . ."

(TX) 0900 (15)-0900 (30)—KØALL K1JX, KØALL K1JX, KØALL K1JX, BREAK . . . (momentary hiss) . . . KØALL K1JX, KØALL K1JX, KØALL K1JX

(RX) 0900 (30)-0900 (45)—"Hiss . . . ØALL K1JX . . . Hiss . . ."

(TX) 0900 (45)-0901 (00)—KØALL K1JX, KØALL K1JX, KØALL K1JX, BREAK . . . (momentary hiss) . . . KØALL K1JX, KØALL K1JX, KØALL K1JX

Some time later

(RX) 0911 (00)-0911 (15)—"Hiss . . . JX KØALL K1JX KØ . . . Hiss"

(TX) 0911 (15)-0911 (30)—KØALL K1JX S2, KØALL K1JX S2, BREAK . . . (momentary hiss) . . . KØALL K1JX S2, KØALL K1JX S2

(RX) 0911 (30)-0911 (45)—"Hiss"

Continues like this until sometime later

(RX) 0913 (30)-0913 (45)—"Hiss . . . K1JX KØALL S2 K1JX KØALL S2 K1JX KØ . . . Hiss"

(TX) 0913 (45)-0914 (00)—ROGER S2, ROGER S2, ROGER S2, ROGER S2, BREAK . . . (momentary hiss) ROGER S2, ROGER S2, ROGER S2, ROGER S2

(RX) 0914 (00)-0914 (15)—"Hiss . . . S2 S . . . Hiss"

(TX) 0914 (15)-0914 (30)—ROGER S2, ROGER S2, ROGER S2, ROGER S2, BREAK . . . (momentary hiss) ROGER S2, ROGER S2, ROGER S2, ROGER S2

Continues until some time later

(TX) 0917 (15)-0917 (30)—ROGER S2, ROGER S2, ROGER S2, ROGER S2, BREAK . . . (momentary hiss) ROGER S2, ROGER S2, ROGER S2, ROGER S2

(RX) 0917 (30)-0917 (45)—"Roger Roger Roger Roger Roger Roger Roger . . . 73, 73"

(TX) 0917 (45)-0918 (00)—73, 73 RON BREAK; "73 Clarke"

Calling CQ for random contacts on 2 meters is a similar process. The time sequences are the same, except that you call CQ instead of another station during the appropriate 15-second period (CQ K1JX, CQ K1JX . . .). The greater challenge here lies in identifying the caller, exchanging reports and acknowledging, all without any prior knowledge. Usually, random CQing is carried on at 144.200 and 5 kilohertz increments up and down from calling frequency (144.195, 144.190, 144.205, 144.210, and so on). There is so little 220 meteor-scatter activity that almost all work there is done by schedule.

You can get started by listening to 6 meters during any VHF contest or on most weekends. If you hear stations calling CQ, give them a call—just be ready for a quick reply. If you're only on HF, listen to 10 meters during the ARRL 10-Meter Contest. And you can try 2 meters during the meteor showers. No matter what your planned activity, remember one thing: Keep it short and sweet.

What Kind of Equipment Do I Need to Work Meteor Scatter?

As with any weak-signal work, a sensitive receiver, legal-limit power amplifier and high-gain antenna will make meteor-scatter communications easier. If you don't have these things, not all is lost!

For 10-meter work, all you'll need for many meteor-scatter QSOs is a standard 100-W transceiver and a three- or four-element beam. If you have a kilowatt amplifier, you'll be able to work even more stations.

At 6 meters, you can use as little as 10 W and a small Yagi to work some of the "big guns"—if you're patient. You'll enjoy a slew of contacts with 100 W and a four-element beam. If you run high power and have a good receiving preamplifier, you'll practically be able to ragchew with other big stations.

On 2 meters, the average station consists of a multimode transceiver, 100- to 160-W amplifier and a single long Yagi. You'll be able to make many a schedule with a setup like this, but if you're interested in random contacts you'll probably want more. A good station for that type of operation might include a pair of long antennas, a low-noise preamplifier and a 500- to 1500-W power amplifier.

Signals at 220 MHz are much weaker, so a better station is desirable. You'll want a low-noise receive preamplifier and a pair of antennas. Although contacts are possible with a 100-W "brick" amplifier, a tube-type amp capable of 300-500 W or more is a big help.

In Search of the Perfect Picture

Part 2: Here's the "how-to" installment you've been waiting for. You're now one step closer to the perfect picture!

By Clayton W. Abrams, K6AEP
1758 Comstock La
San Jose, CA 95124

Probably the most exciting product to be introduced to SSTV in the past few years is the Robot Research Model 1200 Color Scan Converter.[1] This unit is in a class by itself because of its high-resolution capability and computer interface. The interface is unique and allows the converter to be expanded beyond its intended SSTV application. The converter has all of the attributes of expandability, resolution, manufacturer's reputation and microprocessor control I discussed in Part 1. The converter also has many built-in features not available in competitive units. These additional features are accessible only by a host computer attached to a parallel or serial interface within the 1200. Robot Research produces units with less capability and cost, but these units do not allow for expansion and upgrades as does the 1200. The 1200 can display 240-line color pictures with 256 pixels per line. Each pixel can have over 200,000 unique colors! To see how this is possible, let's pull out our screwdriver and open the 1200 to see how it works.

Inside the Robot 1200

At the heart of the 1200 is an Intel 8031 microprocessor. This is a relatively new IC. It has built-in parallel ports, timers, RAM, a serial port and a rich instruction set. The instruction set is designed to allow for the easy movement of bits and bytes in memory. For example, the processor allows single-bit memory locations to be addressed directly as you would 8-bit memory locations! The processor also has a high code-execution speed that adds to its usefulness. This processor is used as a "traffic cop" to interpret operator instructions from the front panel or computer interface. A 16-kbyte × 8-bit EPROM (27128) contains the microcode or intelligence for the converter.

Table 1
High-Resolution Picture Memory Requirements

Mode	*Color, 240 lines (bytes)*	*B & W, 240 lines (bytes)*
No compression	184,320	61,440
C1 image compression	138,240	46,080
C2 image compression	61,440	23,040

To discuss each microcode instruction would be impractical. I can, however, discuss some of the major categories of the computer-controllable instructions that allow the code to be more easily understood.

Robot 1200 Commands

Read/Write Commands: These commands allow the picture information to be transferred to and from a host computer by means of an internal parallel interface. The commands allow portions of pictures, entire pictures, full-resolution pictures or compressed-resolution pictures to be transferred. The memory requirements for the host computer range from 185 kbytes to 31 kbytes, depending on the picture resolution involved. A total of 13 commands is in this set.

Memory-Selection Commands: A total of seven commands tells the 1200 where in memory the picture is to be moved or loaded. The 1200 is segmented into two "pages" or low-resolution picture areas of one large, high-resolution picture area.

Special Functions: Some of the more exciting features of the 1200 are controlled by 14 special-function commands. These include sending tones from the 1200, inverting images, displaying a gray scale, test-pattern generation, adding graphic characters to pictures and zooming to any screen location. Black-and-white or color pictures can be sent to a printer attached to the parallel port.

Control and Status Commands: These commands allow the computer to access any of the front-panel controls of the 1200. This permits memory selection and speed changes to be made from the computer. Two additional functions can also be computer selected—the panel status and the vertical position of the in-memory SSTV frame last transmitted.

Selecting a Computer

With the rich instruction set the 1200 has, an obvious enhancement to the SSTV system is the addition of a controlling computer. With the proper interface, the computer can not only gather picture data from the 1200, but it can use the 1200 as an external display interface.

To accept picture information from the 1200, the computer must have a large amount of memory and the means of directly addressing this memory. The memory requirements for picture storage are shown in Table 1. As you can see, a high-resolution picture occupies a lot of memory. The two compression modes allow pictures to be saved in less memory. The C1 compression mode is equivalent to the high-resolution mode, but takes 46 kbytes less. The C2 compression mode does cause a slight degradation in picture quality, but the resulting picture is still amazingly good using this limited amount of memory.

Once an image is transferred to the computer, you can perform image analysis or

†Part 1 appears in December 1985 *QST*, page 14.
[1]Notes appear on page 24.

save the picture to disk. When choosing a computer system to use with the 1200, you should select a computer equipped with a microprocessor that can handle large amounts of data and one which supports high-volume disk storage. Two popular computers now available meet these criteria. One computer uses an 8088 microprocessor; the other has a 68000 microprocessor. I chose the 8088-based system, an IBM PC-XT, for this project because of the large amount of software support and ease of software development. I found that a hard disk is a desirable accessory if you plan to perform picture storage, especially high-resolution color pictures. If floppy disks are used for storage, only one high-resolution picture can be stored per disk.

Next, you must decide what programming language will be used to write the necessary software. I wrote the software in BASIC and C. (This software has not been optimized.) Assembly language is too difficult to write and understand, and BASIC is too limited and slow to use alone. I found C to be almost as fast as assembly language and relatively easy to code. I use C in all of my advanced PC projects.

Computer Interface

Two methods of interfacing the 1200 to the computer exist: serial and parallel. The serial interface is by far the simplest. All you need is the asynchronous communications hardware for the PC and some simple driving software. The 1200 has a built-in serial port that communicates through an interface at 4800 bauds. This interface is a one-way communications path only; no handshake is included in the 1200's microcode. Therefore, all control-program timing loops must be written carefully. This interface allows only graphics information to be placed on the display. The available commands for use in the serial mode are a subset of the commands mentioned previously. A use for this interface will be discussed later.

The parallel interface is the more flexible of the two. Before deciding how to tackle this interface, I had to make some decisions on what I was trying to accomplish. Although I found the 1200's features extensive, I wanted more. I required the ability to receive WEFAX. This is as important to me as SSTV. How could I accomplish this feat? One way was to rewrite the 1200 microcode. This could be done, but it would require a lot of work. The easier path was to have the computer accept the analog data, then transfer it to the 1200. All that's required to do this is an analog-to-digital converter (ADC) on the interface card along with the 1200's parallel-interface hardware.

I could have purchased an interface card from John Bell Engineering, but I did not have a spare full slot in my PC to hold the card.[2] Therefore, I decided to design my

Table 2
Metra-Byte PIO-12 To Robot 1200C Connections

DB-25M Pin No	*1200C Signal*	*DB-37F Pin No*	*Metra-Byte Signal*
1	Data out 0	37	PA 0
2	Data out 1	36	PA 1
3	Data out 2	35	PA 2
4	Data out 3	34	PA 3
5	Data out 4	33	PA 4
6	Data out 5	32	PA 5
7	Data out 6	31	PA 6
8	Data out 7	30	PA 7
9	NOT out strobe	25	PC 4
10	Output busy	24	PC 5
11	Ground	19	Digital common
12	Ground	17	Digital common
13	Ground	15	Digital common
14	Input data 0 (LSB)	10	PB 0
15	Input data 1	9	PB 1
16	Input data 2	8	PB 2
17	Input data 3	7	PB 3
18	Input data 4	6	PB 4
19	Input data 5	5	PB 5
20	Input data 6	4	PB 6
21	Input data 7	3	PB 7
22	NOT input strobe	22	PC 7
23	Input busy	29	PC 0
24	Ground	13	Digital common
25	Ground	11	Digital common

Care should be taken to ensure correct connections before attempting to connect the Robot and the computer. The Metra-Byte connector has +5, −5 and +12 V dc on unused pins.

To use the PIO card with the software, the board address must be 280 H or 640 decimal. The top left of the card has an 8-position DIP switch that must be set as follows:

8	7	6	5	4	3	2	1	0
ON	OFF	OFF	ON	ON	ON	ON	ON	ON

own card to fit the small I/O slot on the PC-XT mother board. Another option exists for those of you who are not interested in WEFAX operation: Use a Metra-Byte card.[3] Pin-out information for the Metra-Byte card is shown in Table 2.

The parallel interface requires eight bits of bidirectional data and two bits each way for the handshake signals. Much to my surprise, I did not have to place interface drivers on the card. This is because data is transferred in one direction only at a time, and there's a long delay between transfers. So, if any ringing or noise is present on the interconnecting line, it is not seen. (I currently use an interface cable 20 feet long without problems.)

Next, I had to determine at which address I could place the card. In the PC-XT, only a small band of I/O addresses is available that do not conflict with any existing hardware. One range of usable addresses is Ø2ØØH to Ø3ØØH; I chose to use an address of Ø28ØH (H designates a hexadecimal address).

The schematic diagram for the homemade interface card is shown in Fig 1. This card uses two 8255 ICs for the I/O ports. The first 8255 is used to communicate between the PC and the 1200. The second 8255 handles the analog signals. For the ADC, I chose the National ADC0809. This is a low-cost IC ($4.95), and is a reasonably fast and accurate 8-bit ADC with an 8-way multiplexer. The IC is strapped to allow for input signal amplitudes of 0 to 5 V. Strapping is accomplished by connecting the reference on pin 12 to +5 V and connecting the reference ground (pin 16) to ground.

I use the second analog input at pin 27 for all my FAX signal inputs. To digitize FAX requires relatively slow ADC operation. The ADC0809 has a conversion time of 100 μs—more than adequate for this type of operation. A sample-and-hold circuit is not required. Only one additional input signal is required for FAX: a sync signal derived from the FAX decoder interface. This pulse is fed to port C of the 8255 and is conditioned by a single gate. Conditioning is required for noise reduction and to bring the input signal to TTL levels. The FAX interface has an output level of +8 V. This signal tells the software that data will immediately follow detection of the sync signal.

The remaining seven analog input signals to this interface can be used for any type of instrumentation application you wish. One possible application is the reception of other SSTV formats not provided by the Robot 1200. With a little imagination, other applications can be designed.

One port on the second 8255 is not used. This allows eight free bits for use in other applications. This port is intended to be used as a digital-to-analog (D/A) port and is left free for possible use as an SSTV generator. A DAC and VFO could be installed. With a little clever software, FAX or SSTV signals can be generated by the PC.

Software

Language Types

Now that we've constructed a bit of hardware, how do we fit it all together? The "glue" we use is software. (I call it "glue" because it's sticky to write and ties things together.) Some of the software is written in IBM/Microsoft® BASIC. Since the software listings (BASIC and machine language) are so long, they are not published here.[4]

As mentioned earlier, BASIC is not ideal for this application. The language has only one advantage: It is used and understood by many people. When the programs are run in the interpretive BASICA mode on the PC, operation is quite slow. To speed up the programs, you can compile them using the IBM/Microsoft BASIC Compiler. Both programs are written so that they are compatible with the BASIC V1 Compiler. When compiled, the software

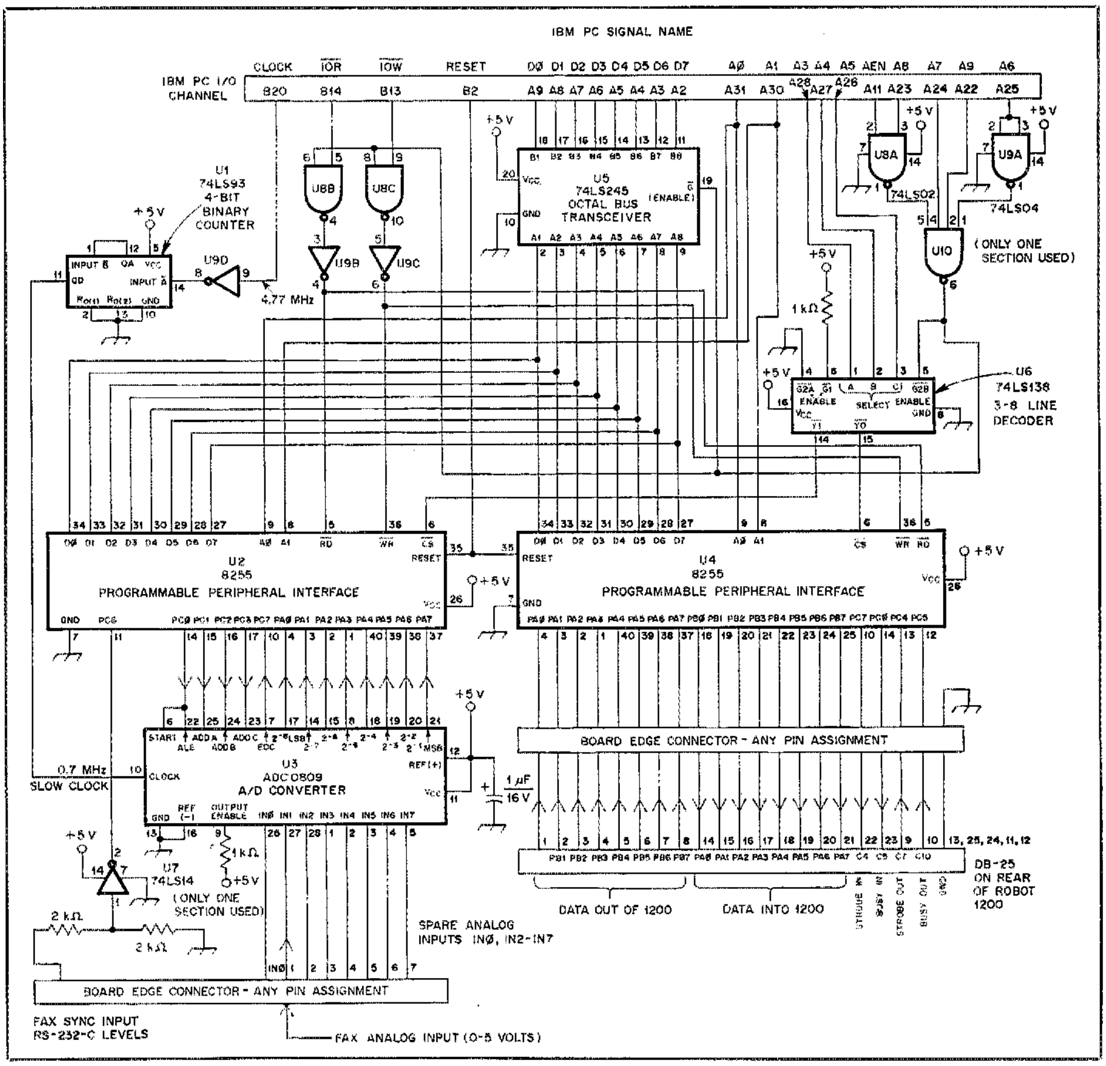


Fig 1—Schematic diagram of the PC/Robot 1200 interface. The base address for U2 is 286H; for U4, 28ØH.

will run at least 10 times faster. To go even faster, another language must be used. Two possibilities are Forth and C. Pascal is not a good choice since it severely lacks I/O-handling capability.

One of the problems the software has to conquer is how to transfer 183 kbytes of information to the RAM (random-access memory) in the PC. Few languages for the PC support the ability to address directly all of the available RAM. Only three ways currently exist to do this: BASIC, C and assembly language. In BASIC and assembler, you must figure out how to use the 8088 segmentation register. This can be very difficult for many novice programmers to do. If C is used, you don't have to worry about this! An array can be declared and addressed directly in the large memory models of most professional C compilers such as the CI-C86, Mark Williams and Microsoft compilers. The Lattice C compiler is one of the more popular compilers and is the one I use for FAX.

BASIC Programs

Let's examine the two BASIC programs that control the 1200. These programs are called SERIAL.BAS and PARALLEL.BAS. The program names describe the type of interface with which they are used.

SERIAL.BAS: This program is menu driven. The menus allow you to select all of the built-in Robot 1200 functions such as test-pattern generation, camera-frame grabbing, zooming in on images and the generation of various size characters of a multitude of colors at different screen positions. The program assumes that the PC has an asynchronous communications interface card in the COM2 position. If your system has just one communications port, change line 19Ø to COM1. On the asynchronous DB-25 connector, place jumpers between pins 4 and 5, and 6 and 20. These jumpers tell the port not to expect any handshaking with the 1200. Program lines 24Ø through 27Ø are software delays for transmission of the SSTV RGB sequence.

These WEFAX pictures were captured by K6AEP on August 15, 1985. At the left, Hurricane Danny is shown slamming into the east coast of Louisiana. The photo on the right shows the tropical quadrant of Danny.

This sequence is used when images are transmitted to older color SSTV systems. The software delays are approximate and are the delays between picture transmission. Watch out when using software delays in BASICA. This version of BASIC has a built-in function called "garbage cleanup" or a "garbage collector." This means that the BASIC intepreter will periodically interrupt program execution to discard temporary variables no longer in use. Because of this, exact software timing loops cannot be counted on. Software delays in IBM BASIC are approximate and will vary each time the program is run.

Program lines 31Ø to 35Ø contain the strings holding call signs and other specifics that are displayed. Change the contents of these strings to hold the correct information.

PARALLEL.BAS: Also written in IBM/Microsoft BASIC, this program allows commands to be routed to and from the 1200 via the parallel interface of Fig 1. You can run this program under BASICA, but this is not recommended because of the slow execution speed; this program should be compiled for the reasons mentioned earlier. PARALLEL.BAS provides picture transfer, disk storage, character generation and other features. Like SERIAL.BAS, PARALLEL.BAS uses the same areas for text messages and the COM2 serial port. Two delay constants in lines 42Ø and 43Ø can be changed to accommodate the compiler or serial port.

The program allows for two picture sizes to be transferred—184 kbyte (full RGB) or compressed resolution (C2) 61 kbyte. A segmentation-register location of 45ØØ was chosen to store the pictures. This location was chosen by trial and error and is largely dependent on what type of software you're using. If you have Sidekick™ and a printer spooler installed when you try to transfer pictures, the segmentation registers may have to be changed. The register is defined in line 2Ø4. A simple BSAVE command is used to save pictures to disk; BLOAD is used for loading. These commands are limited to handling 64 kbytes at a time. If you wish to save or load high-resolution pictures using these commands, you'll have to develop a method to append the files once they are saved to disk. The disk routines are located in lines 4ØØØ through 427Ø, inclusive.

Lines 331Ø to 396Ø contain the picture-transfer routines. These routines expect that an 8255 parallel interface is attached to the computer at the addresses defined in lines 23Ø to 31Ø. These lines may be altered to contain any address in the PC I/O memory map. The handshake lines for the parallel interface are in lines 26ØØ to 267Ø. Subroutine access to the parallel interface is through these lines. The remaining portions of PARALLEL.BAS are similar to SERIAL.BAS.

WEFAX

Currently, a number of satellites orbit the earth and stream pictures back to earth on a daily basis. Some of these satellites use signals in the VHF range and others use the microwave (S band) frequencies. These satellites are under the jurisdiction of the National Environmental Satellite Service

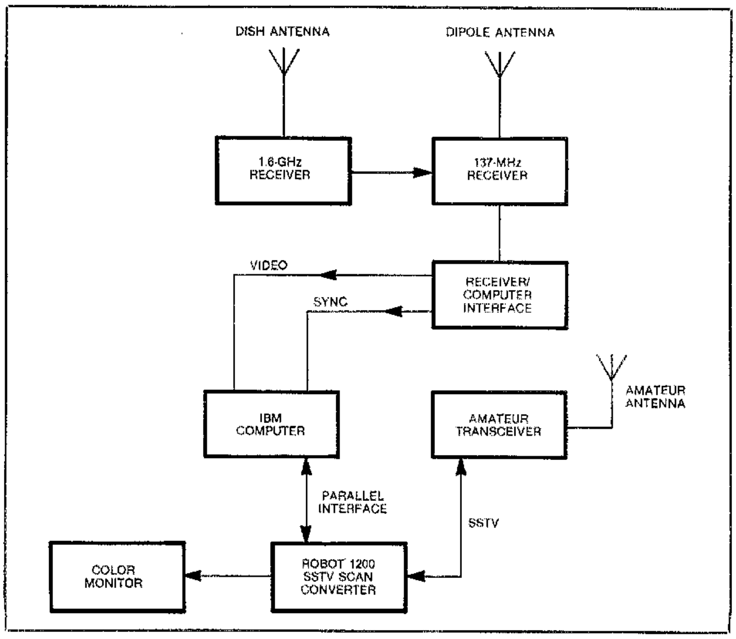


Fig. 2—Block diagram of an S-band satellite receiving station.

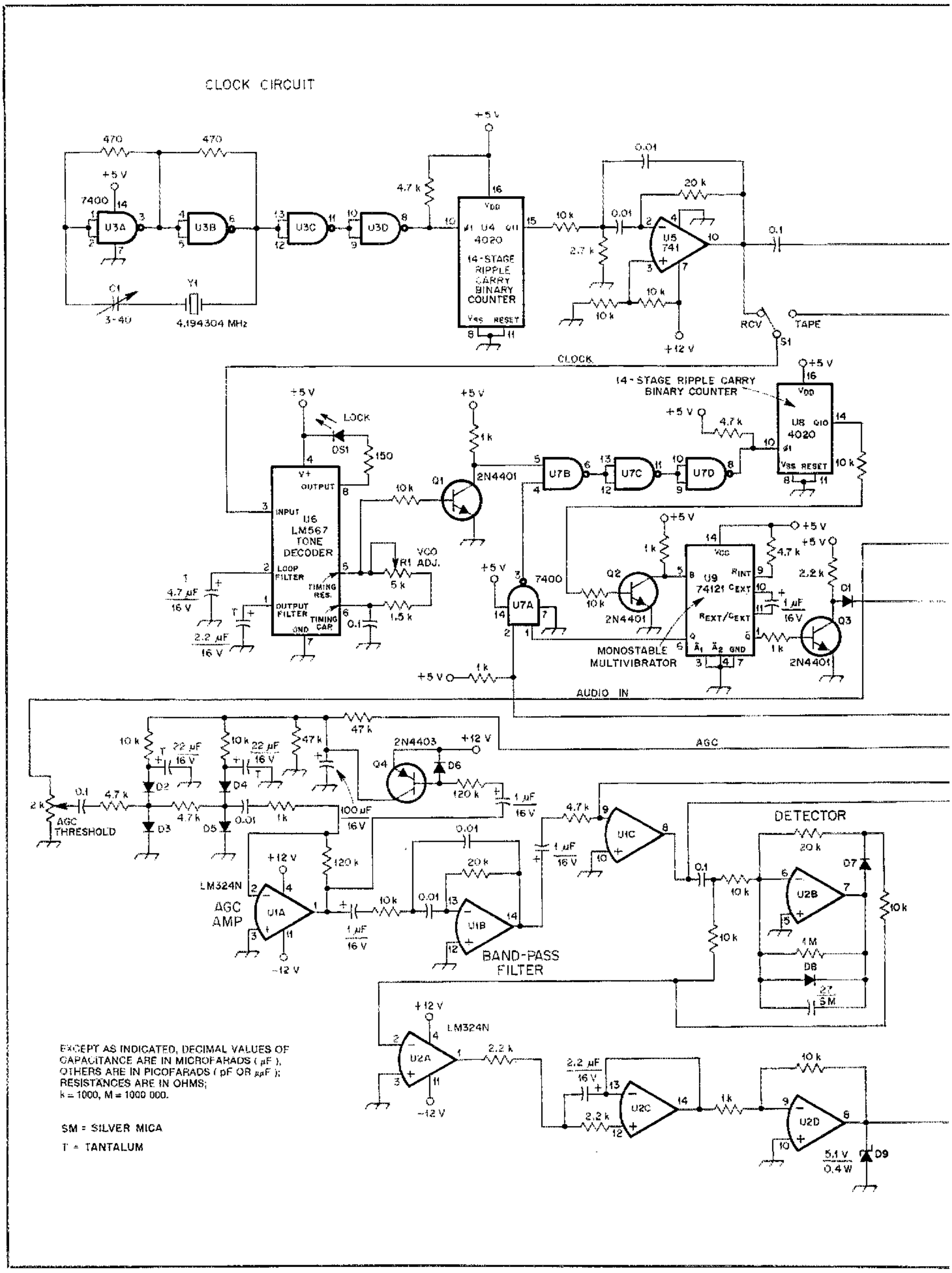
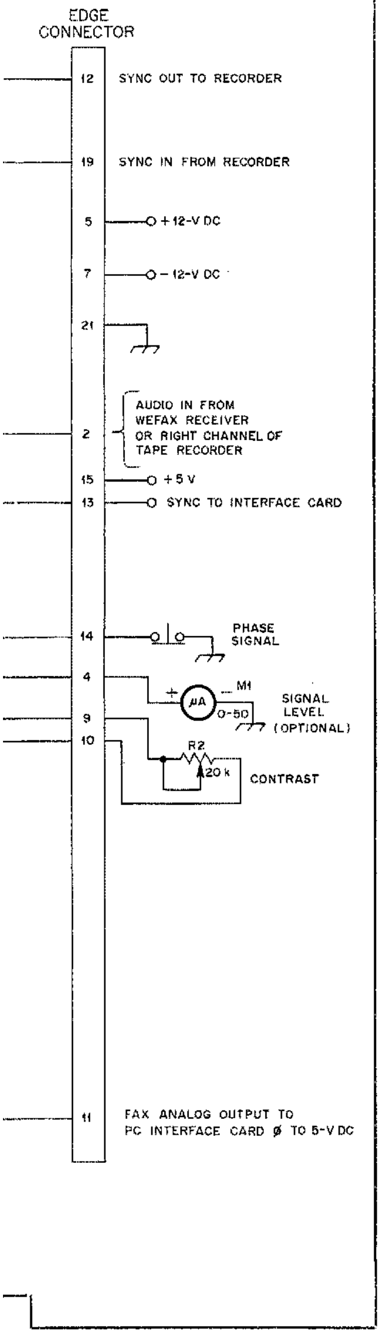


Fig 3—The FAX interface schematic diagram. All diodes are 1N4148 or equivalent.



(NESS) of the National Oceanographic and Atmospheric Administration (NOAA) of the US Department of Commerce. Some of the satellites orbit the earth at altitudes of 600 miles or so; these are called *polar orbiters.* Other satellites orbit the earth at the same speed at which the earth rotates and at altitudes of about 23,000 miles. These satellites are called *geostationary.* With geostationary satellites, you can point your receiving antenna at one location in the sky and receive continuous pictures of the earth's surface and atmosphere.

Your WEFAX Station

Over the years, many amateurs have used their skills to receive WEFAX signals and use the resultant data to predict local weather. This type of reception is closely related to SSTV; the only major difference is the type of front-end electronics equipment used. Providing a blow-by-blow account of setting up a complete WEFAX receiving station is beyond the scope of this article,[5] but a brief description is in order.

To receive the VHF satellite signals, the receiver should have a wide bandwidth (30 kHz) and be capable of receiving signals at 137 MHz. The antenna may be a simple crossed dipole with a vertical pattern. The S-band satellite receiving station requires a 1691-MHz converter ahead of the VHF receiver. A block diagram of such a station is shown in Fig 2. This type of gear is difficult for the average amateur to construct, but it is available from commercial sources.[6,7] The VHF receiver used with the converter should have a variable IF. This is necessary because the microwave downconverter can drift 10 to 20 kHz, depending on the outside temperature. For S-band signals, the antenna can range from a high-gain Yagi to a homemade dish. I found that a 4-ft-diameter dish, a GOES receiver and a preamplifier with a noise figure of 2 dB can produce closed-circuit picture quality at my QTH.

The FAX/Computer Interface

Once you can hear the satellite, the next step is to convert the image into a form that can be placed directly into the computer. "Color Computer SSTV" (*73,* Nov/Dec 1984) provides some background on the signal formats that are emitted by the satellites. The circuit for the decoder shown in Fig 3 was developed by Dr. Ralph Taggart, WB8DQT, for use with the Radio Shack TRS-80C® Color Computer. An earlier version of this circuit was published in the "Color Computer SSTV" article. If you do not wish to build the interface, you may purchase it.[8] The interface may be placed in a box with its own power supply and connectors.

Video Circuits

Video information (at audio frequencies) from the VHF/FM receiver or the right channel of the stereo tape recorder enters at edge connector pin 2 and is amplified by U1A. U1B is a 2400-Hz active band-pass filter, and U1C is a gain block with the gain controlled by the 1200's front-panel CONTRAST control. Video detection, filtering and buffering are done by U2. U2A and B provide precision full-wave detection; U2C is the active low-pass post-detection filter, and U2D inverts and buffers the signal before sending it to the ADC via pin 11. The peak white level is set by the CONTRAST control (R2), but it is limited to +5 V by means of a Zener diode (D9) at the output of U2D.

Clock and Sync Circuits

FAX signals may be handled directly or a stereo tape recorder may be used to record and play back the signals. During recording, the signal information is fed to the right channel and a synchronization signal to the left channel. The interface clock is the means by which the computer syncs the video information with the display. Oscillator U3 operates at 4.19304 MHz. The output frequency is divided by a factor of 2040 by U4. The resultant frequency is 2048 Hz. This signal is buffered and filtered by U5 and fed to pin 12 of the edge connector for use during recording.

When the RCV/TAPE switch (S1) is in the RCV position, U6, a phase-lock loop tone detector, receives the sync signal directly from the clock circuit. With S1 in the TAPE position, the incoming 2048-Hz sync signal from the left channel of the tape recorder at pin 19 is fed to U6. The VCO output of U6 is buffered to TTL levels by Q1 and routed through a series of phase-control gates and a buffer (U8). This results in a 2-Hz or 120-LPM (line-per-minute) clock signal. The signal is then buffered by Q2, which drives a 5-ms single-shot trigger, U9. Output from U9 drives an RS-232-C level buffer that is internally connected to the PC interface. The other output of U9 is connected to a phase circuit. This phase circuit extends the duration of the single shot so that the video portion of the detected FAX signal is placed at the center of the display.

FAX Software

On the disk with the BASIC programs is a simple program written in C that can be used to receive FAX signals with the PC/Robot 1200 combination. This program assumes that the hardware described in this article is constructed as shown. Written in Lattice C, the software makes calls to the ROM BIOS and may not function on some of the IBM PC compatibles. The program feeds picture bytes to the computer and transfers them immediately to the 1200. Provisions are made to reset the picture to the top of the screen to permit phasing the sync pulses. Software delays are used for timing the reception of the FAX signals. For those of you who

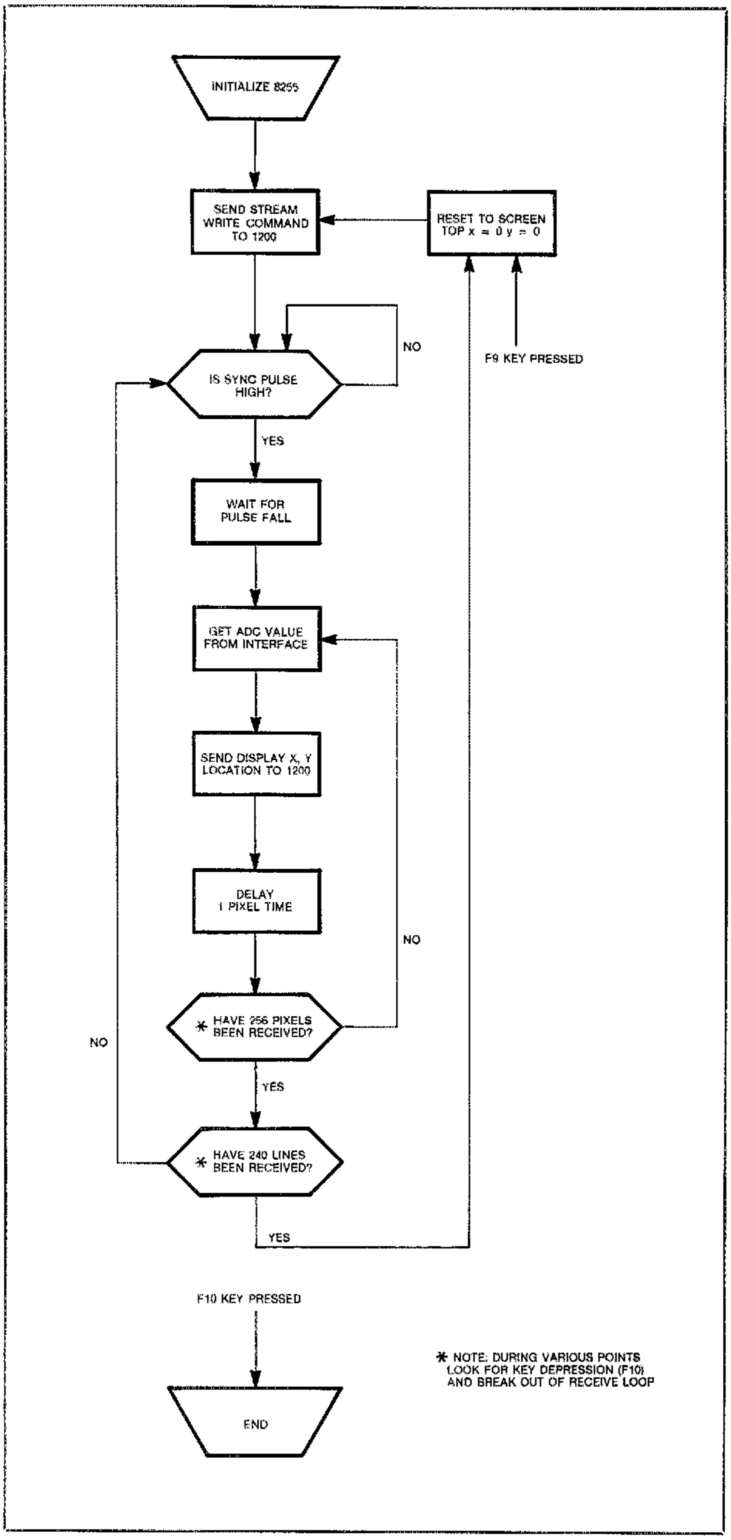


Fig 4—FAX software flowchart for K6AEP's program.

wish to know more about writing your own FAX software, Fig 4 provides a flow chart of how this program functions.

Conclusions

This PC/Robot 1200 project has been very rewarding. It has touched many new areas of Amateur Radio that were not reachable with the technology that existed only a few years ago. I expect numbers of units like the 1200 will become available with computer interfaces. These units will attach to off-the-shelf personal computers to create systems of a complex nature and perform functions never dreamed of by their designers.

I would like to thank my friend and associate, Dr. Ralph Taggart, for his help in designing the FAX interface and allowing me to publish the circuit. Thanks also to Robot Research for their assistance in providing photographs of the 1200. I hope many of you will benefit from this article. Perhaps you can improve on my work—I'm anxious to hear from you!

Notes

[1]Robot Research Inc, 7591 Convoy Ct, San Diego, CA 92111, tel 619-279-9430.

[2]Universal I/O card 83-064—available from John Bell Engineering, 1014 Center St, San Carlos, CA 94070, tel 415-592-8411.

[3]This card bears the part number PIO-12 and is available from the Metra-Byte Corp., 254 Tosca Dr, Stoughton, MA 02072, tel 617-344-1990. The price is $97 plus shipping. The Metra-Byte card has a 37-pin male D connector that protrudes through the rear of the PC. The mating cable should use a 37-pin female D connector (DC37S for solder connections, or AMP 745242-1 for insulation-displacement cable).

[4]Contact the author for information on obtaining the software. Please include a business-size SASE; foreign correspondents should include two IRCs.

[5]More information can be found in the *New Weather Satellite Handbook*, by Ralph Taggart (Peterborough: Wayne Green Publications, 1983). Unfortunately, this book is now out of print.

[6]Vanguard Labs, 196-23 Jamaica Blvd, Hollis, NY 11423, tel 718-468-2720.

[7]Spectrum International Inc, PO Box 1084A, Concord, MA 01742, tel 617-263-2145.

[8]RTM Circuit Boards, 205 Elm St, Van Horne, IA 52346.

Strays

And on the Last Page ...

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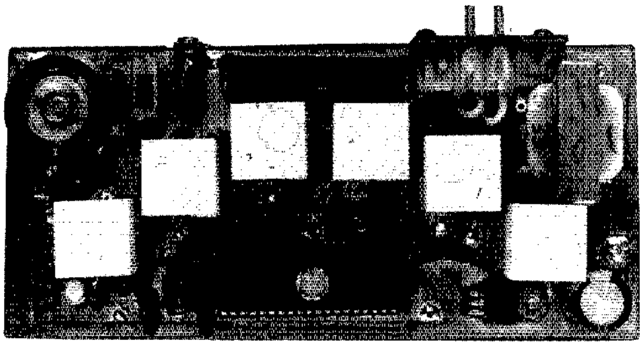
Send Error-Free Code with One Hand



This small, one-hand keyboard keyer includes its own microcomputer.

By W E Quay, W4MKC* and R H Turrin, W2IMU**
*4128 SE 10th Ave, Cape Coral, FL 33904
**PO Box 65, Colts Neck, NJ 07722

Standard keyboard keyers offer the advantage of error-free character formation, but require two-hand operation and a large keyboard. We will describe a small and unusual one-hand electronic keyboard keyer that generates Morse code characters from multiple key closures. The circuit uses six keys that provide a sufficient number of key closures to accommodate the English alphabet, the decimal numbers, selected punctuation marks and a few special radiotelegraph characters. Five keys would not provide sufficient combinations to develop this format of characters: Six keys allow 63 combinations—more than enough to accommodate all the characters.

The keyer design is based on the use of a single programmable Intel 8748 microcomputer with internal EPROM (*E*rasable *P*rogrammable *R*ead *O*nly *M*emory). With this approach, the microcomputer replaces much circuit hardware. While this may not be the most economical approach, it minimizes construction time, part count and size. A dual timer (556) acts as the code-speed clock and audio sidetone oscillator.

Operating Features

Special operating features of the keyer are:

Initialization

When the keyer is turned on, a sequence of five dots is produced by the sidetone monitor. Transmitter keying is not implemented at this time, but the first keyboard entry will drive both the monitor and the output to the transmitter in parallel. These five dots provide an audible indication that the keyer has been turned on and an indication of the keyer speed setting. This feature is provided instead of a pilot light.

Automatic Space Bar

The keyer does not use a space bar, but provides that code characters do not appear at the keyer output until all keys have been released. To send a character, it is necessary to press only those keys that form the input pattern for the desired character, then release all keys and the code output will start. All character generation is self completing, which means that a space equal to one dash length follows the end of each character without interruption. This ensures proper character spacing, a feature commonly found in most modern electronic keyers.

Overlapping Key Accumulator

In forming the multiple-key closures, it is not necessary that all keys be pressed simultaneously. The keys may be pressed in any sequence provided they overlap in time. The last key of a sequence, when released, initiates the code output. The operating program also provides for software key debounce of about 10 ms.

Two-Character Buffer

It is highly desirable to have some buffering of the output in any keyer. The short Morse code letters, such as "E", require less time to complete and would ordinarily require rapid finger keying to begin the next letter. With a buffer, one can generate characters ahead of the output and send smooth, continuous code output without having to hurry the input. The two-character buffer provided in this design is arbitrary, but sufficient to permit the code output to be smooth and still maintain immediate presence of sending.

Abort Key Code

A simple method of correcting errors before transmission is provided. This feature permits the current input code to be aborted simply by pressing all six keys before the last one is released.

Circuit Description

The schematic diagram is shown in Fig 1. A PC board is recommended, but not necessary. A socket is required for U2, but sockets are optional for the other ICs. Wiring is not critical, except for the code-speed timing circuit. Half of the 556 dual timer, U1, is a free-running clock pulse generator. The clock pulse is applied to the interrupt (pin 6) of the microcomputer. The actual dividing process to generate dots and dashes is the function of the microcomputer program. The length of a single dot is equal to 16 timing-pulse periods. The RC values shown in Fig 1 produce a Morse code speed range of approximately 10 to 40 WPM. The 0.1-μF timing capacitor should be connected directly from U1 pins 8-12-13 to U1 pin 7 to ensure that the output timing interrupt pulses have a pulse width of less than 10 μs. The other half of U1 provides a keyed sidetone oscillator that drives a small speaker.

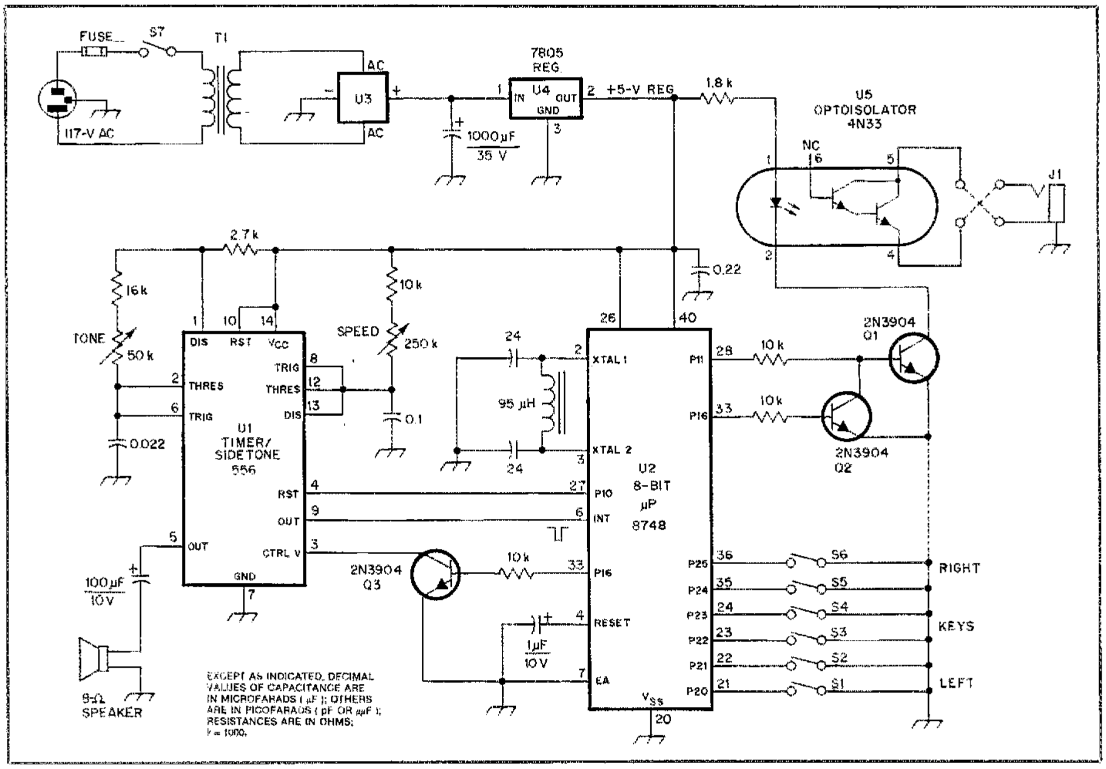


Fig 1—One-hand keyer schematic diagram.

Q1-Q3—NPN transistor, 2N3904.
U1—Dual timer, 556.
U2—Microcomputer, Intel 8748.
U3—1.0-A, 50-PIV diode bridge (RS 276-1161).
U4—Voltage regulator, 5-V (RS 276-1770).
U5—Optoisolator, Darlington, Motorola 4N33 or equiv.
T1—Power transformer, 12-V, 300-mA (RS 273-1385).

The microcomputer clock tank, connected between pins 2 and 3 and ground, should have short leads. The oscillation frequency will be around 3.6 MHz and is not critical. The 8748 IC bypass capacitor should have low lead inductance, and should be connected directly between pins 20 and 40, which are at opposite ends of the large IC. A 0.25-inch-wide copper strip running between the IC pins is recommended as a common ground strap.

Transmitter keying is accomplished by an optoisolator that permits wiring the polarity to accommodate the transmitter. Most modern transmitters can be keyed directly with this method. The output transistor in the optoisolator has a reverse breakdown voltage of about 30 V and a forward current rating of about 50 mA. The other three transistors are used as logic switches to inhibit keying during microprocessor initialization.

The Keyboard

The input keyboard is a critical part of this keyer—it must provide a comfortable and functional interface between the operator and the electronics. Generally, Amateur Radio telegraph operators prefer to use only one hand for generating code, keeping the other hand free for housekeeping chores such as turning knobs, throwing switches, thumbing through logs or papers and possibly writing cryptic notes. Accordingly, a prime requisite of this keyboard is to be operable with one hand. The six keys are placed in an arc, and the symmetry of this arrangement allows right- or left-hand operation. This keyboard represents our best single-handed operator design, but this does not preclude using whatever arrangement you find most comfortable.

The keys must not require too much pressure to operate since multiple keys must be pressed during operation. They should have fairly large tops for easy access, and the closure travel distance should not be too great or speed will be sacrificed. We used standard computer-grade, reed-switch keys modified to meet the requirements. It may be more appropriate and convenient to use keys that present a low profile for operating ease, such as the types used in hand calculators.

Microcomputer Software

The heart of this keyer's operating system is the program that is entered into the 8748 microcomputer EPROM. The 8748 has 1020 bytes of erasable programmable space available, arranged in four 255-byte pages. Only about 150 bytes are used for the operating program, and about 50 for a look-up conversion table that generates the output code characters. Table 1 shows the program listing for the complete operating system, including the character look-up conversion table for the authors' choice of input key combinations, and the corresponding international Morse code and special characters. The look-up conversion table is purposely placed in page 3 of the EPROM because a simplified instruction for accessing this type of table is available in the 8748 microcomputer. The input key codes are shown in Table 2. The choice of input key codes is based partly

Table 1

Program Listing for the 8748 Microcomputer EPROM

Line No. Decimal	*Line No. Hexadecimal*	*Machine Code Hexadecimal*	*Instruction Mnemonic*
Page #0			
000	00	04	JMP
001	01	0C	#12
002	02	00	NOP
003	03	04	JMP
004	04	55	#85
005	05	00	NOP
006	06	00	NOP
007	07	00	NOP
008	08	00	NOP
009	09	00	NOP
010	0A	00	NOP
011	0B	00	NOP
012	0C	27	CLR A
013	0D	39	OUTL P1, A
014	0E	A8	MOV R0, A
015	0F	A9	MOV R1, A
016	10	AB	MOV R3, A
017	11	AE	MOV R6, A
018	12	BA	MOV R2, data
019	13	01	#1
020	14	A5	CLR F1
021	15	97	CLR C
022	16	00	NOP
023	17	00	NOP
024	18	BF	MOV R7, data
025	19	FC	#252
026	1A	05	EN I
027	1B	BE	MOV R6, data
028	1C	00	#0
029	1D	0A	IN A, P2
030	1E	37	CPL A
031	1F	C6	JZ
032	20	1D	#29
033	21	AE	MOV R6, A
034	22	BD	MOV R5, data
035	23	0A	#10
036	24	BC	MOV R4, data
037	25	14	#20
038	26	0A	IN A, P2
039	27	37	CPL A
040	28	96	JNZ
041	29	3A	#58
042	2A	FC	MOV A, R4
043	2B	96	JNZ
044	2C	36	#54
045	2D	FD	MOV A, R5
046	2E	C6	JZ
047	2F	3E	#62
048	30	07	DEC A
049	31	AD	MOV R5, A
050	32	BC	MOV R4, data
051	33	14	#20
052	34	04	JMP
053	35	26	#38
054	36	07	DEC A
055	37	AC	MOV R4, A
056	38	04	JMP
057	39	26	#38
058	3A	4E	ORL A, R6
059	3B	AE	MOV R6, A
060	3C	04	JMP
061	3D	22	#34
062	3E	FE	MOV A, R6
063	3F	43	ORL A, mask
064	40	CO	#192
065	41	37	CPL A
066	42	C6	JZ
067	43	1B	#27
068	44	FF	MOV A, R7
069	45	C6	JZ
070	46	49	#73
071	47	04	JMP
072	48	44	#68
073	49	FE	MOV A, R6
074	4A	00	NOP
075	4B	00	NOP
076	4C	00	NOP
077	4D	E3	MOVP3 A, @A
078	4E	AF	MOV R7, A
079	4F	04	JMP
080	50	1B	#27
081	51	00	NOP
082	52	00	NOP
083	53	00	NOP
084	54	00	NOP
085	55	AB	MOV R3, A
086	56	FB	MOV A, R0
087	57	C6	JZ
088	58	5C	#92
089	59	C8	DEC R0
090	5A	04	JMP
091	5B	92	#146
092	5C	F9	MOV A, R1
093	5D	96	JNZ
094	5E	63	#99
095	5F	FF	MOV A, R7
096	60	A9	MOV R1, A
097	61	BF	MOV R7, data
098	62	00	#0
099	63	76	JF1
100	64	83	#131
101	65	F9	MOV A, R1
102	66	97	CLR C
103	67	F7	RLC A
104	68	A9	MOV R1, A
105	69	C6	JZ
106	6A	8B	#139
107	6B	FA	MOV A, R2
108	6C	96	JNZ
109	6D	77	#119
110	6E	23	MOV A, data
111	6F	03	#3
112	70	39	OUTL P1, A
113	71	A5	CLR F1
114	72	B5	CPL F1
115	73	E6	JNC
116	74	7F	#127
117	75	04	JMP
118	76	7B	#123
119	77	23	MOV A, data
120	78	01	#1
121	79	04	JMP
122	7A	70	#112
123	7B	B8	MOV R0, data
124	7C	10	#16
125	7D	04	JMP
126	7E	92	#146
127	7F	B8	MOV R0, data
128	80	30	#48
129	81	04	JMP
130	82	92	#146
131	83	23	MOV A, data
132	84	00	#0
133	85	29	OUTL P1, A
134	86	A5	CLR F1
135	87	B8	MOV R0, data
136	88	10	#16
137	89	04	JMP
138	8A	92	#146
139	8B	E6	JNC
140	8C	92	#146
141	8D	B8	MOV R0, data
142	8E	20	#32
143	8F	97	CLR C
144	90	27	CLR A
145	91	AA	MOV R2, A
146	92	FB	MOV A, R3
147	93	93	RETR

Page 1

Empty

Page 2

Empty

Page 3 (Look-up Table for Code Characters)

	Address	*Data*	*Character*
—	04	A0	A
—	06	78	B
—	0C	58	C
—	1C	70	D
—	14	C0	E
—	0E	D8	F
—	1E	30	G
—	16	F8	H
—	0A	E0	I
—	1A	88	J
—	05	50	K
—	07	B8	L
—	0D	20	M
—	1D	60	N
—	15	10	O
—	0F	98	P
—	1F	28	Q
—	17	B0	R
—	0B	F0	S
—	1B	40	T
—	25	D0	U
—	27	E8	V
—	3A	90	W
—	2D	68	X
—	3D	48	Y
—	35	38	Z
—	31	04	0
—	02	84	1
—	03	C4	2
—	12	E4	3
—	32	F4	4
—	22	FC	5
—	13	7C	6
—	33	3C	7
—	23	1C	8
—	11	0C	9
—	21	74	$\overline{BT}$
—	20	AA	.
—	30	CE	?
—	24	32	,
—	09	6C	/
—	26	AC	$\overline{AR}$
—	2A	BC	$\overline{AS}$
—	29	EA	$\overline{SK}$
—	28	A8	$\overline{AA}$
—	18	86	'

on the six-key Braille code. This may not be the most efficient or appropriate code, but it is the code familiar to one of the authors.

Software control makes this keyer a universal code machine. Input key combinations and output codes may be chosen almost at the preference of the builder, with no more required than changes in the look-up conversion part of the program. Programming of the EPROM requires additional equipment and information that is not covered in this article. Contact someone who is able to perform this service, since it has to be done only once. A source of information regarding programming of the 8748 is available.[1] As a last

[1] *MCS-48 User's Manual*, Intel Corp, 3065 Bowers Ave, Santa Clara, CA 95051.

resort, one of the authors will program your 8748 for $5 if the request includes an 8748 with cleared memory and a suitable return envelope with return postage.

Testing And Operating The Keyer

Check the +5 V regulated power supply before installing U1 and U2. If the voltage is correct, 4.8 to 5.1 V, turn off the keyer and install the ICs. Turn on the keyer and, if all is working properly, you should be greeted by a string of five dots at whatever speed was set. As explained earlier, these initial five dots only appear at the monitor output. Next, press some key code combination shown in Table 2 and release the keys. An audible output of the character you chose should be heard on the monitor and also be available at the optoisolator output to key your transmitter.

Should the keyer fail to function, turn it off and check the wiring and part values and placement very carefully. If you used a PC board, check it carefully for errors and hairline cracks. Trail solder along the PC traces wherever it looks suspicious. If the output dots and dashes are irregular in length, the most likely cause is that the interrupt pulse to the microprocessor is too long. Check the wiring associated with U1, especially the 0.1-μF timing capacitor and the ground return path between U1 and U2.

Since the input key combinations will undoubtedly be new to you, it will take a little time to memorize them and become reasonably proficient in their use. Remember to release the keys to get an output and make use of the two-character buffer to maintain the continuity of code output. Our thanks to Gary Blaine, K2SC, for suggesting the microcomputer approach and for programming assistance.

Table 2
Input Key Codes

Character	*Braille Key Codes (left to right)* 1	2	3	4	5	6
A	—	—	X	—	—	—
B	—	X	X	—	—	—
C	—	—	X	X	—	—
D	—	—	X	X	X	—
E	—	—	X	—	X	—
F	—	X	X	X	—	—
G	—	X	X	X	X	—
H	—	X	X	—	X	—
I	—	X	—	X	—	—
J	—	X	—	X	X	—
K	X	—	X	—	—	—
L	X	X	X	—	—	—
M	X	—	X	X	—	—
N	X	—	X	X	X	—
O	X	—	X	—	X	—
P	X	X	X	X	—	—
Q	X	X	X	X	X	—
R	X	X	X	—	X	—
S	X	X	—	X	—	—
T	X	X	—	X	X	—
U	X	—	X	—	—	X
V	X	X	X	—	—	X
W	—	X	—	X	X	X
X	X	—	X	X	—	X
Y	X	—	X	X	X	X
Z	X	—	X	—	X	X
0	X	—	—	—	X	X
1	—	X	—	—	—	—
2	X	X	—	—	—	—
3	—	X	—	—	X	—
4	—	X	—	—	X	X
5	—	X	—	—	—	X
6	X	X	—	—	X	—
7	X	X	—	—	X	X
8	X	X	—	—	—	X
9	X	—	—	—	X	—
$\overline{BT}$	X	—	—	—	—	X
$\overline{AR}$	—	X	X	—	—	X
$\overline{AS}$	—	X	—	X	—	X
$\overline{SK}$	X	—	—	X	—	X
$\overline{AA}$	—	—	—	X	—	X
.	—	—	—	—	—	X
,	—	—	X	—	—	X
?	—	—	—	—	X	X
'	—	—	—	X	X	—
/	X	—	—	X	—	—

Note: Some operators may wish to bridge two or more keys with a single finger or thumb.

Strays

I would like to get in touch with...

☐ anyone with information on the following equipment: Lafayette Radio signal generator (Model TE-20), National receiver (Model NC-90), Cornell Dublier capacitor bridge (Model BN, serial 10501), Readrite Meter Works tube tester (Model 432A) and General Electric ac-battery portable recorder (Model M 8450A). Alvord Paull, N6JJB, 1883 Jasmine St, El Cajon, CA 92021.

☐ anyone with a manual and circuit diagram for Jackson Model CRO-2 oscilloscope. James Connell, KH6JKG, 66-303 Haleiwa Rd, No 202, Haleiwa, HI 96712.

☐ anyone who has worked CAT programs for the Yaesu FT757GX on Texas Instruments 99/4A. LV Beachboard, K5BDH, 130 East Crosby, Slaton, Texas 79364.

☐ anyone with circuit/schematic diagram of a Sylvania CRT SC2799 or a scope manual. H Schroeter, Dorfstrasse 14, 3131 Gollau, Fed Rep of Germany.

☐ anyone with information of modifying the DX100 to improve signal quality. R. Wright, 3260 Lajoie, Trois Rivieres, PQ G8Z 3G8, Canada.

☐ anyone with schematic for IBM Mag Card II power supply. Howard S Robbins, KA8JIX, 15 Stonington Dr, Pittsford, NY 14534.

☐ anyone with operating manual for Knight TR106 6-m transceiver. W R Freas, K3YKM, 435 E Lancaster Ave., St Davids, PA 19087.

☐ anyone using a Timex 2000 or 2068 for Amateur Radio. Manos Darkadakis, SV1IW, Box 23051, 112 10 Athens, Greece.

Next Month in *QST*

Among the technical articles in the February issue you'll find the first of a three-part tutorial on the decibel, as well as a discussion on several uses for computer spreadsheets in the modern ham shack. Also, the Product Review column takes a close-up look at the TS-940S, Kenwood's newest HF transceiver.

On the features side, you'll find a wrap-up of the Amateur Radio events that shaped 1985—from a major preemption ruling and Amateur Radio's response following a tremendous earthquake, to WØORE's historic operation from space. And there'll be a look at the League's *License Manual* series—how to use them to get that first or upgraded ticket. Other items include the results of the Radiosport contest and a look at the DX Contest Awards Program.

• *Beginner's Bench*

The Principles and Building of SSB Gear

Part 5: Man does not live by milliwatts alone! So let's learn how to increase our SSB exciter output power through linear amplification. Our project this month is a 10-W broadband amplifier.

By Doug DeMaw, W1FB
ARRL Contributing Editor
PO Box 250, Luther, MI 49656

Faithful reproduction of the RF input signal, with minimum distortion, is the name of the game when using a linear amplifier. Of course, the amplifier must increase the signal power while preserving the waveform characteristic. If we are to ensure acceptable linear amplification, we must make certain that the low-power driving signal fed to the amplifier is relatively free of unwanted distortion products (and spurious responses that can originate in the SSB exciter unit). A clean driving signal should be available from the circuits described earlier in the series, so let's concentrate this month on the 10-W amplifier we will add to obtain a necessary boost in signal level.

RF Power Amplifiers in General

Whether we are considering vacuum-tube or solid-state power amplifiers, various linear and nonlinear operating classes are available to us. For example, we may use a class-C amplifier (nonlinear) to boost the power of an FM or CW signal without the need to worry about generating distortion products. Similarly, we may employ a class-C amplifier for AM power amplification, provided the modulation is applied to the last stage (class-C) of the transmitter. On the other hand, if we wish to amplify SSB signals, we must use a linear amplifier (class A, class AB or class B) to minimize unwanted distortion products developed within the amplifier. If we have a low-power AM transmitter and wish to increase the effective output power of the station, we need to use a linear amplifier after the transmitter stage to which modulation is being applied. The class of operation is controlled by the bias voltage we apply to the amplifier tubes or transistors. Linearity is dependent also upon the amount of driving power we supply to the amplifier input. Proper coupling to the load (antenna) is also important to linear operation, along with attention to impedance matching between the amplifier and the load.

The different classes of amplifier operation yield unlike percentages of *efficiency*. Class-C service is the most efficient (80%, approximately), and class-A operation provides roughly 33% efficiency. What is efficiency? It is the ratio of the RF power output to the dc power input to an amplifier, expressed as a percentage. For example, if an amplifier tube operated with a plate voltage of 500, and the plate current at resonance was 150 mA, the dc input power would be 75 W (0.150 A × 500 V = 75 W). Now, if the amplifier were operating efficiently in class-C, we would expect an RF-output power of 60 W (80% efficiency). If the same amplifier were changed to class-A operation (33% efficiency), the output power would drop to approximately 25 W.

The rules of efficiency apply rather well to vacuum-tube amplifiers; but solid state amplifiers, by and large, are designed for broadband rather than narrow-band service, and the efficiencies run pretty much the same for class AB or C service—50 to 60 percent, typically. This is caused in part by the need to include negative feedback (some of the output power is routed back to the input of the amplifier). The feedback voltage helps to ensure uniform power amplification across a wide range of frequencies, such as 3 to 30 MHz. Solid-state amplifiers, unlike their tube-type brothers, develop more gain as the operating frequency is lowered. A given transistor that is rated for 30 MHz may develop incredible gain at, say, 3.5 MHz, and this leads to destructive self-oscillation if careful design and feedback networks are not used. Self-oscillation occurs not only in the low-frequency or high-frequency spectrum, but it often takes place at audio frequencies! I have actually heard the transistors "screeching" when strong audio oscillations were taking place in a homemade transistor power amplifier. On one occasion I could see a bluish glow coming from within the transistors (visible through the ceramic heads of the devices) during a period of instability! Needless to say, the transistors self-destructed.

Class-AB and Class-C Circuit Comparison

A lengthy discussion would be necessary in order to define the various classes of amplifier operation. Biasing and the operating angles for AB and C types of amplifiers are subjects treated quite thoroughly in the ARRL *Handbook*, 1986 edition, pp 5-4 through 5-6. Also see p 3-17.

The mechanism of biasing is shown in schematic-diagram form in Fig 1. Theoretically, no collector current flows in Q1 (drawing A) when driving power is absent. No external bias is applied to the base of the class-C amplifier. If Q1 were a tube, a negative voltage would be required at the grid in order to cause plate-current cutoff for class-C service. But, the transistor of Fig 1A draws only leakage current (microamperes) when the base is returned to dc ground as shown. Collector current flows only when a driving signal is applied to the base. The efficiency can be increased somewhat by biasing the transistor to complete cutoff. The addition of a small-value resistor and bypass capacitor between the emitter and ground is the usual technique used for biasing a class-C transistor amplifier. Placing a resistance or negative bias between the base and ground is dangerous, because it applies a prohibitive potential between the transistor base and emitter, which will lead to internal destruction of the device during peaks in driving voltage.

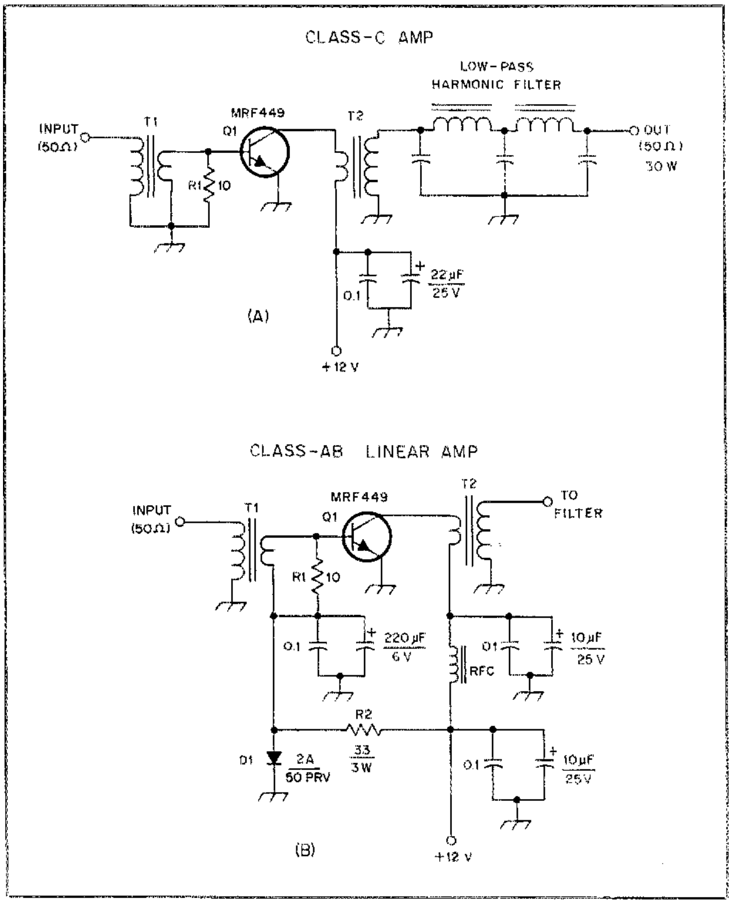


Fig 1—The circuit at A shows how a transistor RF amplifier is biased for class-C operation. T1 and T2 are broadband matching transformers. Circuit B demonstrates the linear-amplification concept. A positive bias voltage of approximately 0.7 is supplied to the base of Q1 to establish class-AB operation. D1 provides the required bias voltage (see text).

The 10-ohm resistor (R1) across the T1 secondary winding does not create a bias voltage when the stage is driven. The dc resistance of the transformer winding is a fraction of an ohm, which negates the effect of the resistor. R1 serves as a load resistor that lowers the Q of the T1 secondary winding. This helps prevent self-oscillation while creating a more constant load for the exciter that connects to T1.

A class-AB amplifier is shown in Fig 1B. The circuit is nearly identical to that of Fig 1A except for the addition of positive bias on the base of Q1. R1 is retained as a load resistor, but the bottom lead of the T1 secondary winding is lifted from ground to permit a positive voltage to reach the transistor base. This voltage causes a steady flow of standing or quiescent collector current when no excitation signal is present. The current increases when drive is applied.

D1 is a silicon diode. Therefore, the barrier voltage is roughly 0.7, which is the effective bias that is applied to Q1. The bias results from the voltage drop across the diode junction. R2 acts as a current-limiting resistor to protect the diode. An RF choke and two additional capacitors have been added to the collector circuit of Fig 1B. These serve as a decoupling network between the collector and base of Q1. This prevents RF output energy from flowing along the +12-V line to the base of Q1. Self-oscillation might result if this precaution were not taken.

Both amplifiers in Fig 1 are single-ended types. In practice, most solid-state RF power amplifiers are push-pull units. Push-pull operation offers the advantage of improved harmonic reduction (cancellation) at the even harmonics (2nd, 4th, and so on). This is particularly important when using solid-state amplifiers, which have substantially more harmonic currents present in the output than is normal for vacuum tubes. In a typical solid-state RF amplifier the 2nd and 3rd harmonics might be only 10 or 12 dB below the peak level of the desired signal power. Therefore, without proper harmonic filtering, a 100-W amplifier might produce 10-W harmonics that could be heard worldwide, depending on the antenna being used!

Pros and Cons of Tubes and Transistors

Tubes withstand output-load mismatches much better than transistors do in a severe case. When a high SWR exists between the transistor amplifier and the load, collector-to-emitter RF voltage can soar to prohibitive levels. This excessive peak voltage may exceed the safe ratings of the transistor, thereby causing immediate destruction of the device. Tubes are more tolerant of high peak voltages.

Heat is the enemy of tubes or transistors. We must be sure to provide ample heat sinking for our transistors. This is done by thermally coupling the transistor body to a large metal surface or heat sink. The heat sink absorbs much of the transistor heat and helps to keep the transistor junction temperature within safe boundaries. My rule of thumb for cooling transistors is to apply normal rated power for one minute, then turn off the amplifier and drive. If the heat sink is just warm to the touch, all is well. If holding my finger on the heat sink causes discomfort, I switch to a larger sink. This method has always worked for me, however unscientific it may be.

A notable advantage of a broadband transistor amplifier is that fixed-tuned filters and broadband matching transformers can be used in the output circuit. This eliminates the need to dip and load (tune) the output tank when changing operating bands or frequencies. Contesters, DXers and handicapped operators find this feature especially attractive.

Amplifier Distortion

Earlier, I referred to linear amplifier intermodulation distortion (IMD). This form of distortion takes place when an amplifier is fed more than one input frequency (tone). The tones combine to produce additional amplifier output signals that are not present at the input of the amplifier. These are unwanted signals. The human voice contains many varying-frequency bursts that can generate amplifier IMD products. They cannot be eliminated, but good design and proper operating procedures can limit the power of these responses. Fig 2 shows a spectral display of the output of a linear amplifier that is driven by a two-tone signal. The two high peaks at the center are the desired output responses. Left and right of these peaks we can see IMD-product responses (3rd-, 5th- and 7th-order IMD products). The first responses (3rd order) are over 30 dB below peak power, which is considered accept-

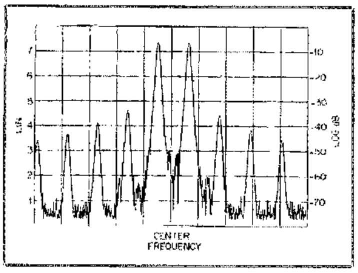


Fig 2—Spectrum-analyzer display of a two-tone SSB signal. It shows the IMD products caused by the two tones. Each horizontal division is equal to 1 kHz, and each vertical division represents 10 dB. See text for a discussion of the IMD phenomenon.

able. The 5th- and 7th-order products are somewhat lower in amplitude. If the IMD products are too great in magnitude, our signals will be excessively broad and will cause interference to others who share the amateur bands with us. The usual cause of excessive IMD in commercial amateur gear is the operator. That is, he or she may turn up the audio gain too high, shout into the mic, and grossly overdrive the linear amplifier.

A Practical Linear Amplifier

Fig 3 contains a schematic diagram of this month's workshop project. Circuit boards and parts kits for this amplifier are available from A & A Engineering.[1]

The circuit shows a pair of Motorola MRF475s in a push-pull arrangement. Broadband transformers (T1 and T2) provide a match to 50 ohms at each end of the amplifier. C1, across the primary of T1, tunes out unwanted reactance of the primary winding. This helps ensure a low SWR if the amplifier is used at frequencies in the 14- to 29-MHz range: This circuit is suitable for operation from 1.8 through 30 MHz when the appropriate filter is used at FL1. Suitable filter constants and parts values are available in the transmitting chapter of the ARRL *Handbook*.

C2, C3, R1 and R4 of Fig 3 are used as gain-leveling components. As the operating frequency is lowered, these components pass smaller amounts of the driving signal, thereby compensating for the increased transistor gain versus frequency mentioned earlier. Without this network we would have to reduce the driver output as the operating frequency was lowered. With the network in place, the exciter can operate at the same power-output level from 160 through 10 meters, should you choose to incorporate this circuit in an all-band rig.

Bias for class-AB service is developed by means of D1, as discussed with relation to Fig 1B. The efficiency of this amplifier is between 50 and 60 percent.

Negative feedback is provided by the inclusion of R6, Z1 and Z2. As the operating frequency is lowered, the feedback network allows more and more output energy to be fed back to the input circuit. This provides a gain-controlling action. R6 is located on the FL1 side of T2, and the hookup-wire leads from R6 are passed through the core of T2 (to the Q1, Q2 side of T2), where ferrite beads Z1 and Z2 are located. The wires continue along the PC board to the base pads for Q1 and Q2. The wires that pass through the T2 core pick up some of the output energy of the amplifier. Z1 and Z2 offer less and less resistance to the flow of RF current as the operating frequency is lowered. Therefore, we actually have two mechanisms for gain control versus fre-

[1]Notes appear on page 32.

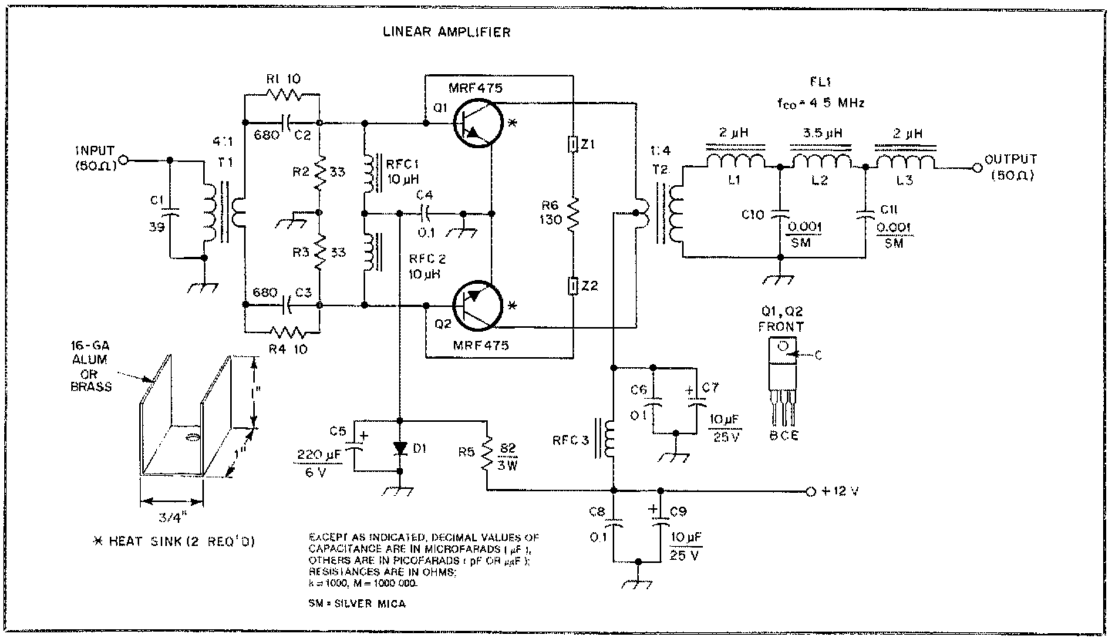


Fig 3—Schematic diagram of a 10-W linear amplifier. Capacitors are disc ceramic unless otherwise noted. Polarized capacitors are electrolytic or tantalum. Resistors are ½-W carbon composition except for R5, which is a 3-W unit.

D1—2-A, 50-PIV silicon rectifier diode.
L1, L3—20 turns of no 22 enam wire on an Amidon T50-2 toroid core.
L2—26 turns of no 24 enam wire on an Amidon T50-2 toroid core.
Q1, Q2—Motorola power transistor. Avail. from MHz Electronics, 2111 W Camelback Rd, Phoenix, AZ 85015. Also see note 2 for imported equivalent.
RFC1, RFC2—Miniature 10-µH RF choke (Mouser Electronics or equiv).
RFC3—5 turns of no 22 enam wire on an Amidon FT50-43 toroid.
T1—Two rows of three each Amidon FT37-43 toroids. Glue toroids together to form two sleeves, then glue sleeves together side by side to form balun core. Epoxy cement recommended. Primary has 4 turns of no 24 enam wire. Secondary consists of 2 turns of small insulated hookup wire.
T2—Amidon large balun core, no 43 material (ferrite, 900 μ_i). Primary has one turn of no 22 hookup wire. Secondary has two turns of hookup wire. Feedback-loop hookup wire is passed through core (see text).
Z1, Z2—Jumbo Amidon ferrite bead, no 43 ferrite material (see text).

quency (feedback and input-leveling networks). This general scheme was borrowed from Motorola application notes.

T2 serves as a matching transformer to interface the 29-ohm collector-to-collector impedance to the 50-ohm harmonic filter. We may calculate the collector impedance of a single transistor by means of $Z = V_{ce}/2P_o$. Thus, if a transistor provided 5 watts of power output and the collector-to-emitter voltage was 12, the equation would become 144/10 = 14.4 ohms.

FL1 is a low-pass filter designed for a cutoff frequency slightly above the highest desired operating frequency (4.5 MHz in this case). Our filter ensures that all harmonic responses are at least 40 dB below peak desired output power. RFC3 and the related bypass capacitors act as a decoupling network for the +12 V supply line, as discussed earlier. C5 charges to help regulate the 0.7-V forward bias for Q1 and Q2. C7 and C9 function as bypass capacitors for VLF and audio frequencies. This minimizes the occasion for low-frequency self-oscillation. C6 and C8 act as bypass capacitors for the RF frequencies between 1.8 and 30 MHz. C4 serves in the same manner.

The driving power required to provide 10 W of amplifier output power is between 1 and 2 W. Less power would be needed if T1 did not have some losses, and if the RC leveling network were not present.

Construction Notes

When designing your own PC boards, be sure to keep the layout in a straight line to reduce unwanted coupling between the input and output parts of the circuit. Also, keep all PC-board foils large and direct. It is vital to minimize unwanted stray inductances in the low-impedance sections of the amplifier circuit. Wide, short foils reduce the inductance of the circuit-board elements.

The PC board used should be copper clad on both sides. The foil on the unused side of the board is included as a ground plane to help stability. It should be made common to the ground foils on the etched side of the board at several points. This can be done by passing short pieces of bus wire through the board, then soldering them in place on both sides of the PC board.

The metal tab of the MRF475 transistors is common to the collector. The homemade heat sinks are mounted on isolated PC pads to prevent short circuiting the +12-V line. The copper around the heat-sink mounting-screw holes (on the ground-plane side of the board) is etched away to prevent the screw heads from contacting the ground plane. Heat-sink compound (silicone grease) is used between the transistor bodies and the heat sinks. The Q1 and Q2 collector leads are snipped off, since the tabs serve as the circuit connection in this design.

You may substitute similar TO-220 transistors for the MRF475s. The devices specified were earmarked for CB use and carry specifications for 27 MHz. Any bipolar transistor with similar ratings should be suitable.[2] V_{ce} should be 24 V or greater, P_d at 10 W and the gain should be 10 to 13 dB at 30 MHz.

In Closing

Space was available here for the bare essentials of amplifier design and operation. I hope you will garner an up-to-date copy of the *ARRL Handbook* and dig deeper into the matter of linear amplifiers. Although the circuit in Fig 3 produces only 10 W of output power, you should be pleased with the contacts you will make on 75 meters—especially during the daylight hours when the band is not heavy with QRM.

Notes

[1]A & A Engineering, 7970 Orchid Dr, Buena Park, CA 90620, tel 714-521-4160.

[2]Two power transistors for $6, available from State Street Sales, PO Box 249, Luther, MI 49656.

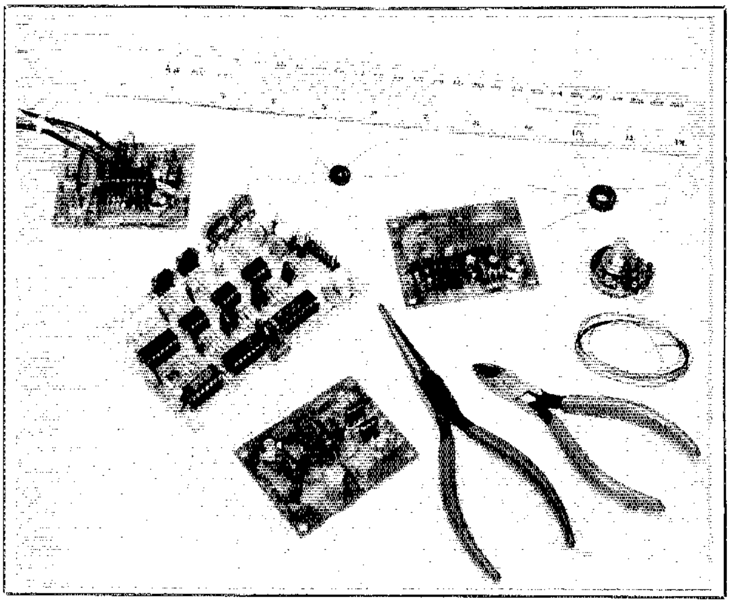
Strays

THE WHOLE KIT AND CABOODLE

☐ Do you like to build your own radio gear? Do you like the feel of excitement that comes from seeing something you've constructed with your own hands both looking and working well? Perhaps you've put off assembling some of the projects you've seen in *QST* simply because you don't want the hassle of parts procurement or the added work of etching a single PC board. Others of you may not, for one reason or another, be able to handle the small parts used in modern electronic equipment, but would still like the use of a project you've seen in *QST*. Well, don't let any of these reasons stand in your way!

To make things easier and more pleasant for *QST* readers, we've arranged to have many of the construction projects that appear in the journal be available from A & A Engineering in three forms: full kits of parts, semi-parts kits and assembled units. Some of the recent projects are shown in the accompanying photo.

So heat up that soldering iron and start building! For more information, contact A & A Engineering, 7970 Orchid Dr, Buena Park, CA 90620, tel 714-521-4160. —*Paul K. Pagel, N1FB*



Cable Television Interference: 1986

Here's how to make CATV + Amateur Radio = a happy coexistence.

By Greg Bonaguide, WA1VUG
Contributing Editor
PO Box 12248, St Petersburg, FL 33733

If you are experiencing interference caused by a leaking TV cable (CATVI), you may find it hard to believe that some hams can place their 2-meter FM radios atop a cable-fed TV set and experience no interference. Yes, even with the FM receiver tuned to 145.25 MHz! Sound strange? It's true in some locations—unfortunately, it is not true in all cable areas. In this article, I will discuss why interference from (and to) "the cable" happens. In a future *QST* article, I will give you some pointers on dealing with that interference.

Let's start this update with some vocabulary. A cable system that causes (or experiences) interference is called a "leaking cable." This means the signals that should be confined to the cable are getting out—that is called egress. Leaking also can mean that signals from outside can be getting in—we call that ingress.

Have you "heard" a leaking cable? Some hams (particularly VHF mobile operators) know the characteristics of CATV leakage all too well. While driving through a certain area, a carrier suddenly appears on frequency and rises to a significant (perhaps S9 +) signal strength before receding and finally disappearing. This "trouble" area may wipe out ongoing amateur communications on some frequencies for several hundred feet or more. These "trouble spots" aren't as rare as they once were, prompting concerned hams to ask *why* the interference occurs, *where* it comes from, and *what actions*, if any, can be taken to cure it.

Why this problem with CATVI? As it turns out, growth for both Amateur Radio and CATV helped to bring about today's interference problems. The growing popularity of 2-meter FM forced amateurs below 146 MHz in pursuit of uncrowded spectrum space for repeaters. Similarly, CATV experienced a boom, not only in terms of new subscribers and wider geographical coverage, but also in new and extended cable services. These new services required more spectrum than the early 12-channel VHF cable systems could provide. New channelization plans were formed and implemented. Today, Amateur Radio and CATV operators legally use the same frequencies in the same geographical areas. This does not mean that we share frequencies in the proper meaning of the word. Cable systems are allowed to use frequencies inside their cables that are assigned exclusively to such services as broadcasting, public and safety services—and Amateur Radio. The most prominent CATV interference problem is found around the cable-channel-E visual-carrier frequency—145.25 MHz (see Table 1). Leakage levels adjacent to and near some cable systems are so high that repeater operations are impossible in parts of their normal service area. Repeater operations follow a band plan nationwide; in the heavily populated areas of the country, alternative repeater frequency pairs are not available.

Table 1
Common Channelization Plans

Channel Name		*Visual Carrier Frequency* *Standard*	*HRC*	*IRC*
2		55.25	54.0	55.25
3	Low	61.25	60.0	61.25
4	VHF	67.25	66.0	67.25
4A				73.25
5		77.25	78.0	79.25
6		83.25	84.0	85.25
A-2		109.25	108.0	109.25
A-1		115.25	114.0	115.25
A		121.25	120.0	121.25
B	Mid	127.25	126.0	127.25
C	Band	133.25	132.0	133.25
D		139.25	138.0	139.25
E		145.25	144.0	145.25
F		151.25	150.0	151.25
G		157.25	156.0	157.25
H		163.25	162.0	163.25
I		169.25	168.0	169.25
7		175.25	174.0	175.25
8		181.25	180.0	181.25
9	High	187.25	186.0	187.25
10	VHF	193.25	192.0	193.25
11		199.25	198.0	199.25
12		205.25	204.0	205.25
13		211.25	210.0	211.25
J		217.25	216.0	217.25
K		223.25	222.0	223.25
L		229.25	228.0	229.25
M		235.25	234.0	235.25
N	Super	241.25	240.0	241.25
O	Band	247.25	246.0	247.25
P		253.25	252.0	253.25
Q		259.25	258.0	259.25
R		265.25	264.0	265.25
S		271.25	270.0	271.25
T		277.25	276.0	277.25
U		283.25	282.0	283.25
V		289.25	288.0	289.25
W		295.25	294.0	295.25
AA		301.25	300.0	301.25
BB		307.25	306.0	307.25
CC	Hyper	313.25	312.0	313.75
DD	Band	319.25	318.0	319.25
EE		325.25	324.0	325.25
•		•	•	•
•		•	•	•
•		•	•	•
UU		421.25	420.0	421.25
VV		427.25	426.0	427.25
WW		433.25	432.0	433.25
XX		439.25	438.0	439.25
YY		445.25	444.0	445.25
ZZ		451.25	450.0	451.25

In a perfect world, a CATV system would be totally closed. That means no television signals getting out and no amateur signals getting in. Theoretically, the well-shielded coaxial cable used by the CATV industry will confine its signals. In "real world" cable systems, however, complete isolation is difficult to achieve. Any "cracks" in the closed cable may cause varying degrees of interference. Further, because amateurs use receiving equipment designed to detect extremely low-level signal energy, amateur installations are particularly sensitive to cable leakage.

The CATV System

Fig 1 is a simplified illustration of a typical CATV system. The headend is the control center of the cable system. Here, off-the-air TV signals, satellite signals (such as ESPN, HBO and others) and local originations (weather, community events, and so forth) are processed and, by

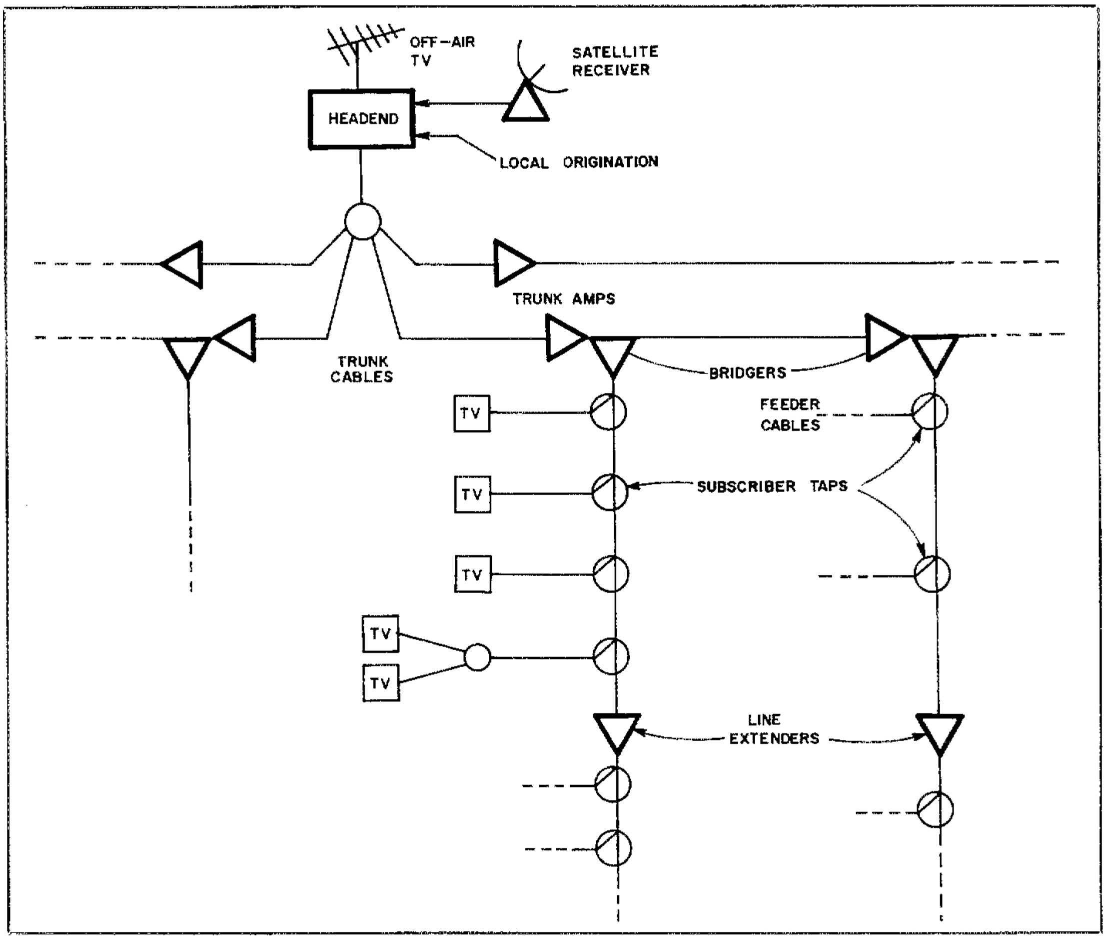


Fig 1—A typical CATV installation consists of the headend, trunk and distribution systems. Cable signals originate at the headend. The trunk system carries the signals to the various parts of the service area. Individual subscribers receive their signals from the distribution system.

modulation or conversion, put on the various cable channels. This composite block of TV signals, extending from 54 MHz to as high as 450 MHz, forms the CATV signal that is fed into the coaxial cable for "downstream" distribution.

There are two distribution systems used for transferring cable signals from the headend to the subscriber's TV set. The first, called the trunk system, forms the main distribution artery, bringing CATV into the far reaches of the community. Trunk amplifiers are placed along this trunk system to make up for cable attenuation and distribution losses.

Bridging amplifiers transfer the CATV signal from the trunk system into the second distribution artery, the subscriber system. Passive directional couplers placed along the subscriber system form taps that divert signal energy from the cable into individual subscriber converter boxes. Line-extending amplifiers compensate for cable attenuation and system losses.

Subscriber taps are usually located along the metal-sheathed cable, with a cable similar to RG-59 or RG-6 forming the "drop" to a grounding block. This grounding block is often mounted to the side of a subscriber's house. At the block the shield of the subscriber drop cable is connected to ground. A second piece of coaxial cable connects to the other side of the grounding block and weaves its way to the CATV converter box or subscriber's TV set.

Cable Power Levels

There is some misconception about the power levels used by the CATV industry. Amateurs experiencing CATVI tend to believe that CATV operators use high power levels. CATV system engineers are concerned with preserving signal-to-noise ratio (S/N) and low distortion—that means enough, but not too much power. Higher power gives better S/N, but it also increases distortion. CATV signals need only be as strong as local TV broadcast signals to give excellent results on most home TV receivers. For this reason, the trunk signal level is maintained at around 13 μW. In CATV talk, that translates to +30 dBmV (decibels referenced to 1 mV across 75 ohms). At first glance, this may not seem like a significant amount of power, but keep in mind that a typical amateur 2-meter FM receiver may have a sensitivity of 0.2 μV (across 50 ohms) for 20-dB quieting, which is equal to 0.08 pW ($\mu\mu$W). The cable-signal level is 82 dB greater than the minimum discernible 2-meter signal. That means that shield attenuation and propagation losses of greater than 82 dB will result in no discernible signal. Levels on the subscriber distribution system typically run higher (from 84.13 μW [+38 dBmV] to as high as 1.33 mW [+50 dBmV]). True, the power level found on a CATV line is extremely small; nevertheless, it can cause interference if system integrity is not maintained.

Leakage Points

Not surprisingly, there are many places where leaks are possible between the headend and the subscriber's TV set. Trunk lines have two main leakage sources. One is related to an older type of Hardline connector used on the aluminum-jacketed cable. As the outer clamp is tightened down over the bare aluminum sheath, the soft aluminum deforms under the pressure. This prevents good mechanical bite and may lead to loss of electrical conductivity. Even if a good connection is made initially, long-term exposure to wind, rain and airborne contaminants may allow corrosion to build up, effectively insulating the connector from the sheath. An entire length of cable can radiate like an antenna when this occurs. Even with improved connectors, corrosion or sloppy installation may still lead to connector radiation. This can occur at amplifier housings and passive components (power dividers, filters, directional couplers) or at cable-splice points.

The other kind of trunk leak is caused by splits or cracks in the aluminum jacket of the cable. These cracks occur because trunk lines are usually supported by utility poles and are subjected to many of the same mechanical stresses as telephone and electrical cables (rubbing or falling branches, automobile/pole collisions, wind, icing, and so forth). Trunk amplifiers, correctly installed and operated, rarely cause interference.

The subscriber distribution system uses coaxial Hardline just as the trunk system does and is prone to the same types of leakage. The bridging amplifiers and line extenders placed along the subscriber distribution system cause little interference, as long as they are installed and operated properly. Unterminated passive directional couplers (subscriber taps) may, however, be a source of leaks.

Generally, there are four taps available at each directional coupler. Unused taps are supposed to be terminated in a 75-ohm load for proper operation. The termination provides a load resistance and shielding for the connector. If a tap terminator (consisting of a 75-ohm resistance in an F connector) is missing, or an improper termination has been used, the tap can leak like a spigot. While these types of directional-coupler leaks are rather common, they are also among the easiest to fix.

In many instances, the causes of CATV interference are found between the utility pole and the subscriber's TV set. The drop line, consisting of coaxial cable similar to RG-59 or RG-6 except that it has multiple layers of shielding, is usually free to wave in the breeze, and may suffer from mechanical damage. The fittings used on the ends of these drop lines are another potential source of interference. Inexpensive F connectors may prove virtually impossible to install in such a way as to avoid interference. The biggest problem with F connectors in general is getting good mechanical and electrical contact between the aluminum fitting and the aluminum shielding of the cable. If a good connection is not made, the entire drop line may radiate.

The grounding block, found on the side of the subscriber's house, is an electrically important connection. It mates the coaxial-cable shield with an acceptable ground. (Acceptable grounds vary from state to state.) If corrosion is present, connections are defective or the heavy wire running from the block to the system ground is broken or missing, interference caused by ingress is likely.

Subscriber ignorance can also pose interference problems. Sometimes, an F connector may get pulled away from its aluminum shield or yanked right off the end of the coaxial cable at a TV converter box. Instead of calling the cable company to install a new F connector, the subscriber may just stick the end of the cable back into the converter. Seeing that his picture is restored to its original quality, he may opt to "leave well-enough alone," unaware of the radiation coming off the line. There are also those who try to feed additional TV sets using homemade signal splitters. Connections are sometimes made directly from 75-ohm coaxial cable to 300-ohm twin lead, causing unwanted radiation.

These are the most common leakage sources in a CATV system. If interference is heard in a particular area, these are the items likely to be investigated first. Of course, it would be to everyone's benefit if cable operators implemented a maintenance program to repair leaks as soon as they occurred. Unfortunately, rigorous monitoring programs can be expensive, and most systems operate on a tight budget. System employees are generally kept busy with the day-to-day responsibility of hooking up and terminating subscribers, and have little time to patrol cables. There is an answer to the patrol problem. Many cable establishments require employees to tune the FM radios in company vehicles to a frequency in or near the FM broadcast band. In the cable, a distinctive signal is carried so that cable leakage can be easily identified. Even with this type of monitoring, it is possible to miss leaks in the miles of cable found in a typical system. (These would be the leaks that occur where the cable runs through alleys or easements far from the road.) Feedback from amateurs is actually appreciated; cable operators are concerned about the state of their systems. There are mutual benefits: Hams stand to be rid of interference, and the cable operator may discover either illegal subscriber hookups or leaks that are detrimental to the overall picture quality being received by subscribers.

Recent Developments

Today, more than ever, the cable companies are taking a sincere interest in complaints lodged by amateurs. And no wonder! Today's cable technology features bidirectional signal flow. This could lead to more interference problems, unless leakage (ingress and egress) can be controlled.

Bidirectional cable is very attractive because it ushers in a whole new world of possible cable services. Chief among these are various interactive services that may soon permit subscribers to bank, shop and even go to school without leaving home. Some of the other services already in use employ only one-way "up stream" signal flow from the subscriber to the headend. Burglar and fire alarms and utility metering are examples of these upstream-only applications. Upstream transmissions use frequencies in the range from 5 to 30 MHz, overlapping several HF amateur bands. The cumulative effect of several Amateur-Radio signals "leaking" into the CATV system could be a severe overload problem. As the upstream signal moves toward the headend, amplifiers will intensify these signals, delivering large, disruptive bursts

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CATV Glossary

CATVI—Interference to or from cable television
dBmV—decibels referenced to 1 millivolt across 75 ohms
downstream—moving (as a signal) from the headend toward the subscriber
egress—signals escaping from within the CATV cable
Hardline—a coaxial cable with a solid aluminum sheath
headend—the point of origin for downstream signals
ingress—signals from outside entering into the CATV cable
leak—signal egress and ingress caused by a cable fault
subscriber distribution system—the part of the cable system that delivers signals from the trunk system to the subscriber tap
subscriber drop—the part of the cable system that delivers signals from the subscriber tap to the converter or TV set
subscriber tap—a directional coupler that couples energy from the distribution system into the subscriber drop
trunk system—the "backbone" of the cable plant that delivers signals from the headend to the subscriber distribution systems
upstream—moving (as a signal) from the subscriber toward the headend

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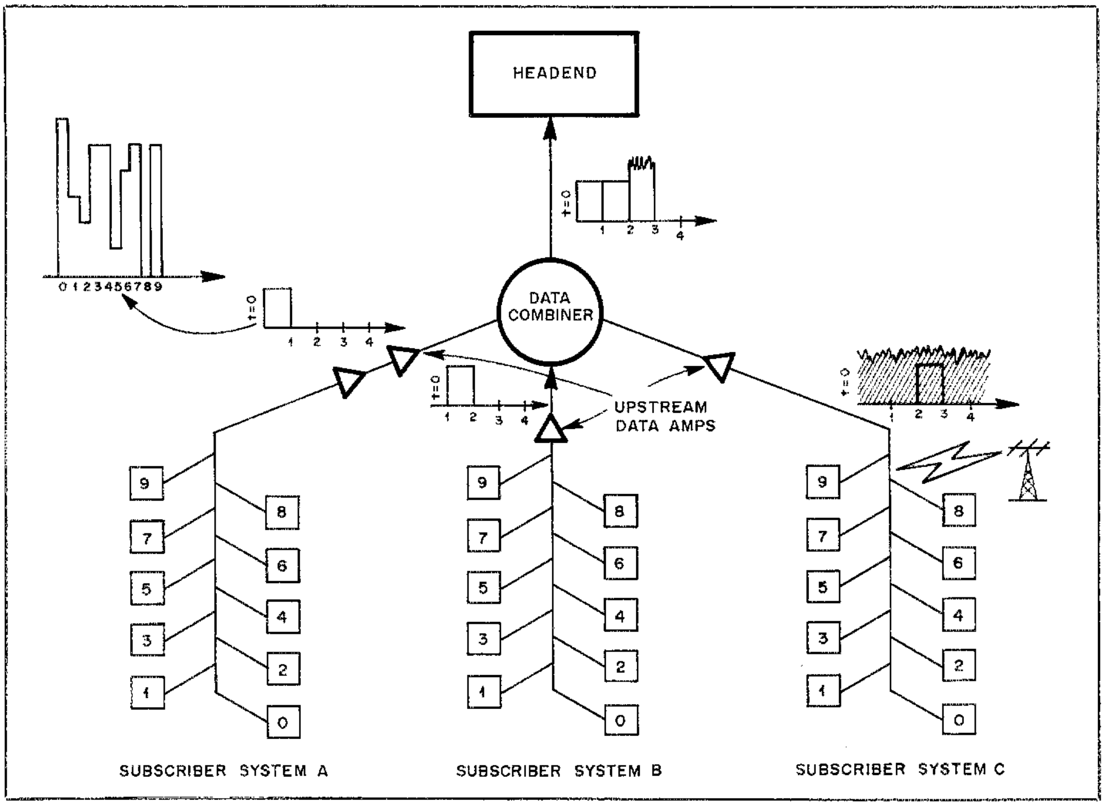


Fig 2—Interference to upstream cable signals is difficult to locate. Here, analysis of the headend composite data signal can only track the interference to subsystem C, which may be several miles long.

of energy. Not only can this ham interference significantly alter the streams of data flowing to the headend, but because it moves upstream it is difficult to pinpoint where (or how) the undesired signal entered the system (Fig 2).

Even a small, sporadic level of energy may be enough to prevent legitimate alarms from being reported. Clearly, in cases such as these, cable ingress and egress must be minimized. CATV systems must be extremely well-isolated from the noncable world.

Today, cable-TV leakage poses problems to amateurs and cable-TV operators. In some areas, interference on 145.25 MHz disrupts amateur communications. Interference from amateur HF stations may cause serious problems to modern two-way cable systems, unless cable operators take steps to clean up cable leaks. Cooperation between amateurs and CATV operators in identifying and correcting leaks can go a long way toward improving communications for everyone.

Strays

I would like to get in touch with...

☐ anyone interested in starting a net on 6-meter FM. Henry Kirschner, WBØYCQ, 266 Carissa Dr, San Luis Rey, CA 92056-1745.

☐ anyone with an instruction book or schematic for a National HRO600 receiver. Wally Cox, RR 4, Box 188, Georgetown, IN 47122.

QEX: THE ARRL EXPERIMENTERS' EXCHANGE

☐ Wonder what you've been missing by not subscribing to *QEX,* the ARRL newsletter for experimenters? Among the features in the December issue were:

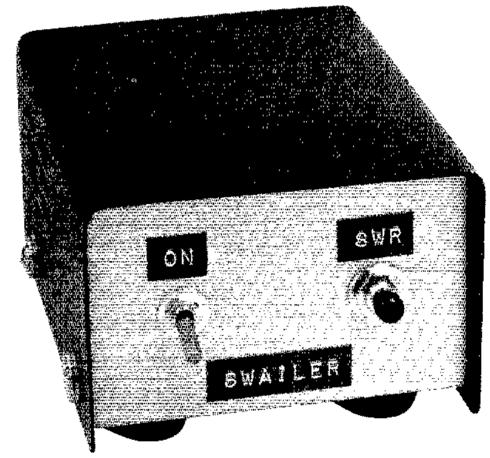
• W Conley Smith, K6DYX, shares his notes on TELEFAX for the Apple® //e and Apple®][+ computers.

• Clint Bowman, W9GLW, tells how to construct a square-wave generator for 47 kHz-52 MHz using the MC1648P IC.

QEX is edited by Paul Rinaldo, W4RI, and Maureen Thompson, KA1DYZ, and is published monthly. The special subscription rate for ARRL members is $6 for 12 issues; for nonmembers, $12. There are additional postage surcharges for mailing outside the US; write to Headquarters for details.

Meet the SWAILER!

Make tuning up easier. You can "hear" your SWR with this Standing Wave Audible Indicator and Level of Effective Radiation monitor.



By George Murphy, VE3ERP
PO Box 759
Alliston, ON L0M 1A0, Canada

The SWAILER is a tune-up aid that not only provides an audible indication of RF output, but also indicates SWR, thus offering a simple method of tuning both the rig and the antenna.

Operation

As an RF-output indicator, the SWAILER functions much the same as many existing audible relative-power indicators in that the transmitter is tuned to obtain the highest possible tonal pitch from the built-in speaker without losing the tone altogether. After maximum output is achieved, the SWR push button is pressed—a change in tone indicates the presence of a reflected wave. While the push button is pressed, the antenna matching network is adjusted for a tonal pitch closer to the original tone. By alternately touching up the transmitter output (with the push button released) and the matching network (with the push button pressed), the two tones can be closely matched. Identical tones indicate an SWR of 1:1.

Circuit Description

The schematic diagram for the SWAILER is shown in Fig 1. A differential amplifier, U1, drives a voltage-to-audio-frequency (V-F) converter, U2. U1 amplifies the difference voltage between input 3 (forward voltage) and input 2 (reflected voltage when S2 is open and zero volts when S2 is normally closed). If all reflected power can be tuned out, the output of U1 will be the same with S2 open as with S2 closed, resulting in identical tones from U2.

Q1, Q2 and Q3 function as a current mirror, necessary for the unit to produce a usable range of audible tones. R4 is a "set-and-forget" control that establishes a usable tonal range.

Input Signals

The SWAILER requires samples of the forward and reflected dc voltages from the transmission line between your rig and the matching network. If your matching network has a meter, or meters, to indicate forward and reflected power, the wiring is probably similar to one shown in Fig 2. To obtain sample voltages for the SWAILER, install a 1/8-inch stereo jack on the rear panel of your matching network and wire it as shown in Fig 2. This must be an open-circuit jack. A closed-circuit jack will ground your meter when the SWAILER is not connected. Solder a 0.01-μF capacitor between each jack lug and the ground lug if your matching network does not already have them at the point where you wire into the meter circuit. If your matching network does not have metering, an SWR indicator, such as the Radio Shack no 21-525 Field Strength/SWR Meter, with a stereo jack installed as described above will be required. If your SWR indicator has a nonmetallic case, make sure that the sleeve of the jack is directly connected to the internal ground of the meter circuitry. You will also require a cable, made up of two-conductor shielded wire, with a 1/8-in stereo plug at each end, and each end of the shield grounded.

Construction

The SWAILER can be installed in any small metal enclosure. I used a Radio Shack no 270-251 cabinet with S1 and S2 mounted on the front panel, and J1 on the rear panel. Drill a hole pattern on the rear panel, and secure the speaker over the holes with epoxy glue. When choosing your enclosure, don't forget to allow room for the 9-V battery. Also remember to drill a small access hole in the cabinet top to allow adjustment of R4.

There is nothing critical about parts placement except that C1 and C2, which are soldered across J1, should have leads as short as possible. There are two possibilities for PC boards for this project. Fig 3 shows the layout for a hand-cut PC board that I used in my first unit. A conventional version of this layout, suitable for etching, is shown in Fig 4. Parts placement is the same using either circuit board and is shown in Fig 5. Fig 6 shows placement of the PC board and speaker, and battery space in the cabinet.

Initial Setup

When the SWAILER is turned on, it will emit a low-pitched growl. Turn on the transmitter, with carrier inserted (CW mode), and the tone should rise. Adjust R4 to establish the tone at a mid-range pitch, then tune the transmitter for the highest possible pitch. If the tone disappears altogether, adjust R4 to bring it back into the audible range. The setting of R4 depends on the forward voltage picked up by the SWR indicator and will vary with different power levels. Once set for a particular transmitter and SWR indicator combination, however, it will probably not require resetting.

The SWAILER seems to work best at levels of 100 W or less, so if you have an amplifier, turn it off while you tune up. I

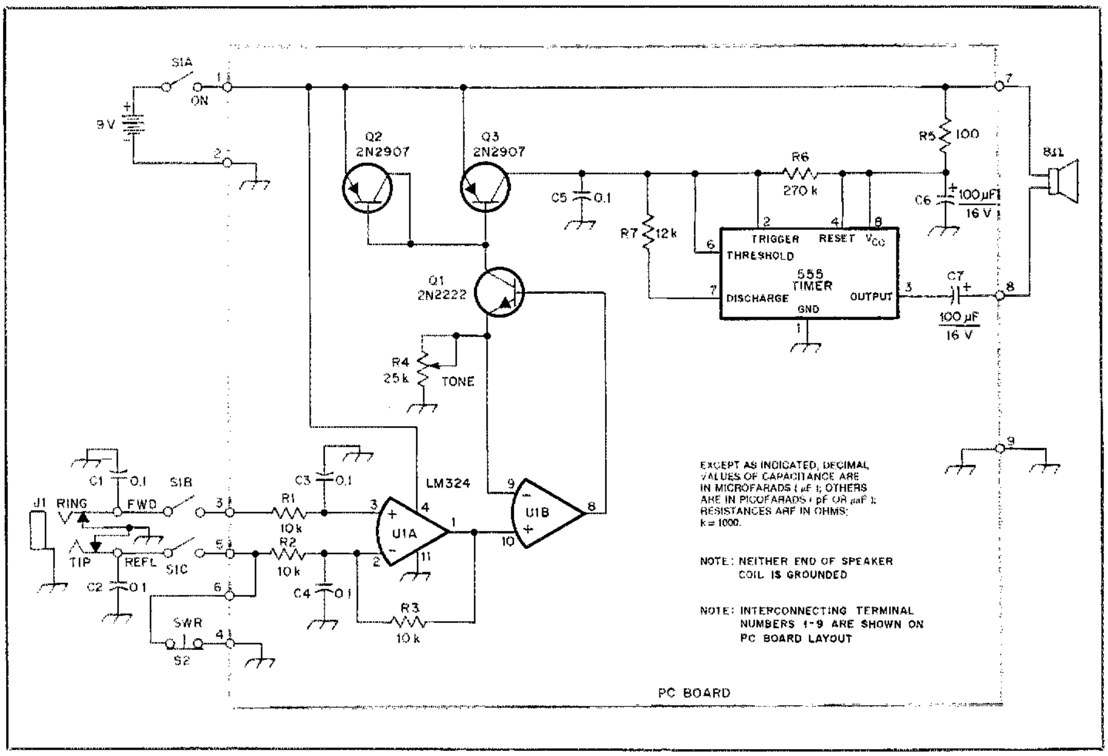


Fig 1—SWAILER schematic diagram. Radio Shack part numbers are shown in parentheses.

C1, C2—0.1-μF disc ceramic (272-135).
C3-C5—0.1-μF PC-mount capacitor (272-1069).
C6, C7—100-μF, 16-V electrolytic (272-1028).
J1—Closed-circuit stereo jack (274-250).
J2—Open-circuit stereo jack (274-249).
Q1—General-purpose NPN transistor (276-2009).
Q2, Q3—General-purpose PNP transistor (276-2023).
R1-R3—10-kΩ resistor (271-1335).
R4—25-kΩ potentiometer (271-336).
R5—100-Ω resistor (271-1311).
R6—270-kΩ resistor.
R7—12-kΩ resistor.
S1—3PST or 3PDT switch (275-661).
S2—Normally closed push-button switch (275-1548).
U1—LM324 quad op amp (276-1711).
U2—555 timer (276-1723).

Miscellaneous

Qty	*PN*	*Description*
1	(276-1999)	14-pin DIP socket.
1	(276-1995)	8-pin DIP socket.
1	(40-245)	2-in. 8-Ω speaker.
1	(270-251)	Cabinet.
1	(270-325)	Battery snap.
1	(278-1276)	Shielded cable, 2-wire.
2	(274-284)	Stereo plug.
1	(21-525)	SWR meter (if required).
9		Push-in terminals.

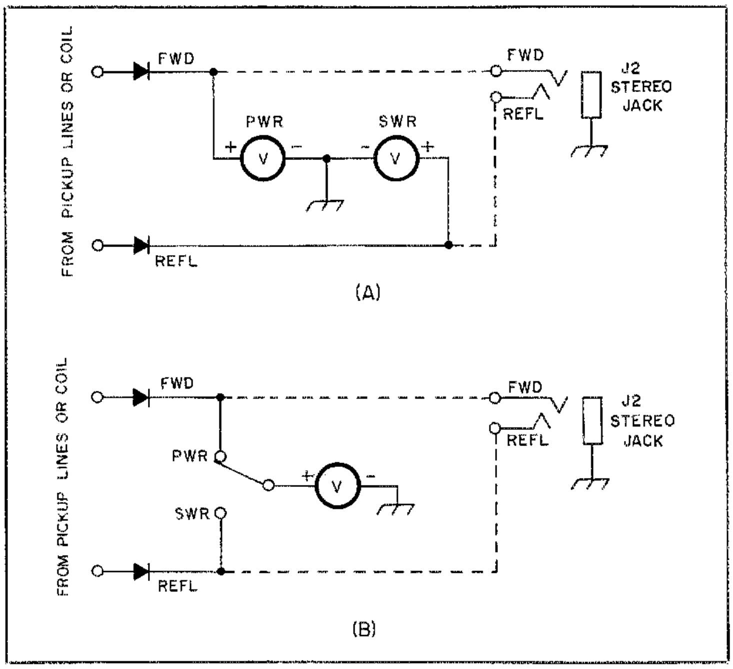


Fig 2—SWR indicator configurations. At A, 2 meters are used. At B, a single, switched meter is used.

do not have an amplifier, so I have no idea what might happen if you fed one into the SWAILER.

When the front-panel SWR button is pressed, the tone will change if reflected

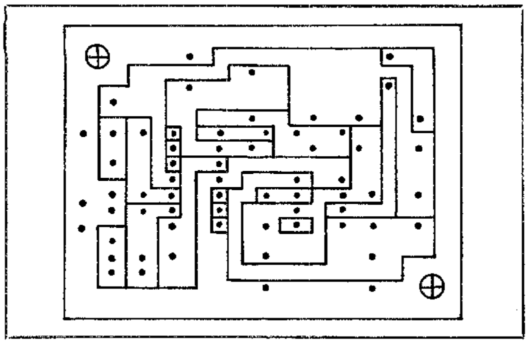


Fig 3—Hand-cut circuit board design.

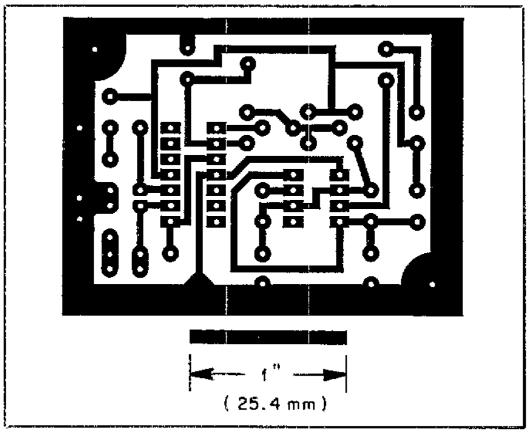


Fig 4—A conventional PC-board design.

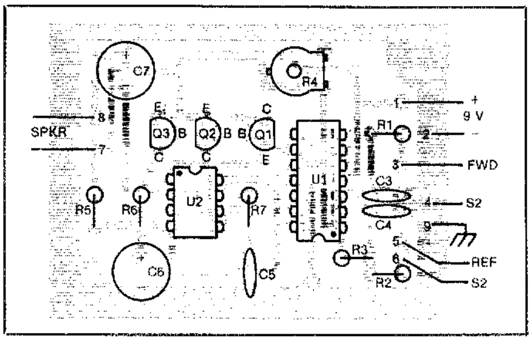


Fig 5—Parts-placement diagram for either PC-board configuration.

power is present. Adjust your matching network until the tone is as close as possible to the original tone. Release the push button from time to time to hear the forward tone, which will probably have changed somewhat. (As you reach a match, the forward power increases.) When the two tones are as close together as you can get them, you have achieved minimum SWR.

Don't expect to be able to match the two tones exactly. Unless you have the "ultimate antenna," there will probably always be a small amount of reflected power present. It may be so small that your meters won't show it, but the SWAILER will sniff it out if it is there.

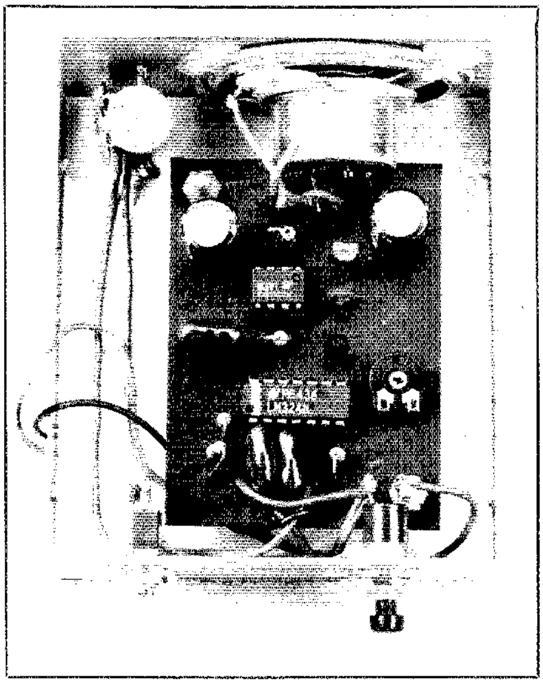


Fig 6—Internal view of the completed SWAILER. Note the position of the speaker on the rear panel.

If you lose the tone altogether during the initial adjustment procedure, adjust R4 until the tone is reestablished. Remember that where the tones are on the musical scale is unimportant—it is the *difference* between them that matters.

For your initial setup, you may want to install an additional SWR meter ahead of your matching network to check things out. The SWR push button on the SWAILER, being normally to ground, may ground the meter in your pickup unit when it is switched to read reflected power. When everything has been checked out, remove the temporary meter, and leave the meter in your pickup unit switched to the forward position to avoid grounding the meter when you are using the SWAILER. If your indicator has a separate meter for reflected power, it will be grounded by S2 when the SWAILER is in operation.

Afterthoughts

The SWAILER has lots of RF bypassing, but is still somewhat sensitive to strong RF fields. My station is upstairs, with no ground, and my antenna is a random wire running right from the matching network, so there is lots of RF in my shack. The SWAILER works fine there, however. Make sure that the SWAILER is completely enclosed in a metal cabinet. Running a ground strap from the cabinet to the station ground system wouldn't hurt. It is important that the cable between your SWR indicator and the SWAILER be shielded.

Conclusion

Try using the SWAILER. Listening to its gentle voice is a lot easier than trying to watch the antics of several meters at the same time.

Most of the credit for developing the SWAILER belongs to Jim Swail, VE3KF, and Lloyd McSheffney at the National Research Council in Ottawa, who took my original design (which didn't work very well), refined it, redesigned it and made it come to life. QST

Build a Homemade Signal Generator

Part 3: Last month we discussed the basic test gear needed in the ham workshop. Now, let's learn how easy it can be to build our own test instruments.†

By Doug DeMaw, W1FB
ARRL Contributing Editor
PO Box 250, Luther, MI 49656

Is your test-equipment budget "flat-broke and busted?" Perhaps you can push aside your reluctance to equip the home workshop with the fundamental apparatus necessary for general testing. If you, like me, dislike spending large sums of money for factory-built test gear, the appeal of low-cost homemade apparatus should cause your soldering iron to be turned on and made ready for this easy project.

Most of us would prefer to have a precision signal generator with calibrated output, wide frequency coverage and digital readout. But, we can ill afford to spend $1000 to $4000 for such an item! A simple homemade instrument is capable of performing a host of repair or design tasks, and we need not be ashamed of owning a modest unit that we built at home. Whatever our philosophy, a signal generator of some type is almost as useful as is our VTVM or VOM.

Signal-Generator Uses

Perhaps the most frequent need for a generator is when we have a receiver to troubleshoot or align. The sensitivity of a receiver can also be checked if we own a generator that has a variable attenuator at the output. This makes it possible to create a weak signal for testing the noise figure (NF) or general receiver sensitivity. At higher output levels from the generator, we may evaluate the automatic-gain control (AGC) action of a receiver. Similarly, large signals from the generator may be used when checking the performance and relative calibration of a receiver S meter.

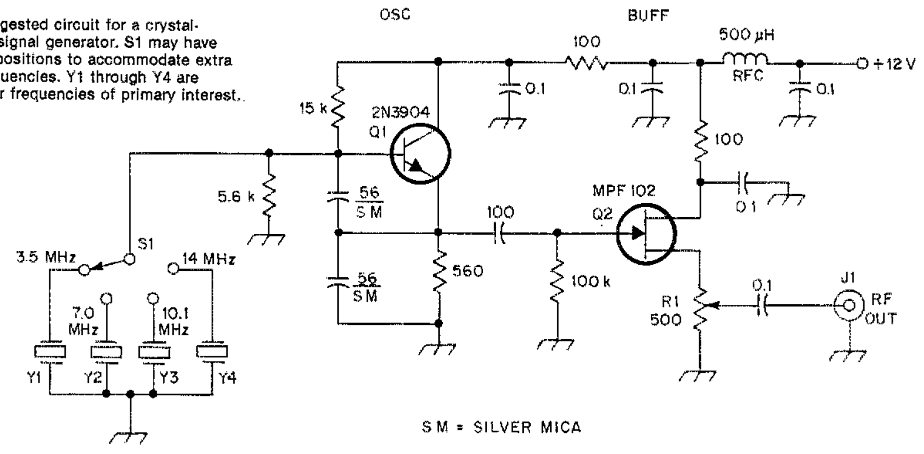
Small-signal RF amplifiers can be tested for gain by means of a signal generator. I have used this method a number of times when evaluating a multistage, low-power linear amplifier that was designed for broadband amplification.

Types of Generators

Modern technology dictates the use of synthesizers in signal generators that are manufactured for commercial use. Certainly, this kind of circuit provides accurate and stable RF energy, but such a circuit is too complex and costly for an inexperienced amateur to tackle. The extreme option is to assemble the simplest of

†Part 1 appears in November 1985 *QST*, page 38.

Fig 1—Suggested circuit for a crystal-controlled signal generator. S1 may have additional positions to accommodate extra crystal frequencies. Y1 through Y4 are selected for frequencies of primary interest.



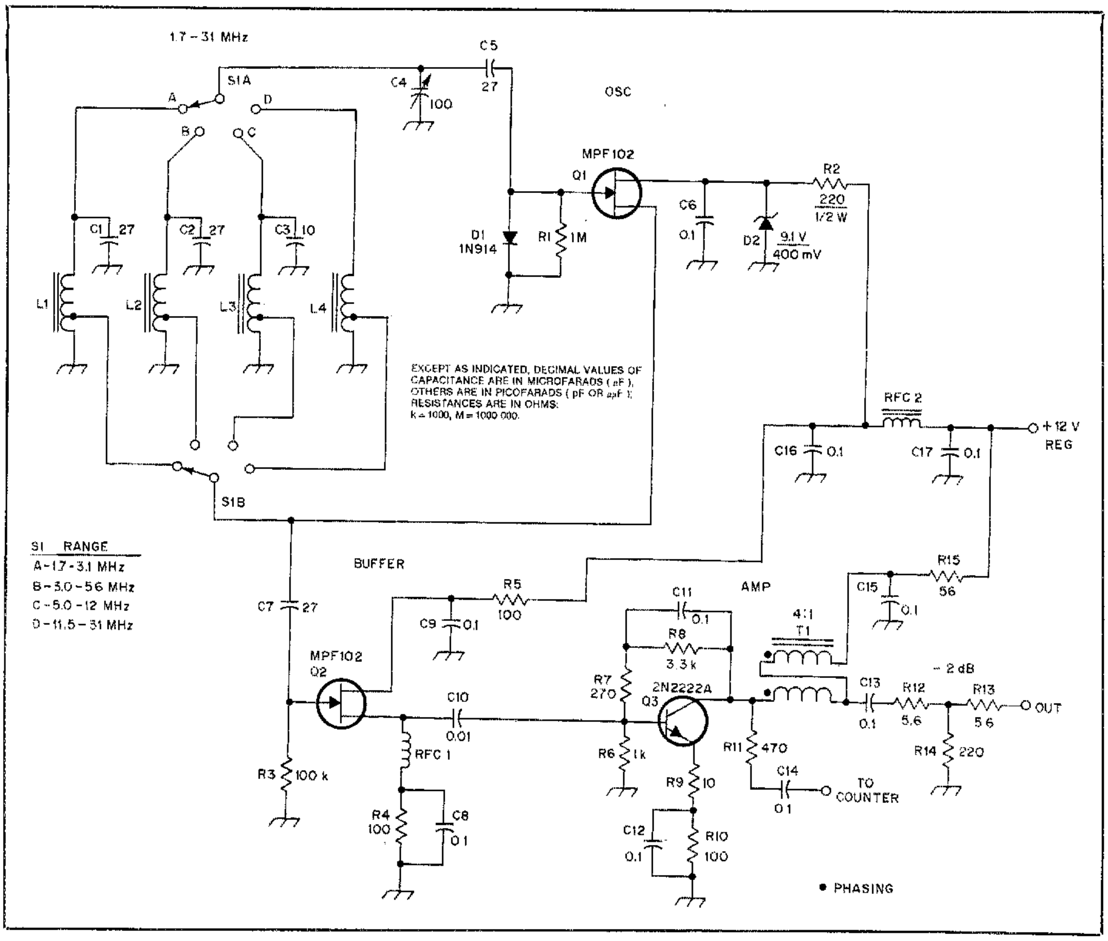


Fig 2—Circuit for a practical tunable HF-band signal generator. Fixed-value capacitors are disc ceramic, except for C1, C2, C3, C5 and C7 (see parts list). Resistors are ¼- or ½-W carbon composition.

C1, C2, C3, C5, C7—NP0 ceramic.
C4—Miniature 100-pF air variable (double-bearing type preferred).
L1—Toroidal inductor, 70μH. Use 32 turns of no 26 enam wire on an Amidon Assoc FT-50-61 ferrite toroid. Tap 8 turns from ground.
L2—Toroidal inductor, 21 μH. Use 18 turns of no 24 enam wire on an FT-50-61 ferrite toroid. Tap 5 turns from ground.
L3—Toroidal inductor, 8.5 μH. Use 41 turns of no 26 enam wire on an Amidon T50-2 powdered-iron toroid. Tap 10 turns from ground.
L4—Toroidal inductor, 1.75 μH. Use 21 turns of no 26 enam wire on a T50-6 toroid. Tap 5 turns from ground. Dip all toroids in Q-Dope® or polyurethane varnish after winding (see text).
RFC1—Miniature 1-mH RF choke.
RFC2—Use 15 turns of no 26 enam wire on an FT-37-43 ferrite toroid.
S1—Two-pole, four-position rotary wafer switch, phenolic or ceramic.
T1—Broadband bifilar-wound transformer, 4:1 Z ratio. Use 12 turns of no 26 enam wire. Twist 8 turns per inch before winding. Core is an FT-50-43 ferrite toroid.

generators by using a quartz crystal to provide a single frequency in one of the ham bands. Several crystals can be switched to allow output on several frequencies or bands. A typical circuit is shown in Fig 1. S1 selects the spot frequencies, Q1 is the oscillator and Q2 is a broadband source-follower buffer. R1 functions as an attenuator, *but does not ensure a 50-ohm output condition.* If you have a collection of crystals for popular test frequencies, you may opt for this circuit. But, the cost of new crystals would make the project more costly than the circuit we will describe later for general-coverage work.

Design Objectives

Accurate frequency readout is important for most test applications. We can do a reasonable job in this area if we employ a vernier-drive mechanism that has a finely graduated dial face. An old HRO (National Radio receiver) dial drive and gear train can be used to advantage if we decide to use analog readout. The dial mechanism from a surplus BC-221 frequency meter would also be suitable for a well-defined readout device. A dial-calibration chart can be created by logging the dial-face settings while measuring the generator output frequency with a frequency counter. Alternatively, we can plot a chart by listening to the generator signal on a calibrated general-coverage receiver.

If you are skilled in the design of digital circuits, you may wish to include a frequency counter with the circuit of Fig 2. It may be possible to buy a used frequency counter at a flea market, then make it an integral part of your signal generator. An outboard counter can be used with the circuit in Fig 2, should you not want to tie up your

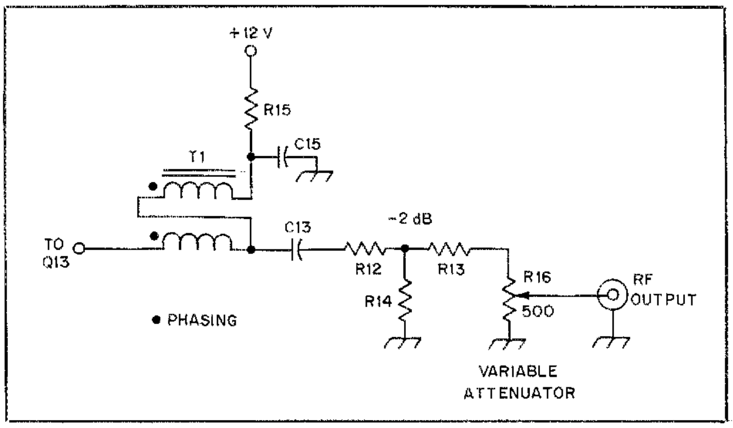


Fig 3—Method for using a variable-output attenuator with the circuit of Fig 2. This technique leaves a great deal to be desired (see text). R16 is adjusted for the generator output level desired.

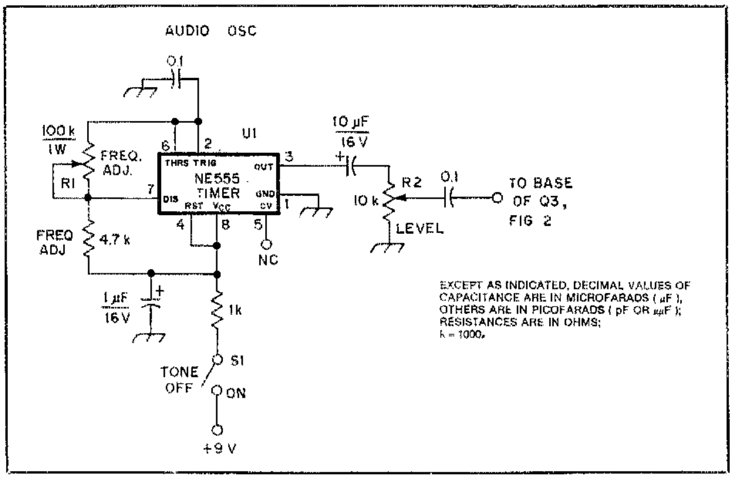


Fig 4—An audio-frequency generator that can be used to modulate the RF signal from the circuit of Fig 2. R1 sets the tone frequency and R2 determines the modulation level. This circuit is suitable also for use as a sidetone monitor or a code-practice oscillator.

counter for singular use.

Frequency stability is a primary need when using a generator. We don't want a signal that creeps and wanders when we are adjusting trimmers in a receiver! This is particularly important today when we consider the narrow bandwidth (selectivity) of modern receivers. A long-term drift of 100 to 300 Hz should be the maximum tolerable amount if we are to use our generator successfully. Solid-state devices and good design can make this order of stability possible.

Variable output power from the generator is also an important need. Ideally, the output impedance of the generator should be 50 ohms in order to have it match the impedances of most receivers and small amplifiers. A continuously variable attenuator (50 ohms) is a complex thing to design and calibrate in microvolts (µV). We will not attempt that feat in this series because the mechanical aspects of the problem are a bit challenging for the beginner. A simple alternative is offered in Fig 3. A better approach to that of Fig 3 is discussed later in this article.

Signal leakage from the generator is also a matter to keep in mind. In other words, we want the RF to come only from the "spigot," or test cable. Stray radiation from the unit will render the output attenuator useless at low power-output levels. The usual preventive technique for reducing stray radiation is to filter the power leads that enter or leave the generator. Also, the cabinet should be well designed as an RF shield (no holes or slots through which RF can escape). A double cabinet (one conductive box within another) is the prescribed approach to reduce leakage greatly. You may wish to design your generator enclosure in this manner. Double-sided PC-board stock works nicely as a double-shield cabinet material if the box walls are joined separately (inside walls and outside walls) with solder at the edges where the walls join. An air-tight cabinet also aids stability by keeping air currents from reaching critical oscillator components.

Tone Modulation

It is not necessary to generate a modulated signal for most of our amateur testing, but if you desire to have an audible tone when conducting receiver tests, you might consider the circuit of Fig 4. Output from this modulator can be coupled to the base of Q3 of Fig 2. This amplitude modulation (AM) will be useful when aligning AM receivers. FM could be generated with this test instrument by adding a varactor-diode modulator to the Q1 circuit. However, except for tests at 29 MHz, there is little need for an FM generator in the HF spectrum. The *ARRL Handbook* contains design data for FM modulators.

A Practical 1.7- to 31-MHz Generator

Fig 2 contains the circuit for our project this month. A tapped-coil Colpitts oscillator is used at Q1 to provide four tuning ranges from 1.7 to 3.1 MHz, 3.0 to 5.6 MHz, 5.0 to 12 MHz and 11.5 to 31 MHz. We could spread the tuning range considerably more by using a smaller-value main-tuning capacitor (C4) and using more coils and switch positions. But, the purpose of this exercise is to provide a simple, low-cost unit. It represents a suitable starting point for equipping the home lab.

A Zener diode (D2) is used at Q1 to lower the operating voltage of the oscillator. Voltages as low as 6 are useful if oscillation can be sustained, since the lower drain-source voltage will reduce drift. Changes in transistor junction capacitance and resistance are lower when the oscillator operates at reduced power levels. You may want to experiment with Zener diodes that provide lower regulated voltages, if you want to reduce drift. However, a small-value capacitor is used at C5 to ensure light coupling to the tuned circuit, and this aids stability also.

Q2 is a source-follower buffer stage. It helps to isolate the oscillator from the generator-output load. The source of Q2 is broadly tuned by means of RFC1. Energy from Q2 is routed to a fed-back, broadband class-A amplifier, Q3. The amplifier response is relatively flat (constant output power) from 1.5 to 35 MHz. T1 is a broadband ferrite transformer that steps the Q3 collector impedance from roughly 200 ohms to 50 ohms. A 2-dB attenuator is used at the output of T1 to provide a 50-ohm termination for Q3 and to set the generator-output impedance at 50 ohms.

A test point is provided for connection of an outboard frequency counter. It is connected to the Q3 collector through a resistor and blocking capacitor. The value of R11 may be larger or smaller, in accordance with the sensitivity of your frequency counter. Use only that value of resistance needed to permit triggering your counter. In other words, use the lightest coupling possible to prevent loading Q3 and robbing power from that stage: The higher the resistance of R11, the lighter the coupling.

C16, C17 and RFC2 form a brute-force RF-decoupling network to keep the generator energy from radiating outside the box on the 12-V supply line. If you have a 0.001-µF feedthrough capacitor available, use it on the outer wall of the equipment cabinet as a + 12 V terminal. This will improve the filtering of the power lead.

We can vary the output power of the signal generator by using the circuit of Fig 3. The 500-ohm control can be mounted inside the case of the equipment and made adjustable from the front panel. The shortfall of this technique is that the generator output impedance will vary as the control is adjusted. At the lowest settings, the potentiometer will create a dead short.

A better way to control the generator output is to attach a step attenuator at the output of the instrument. This will provide calibrated steps of attenuation and will maintain the 50-ohm output characteristic of the unit. An attenuator kit is available from Circuit Board Specialists.[1] Details of the attenuator can be found in *QST*.[2] PC boards and kits for this project are available from A&A Engineering.[3]

Wrap-up

I'd like to leave the choice and style of cabinet up to you. The packaging format will be dependent upon the type of analog or digital readout system you choose. I urge you to use a cabinet you may have on hand, thereby reducing the cost of this project.

Frequency stability for this generator will be improved if you dip each of the completed toroid coils in Q-Dope® or polyurethane varnish. This will prevent the coil turns from moving, which would result in frequency changes. Also, the leads between S1 and the coils should be stiff and direct, and as short as possible. Similarly, keep the lead from S1 to C4 short and rigid.

If you like to build direct-conversion receivers, try this generator as a local oscillator. It can be used also as a VFO for transmitters. If this is done, add a bandspread capacitor (10 or 15 pF) in parallel with C4. Without a bandspread capacitor the tuning rate will be much too fast for VFO operation!

Later in this series we will describe a signal generator for VHF use. Meanwhile, good luck in setting up your test bench!

Notes

[1]Circuit Board Specialists, PO Box 969, Pueblo, CO 81001, tel 303-542-5083.

[2]B. Shriner and P. Pagel, "A Step Attenuator You Can Build," *QST*, Sept 1982.

[3]A & A Engineering, 7970 Orchid Dr, Buena Park, CA 90620, tel 714-521-4160.

New Products

AEA PAKRATT™ MODEL PK-64 DATA CONTROLLER

☐ Advanced Electronic Applications' PAKRATT-64 is the world's first five-mode-in-one Amateur Radio smart data controller. Designed to operate with the C64™ or C128™ computers, the PK-64 works packet radio, RTTY (Baudot or ASCII), AMTOR and Morse code. All software, including the advanced terminal program, is supplied, together with all necessary hardware and cabling to connect with your transceiver and computer. Even the 12-V-dc wall adapter is furnished.

Features common to all modes: on-screen tuning indicator; split-screen operation with status indicators; full disk, cassette and printer capabilities; receive text in one mode, send out in any other mode without having to use disk or cassette; 10 message/command buffers; text editing with block moves; NOVRAM-style parameter/option storage via disk; 20-kbyte QSO buffer; keyboard selectable HF or VHF modem with pre- and post-detection filtering for improved signal-to-noise performance; and built-in frequency counter and software for self calibration.

Morse, Baudot, ASCII, AMTOR features: Baudot RTTY speeds of 60, 67, 75, 100, 132 WPM; ASCII speeds of 110, 150, 300 bauds; and Morse speed of 5 to 99 WPM (Morse receive requires HFM-64 modem option).

Special packet-radio features: AX.25 version 2.0 fully implemented, TAPR-style commands used where possible, connect alarm siren, connect with up to 10 stations simultaneously, date and/or time stamp for incoming messages, user-generated message for auto response to connect, one-key text scroll command, monitor reject command, special "connect check" terminates connection if path is lost, data carrier detect (DCD) and squelch input avoid packet collisions, hardware HDLC allows full duplex communications and invertible squelch input for busy-channel transmit inhibit.

Deluxe HF modem option (necessary for Morse receive): independent dual-channel filtering, improved adjustable-threshold DCD operation, AM detector and front-panel FM-discriminator-style tuning indicator.

The PK-64 is available from your AEA dealer, or for information contact Advanced Electronic Applications, Inc, PO Box C-2160, 2006 196th SW, Lynnwood, WA 98036, tel 206-775-7373. Price class: PK-64, $219.95; HFM-64 deluxe modem, $99.95.—*Bruce O. Williams, WA6IVC*

LADPAC SOFTWARE FOR ELECTRONIC LADDER CIRCUITS

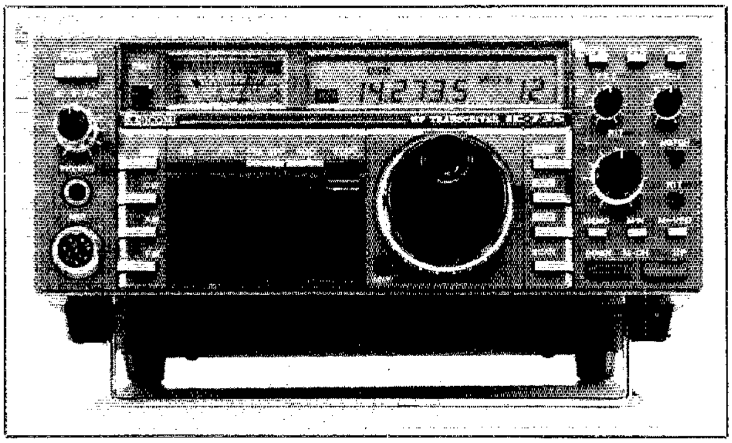
☐ LADPAC consists of five menu-driven, interactive programs. All programs generate or read disk files, providing communications between the various routines. The central core of LADPAC is the General Purpose Ladder Analysis (GPLA) program that will calculate and display in graphs or tables the transducer gain (in decibels), phase, return loss and group delay for an arbitrary filter of up to 49 elements. Elements may include resistors, capacitors and inductors of finite Q, as well as numerous complex elements such as parallel and series resonators, transmission lines (with loss), quartz crystals and even a half-wavelength dipole. Parallel branches may be included in a circuit.

Other programs that are included are: LPF, used in design of Chebyshev or Butterworth filters up to 48th order; BPFDES for design of coupled-resonator LC filters; XFILDES, which can be used to design lower-sideband ladder crystal filters, and Schematic Draw, which reads a disk file generated by any of the other programs and draws the filter schematic on the CRT screen.

The program disk is supplied with a detailed manual in a looseleaf notebook. The manual contains an introductory chapter with installation data, followed by a detailed chapter for each program, an advanced applications chapter and an index. LADPAC operates on the IBM® PC with DOS 2.0, or later, operating system. LADPAC has also been used on the IBM-XT and IBM-AT and several IBM PC "compatibles." A minimum of 192 kbytes of RAM, and at least one disk drive are required, as is an IBM Color Graphics Adapter, or similar equipment. A dot-matrix printer is optional, but highly recommended. LADPAC-87 is identical to LADPAC, but with support for the Intel 8087 co-processor.

LADPAC is copyrighted by Hayward Electronic Systems, Inc. The program disk is not copy protected. Price of LADPAC or LADPAC-87 is $149, postpaid. Available from Hayward Electronic Systems, Inc, 7700 SW Danielle Ave, Beaverton, OR 97005.—*Bruce O. Williams, WA6IVC*

ICOM IC-735 HF Transceiver



ICOM has entered the small, full-featured transceiver market with the IC-735. This compact, low-profile radio has plenty of features for convenient, casual HF operation. It competes directly with the Kenwood TS-430S (reviewed in March 1984 *QST*), and the Yaesu FT757GX (December 1984).

Receiver Features

The '735 uses a triple-conversion (70 MHz, 9 MHz and 455 kHz) scheme to receive SSB, CW, AM and FM signals from 100 kHz to 30 MHz. There are three ways for a signal to enter the IC-735 receiver. Normally signals pass around the RF attenuator and preamplifier to enter what ICOM calls a "direct-feed mixer." When the preamplifier is activated, about 10-dB of gain is provided ahead of the mixer. When the RF attenuator is selected, incoming signals are reduced by 20 dB. Various combinations of the preamplifier and attenuator switches allow four possible mixer-input levels over a 30-dB range. In addition, receiver input and output jacks on the rear panel allow connection of an external receiver or an unswitched outboard preamplifier. See Fig 1.

Receiver selectivity varies with the emission mode. The −6 dB bandwidths are 15 kHz for FM, 6 kHz for AM and 2.3 kHz for SSB and CW. Optional 9-MHz IF filters are available for either a 500- or 250-Hz CW bandwidth. There are no optional SSB filters available. The '735 does, however, include passband tuning for SSB and CW modes and a notch filter. (A narrow setting of the passband tuning nearly equals the performance of the 500-Hz CW filter in the test radio.) Adjacent signals can be reduced up to 28 dB by the notch filter. The noise blanker includes a threshold adjustment from the front panel. This feature is seldom seen in contemporary transceivers, and I feel that any additional control given the operator is worthwhile. Operators can also adjust the receiver audio character with a tone control that is reachable with a screwdriver through an access hole in the case. An audio squelch is provided to reduce unnecessary receiver noise in the shack.

Transmitter Features

Transmit frequency coverage for the IC-735 is shown in the specification table. The HAM tuning-rate switch together with the main tuning knob select the desired band on the amateur frequencies. Sideband selection is automatic—USB on 10 MHz and all bands above 10 MHz, and LSB on 7 MHz and all lower bands. One chooses between sidebands by pressing the SSB-mode switch.

Output power can be adjusted from 10 to 100 W using the RF POWER control. An internal three-speed fan cools the transmitter. The fan always operates during transmissions, but never during reception. When the PA temperature is below 50 °C, the fan operates at low speed. Fan speed increases to medium when the PA temperature exceeds 50 °C and to high when the PA temperature exceeds 90 °C. According to the manual, the '735 can

ICOM IC-735 HF Transceiver/General-Coverage Receiver, Serial No 1257

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: Receive—100 kHz to 30 MHz; transmit—1.80000-1.9999, 3.40000-4.0999, 6.9000-7.4999, 9.9000-10.4999, 13.90000-14.4999, 17.9000-18.4999, 20.9000-21.4999, 24.4000-25.0999, 27.9000-29.999 MHz.	Receive—as specified; transmit—as specified.
Modes of operation: SSB, CW, AM, FM.	As specified.
Frequency display: 5/16-inch liquid crystal digital display.	As specified.
Frequency resolution: 10 Hz, 1 kHz	As specified.
Transmitter:	*Transmitter Dynamic Testing*
Power output: 100-W SSB, CW, FM; 40-W AM.	160 m, 107 W; 80 m, 115 W; 40 m, 117 W; 30 m, 117 W; 20 m, 120 W; 17 m, 120 W; 15 m, 123 W; 12 m, 125 W; 10 m, 120 W. (AM output was not measured.)
Spurious signal and harmonic suppression: Better than 50 dB.	See Fig 3.
Third-order intermodulation distortion: Not specified.	See Fig 4.
Keying waveform: Not specified.	See Fig 5.
Receiver:	*Receiver Dynamic Testing*

		80 m (Preamp	*20 m* out/in)
Receiver sensitivity: Less than 0.15 μV for 10 dB (signal + noise)/noise	Minimum discernible signal (noise floor), (dBm):	−127/−134	−126/−133
Receiver dynamic range: Not specified.	Blocking dynamic range (dB):	Noise limited	Noise limited
	Two-tone, 3rd-order intermodulation distortion dynamic range (dB):	90/92	85/88
	Third-order input intercept (dBm):	8/4	1.5/−1

Receiver recovery time: See Fig 6.	
S-meter sensitivity (μV for S9 meter reading): Not specified.	RF amplifier out/in: 160 m, 64/22; 80 m, 52/16.5; 40 m, 52/16.5; 30 m, 52/16.5; 20 m, 52/17; 17 m, 50/19; 15 m, 52/21; 12 m, 54/21; 10 m, 58/21.
Squelch sensitivity: FM, 0.3 μV.	0.25 μV (preamp on).
Receiver audio output at 10% total harmonic distortion: 3 W.	As specified.
Color: Gray.	
Size (height, width, depth): 4¼ × 9¾ × 10¾ inches.	
Weight: 11 lb.	

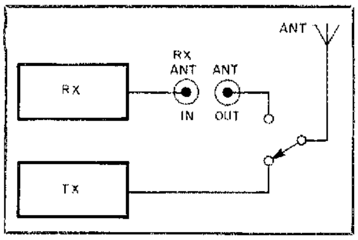


Fig 1—Antenna TR connections for the IC-735. RX ANT IN and ANT OUT are connected by a jumper for normal operation. An external preamplifier connected in place of the jumper needs no TR-switching provisions. An external receiver is controlled by the IC-735 TR circuitry when it is connected to the ANT OUT jack.

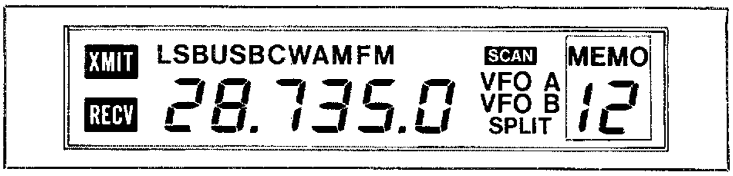


Fig 2—A layout of the IC-735 LCD showing all indicators.

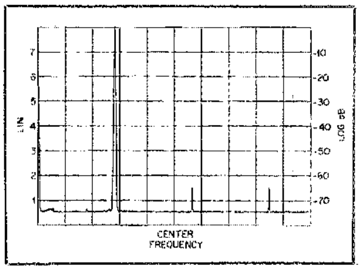


Fig 3—Spectral display of the IC-735. Vertical divisions are each 10 dB; horizontal divisions are each 10 MHz. Output power is approximately 100 W at a frequency of 28 MHz. All spurious emissions are at least 65 dB below peak fundamental output. The IC-735 complies with current FCC specifications for spectral purity.

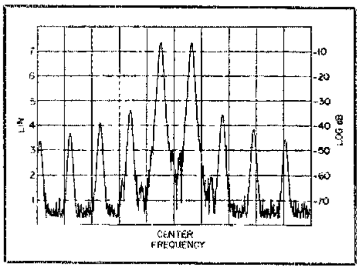


Fig 4—Spectral display of the IC-735 output during transmitter two-tone intermodulation distortion (IMD) test. Third-order products are 33 dB below PEP, and fifth-order products are 39 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 1 kHz. The IC-735 was being operated at rated input power on the 20-meter band.

transmit continuously for long periods with no reduction in power, as long as ambient temperature is 25 °C or less. The unit is designed to operate with an SWR of 1.5:1 or less. According to the operating manual, output power is reduced as SWR increases above 1.5:1, but it is possible to damage the transmitter by operating with a high SWR.

During AM transmissions, the carrier must be adjusted to 40% of the normal output level. The speech processor may be used during AM transmissions. No reduction of output power is necessary during FM transmissions. An optional 88.5-Hz tone unit (UT30) is available for use with tone-access repeaters. The tone is active when transmitting in the FM mode.

Front-Panel Controls

The most used controls are grouped at the center and right of the front panel. At the top right-hand corner are the VFO controls, VFO, A=B and SPLIT. If the VFO button is pressed during memory operation, frequency control is transferred to the VFO that was in use when memory operation began. Another press of the same button transfers control to the other VFO. The A=B button equates the frequency and mode of the second VFO to that of the VFO currently displayed. A=B has no effect during memory operation. When the SPLIT switch is pressed, "SPLIT" appears on the frequency display, and subsequent transmissions take place on the frequency/mode of the second VFO. This allows convenient cross-mode contacts. A second press of the switch cancels split operation.

Below the VFO buttons are two knobs that set the passband tuning (PBT) and notch-filter frequency (NOTCH). The instruction manual describes two different PBT actions. In CW mode, PBT varies the receiver bandwidth from 2.3 kHz (maximum clockwise rotation) to 800 Hz (maximum counterclockwise rotation). In the SSB mode, a detent at the 12 o'clock position corresponds to maximum bandwidth (2.4 kHz), and knob rotation shifts the IF filter center frequency up to 1.8 kHz above or below its normal frequency. PBT does not function during AM or FM operation.

The large knob at the right side of the front panel is the RIT frequency control, with a range of ±800 Hz. To the right of the RIT knob are two on/off push-button switches for the NOTCH and RIT features.

Memory controls, all push-button switches, are grouped at the lower right of the front panel. MEMO transfers frequency/mode control of the transceiver to the memory indicated on the display. The current frequency and mode are written into the memory indicated on the display when the MW (memory write) switch is pressed. When in the VFO mode, a press of the M>VFO button transfers the contents of the displayed memory to the active VFO. When in the memory mode, the M>VFO button transfers the display frequency and mode to the VFO that was in use prior to memory operation. (Since the operator may tune away from a recalled memory frequency without affecting the memory contents, the information transferred need not be the same as the contents of the active memory.) A pair of memory-channel (M-CH) switches (DOWN and UP) change the memory number on the display. When under VFO control, only the memory number changes; in the memory mode, frequency, mode and memory number change to match the selected memory.

The main tuning knob on the IC-735 serves several purposes. A column of buttons to the right of the knob determines the tuning rate. With no button selected, the tuning steps are 10 Hz each. Pressing the KHZ button changes the rate to 1-kHz steps. The MHZ step rate serves as a band switch for general-coverage reception, while the HAM rate switches from one amateur band to the next as the main tuning knob is rotated. When the HAM rate is selected in the SSB mode, the appropriate sideband for each band is automatically selected. Tuning speed varies not only with the selectable step rates, but also with the speed of knob rotation. That is, as the rotation speed increases, so does the number of steps per rotation.

At the bottom of the button column is the SCAN switch, which starts or stops transceiver scanning. (Note that transceiver scanning is different than tuning with the scanning microphone, which is discussed later.) In all scanning modes, the receiver halts when it comes to a signal. Dependent on the scan-timer switch setting, inside the radio, the scan may resume after about 10 seconds or may halt completely. Once the scan continues, it will halt at signals only if the RECV indicator was off (squelch closed) when the scan resumed. An internal jumper selects either a slow- or fast-scan rate. Programmed scan limits are stored in memories 11 and 12. The programmed scan begins at the lower of the two limits and scans to the upper limit at either 10-Hz or 1-kHz steps as determined by the step-rate switches. Scanning can be stopped by again pressing the SCAN button, by transmitting or moving the tuning knob.

A memory scan selects all memories, in sequence, regardless of mode. It is initiated by pressing the SCAN button while in the memory mode. Memories with different modes than the displayed memory are excluded from the scan by pressing the dial-lock button before initiating the memory scan.

It is possible to tune the IC-735 with a scanning microphone. Scan operations and the microphone scan occur at the same jumper-selected rate. I used only the slow-scan rate. At the slow rate, it is possible to stop the scan before passing a signal. The step rate of the scanning microphone is either 10 Hz or 1 kHz, depending on the step-rate switches on the front panel. It is interesting that the dial lock inhibits tuning from the knob, but not from the scanning microphone buttons.

The '735 is one of the first HF transceivers to use a liquid-crystal display. Fig 2 shows the display with all indicators active. The frequency digits are 5/16-inch high. The brightness of the pleasant green display backlight is adjustable through a cabinet-access hole, and the display is easily visible under any conditions of ambient lighting. The display does not show the offset effect of RIT nor the on/off status of the notch filter.

The meter, to the left of the display, shows signal strength during receive and power output (PO) or ALC level during transmit (selectable by a front panel METER switch). When PO is selected, the meter can function as a reflectometer. A three-position, rear-panel switch selects the PO, SET or SWR function. Sensitivity of the reflectometer is not variable—the transmitter power-output level is adjusted to obtain full-scale meter deflection with the switch in the SET position. Reflected power may then be directly read by switching to SWR.

Controls that are less often used are grouped under the meter on the left side of the front panel. They include: noise blanker (NB on/off), ATTenuator (on/off), PREAMPlifier (on/off), AGC (slow/fast) and speech COMPressor (on/off). Below these buttons is a small recessed compartment with a smoke-colored plastic door. I have large fingers and found the door a nuisance. ICOM had foreseen this problem, however, and made the door removable. This compartment houses a switch panel with 12 separate controls—six sliding potentiometers and six push buttons. The sliding controls are: noise-blanker threshold (NB LEVEL), RF GAIN, RF POWER, VOX GAIN and DELAY, and MICrophone GAIN. The MIC GAIN control also functions as a SPEED control when using the optional electronic keyer. Push-button controls are: AM and CW filter (WIDE/NARROW), METER (ALC/PO), VOX (ON/OFF), break-in keying (BK-IN, FULL/SEMI) and keyer mode (ELEC KEY/ MANUAL), which selects the optional electronic keyer.

A group of four push buttons to the left of the switch panel select the mode of emission (SSB, CW, AM and FM). Pressing the SSB button initiates the single-sideband mode with the appropriate sideband selection (LSB under 10 MHz, USB on 10 MHZ and above). Subsequent presses of the SSB button will cycle the sideband selection between LSB and USB.

At the left edge of the front panel are: a push-button POWER switch, concentric AF GAIN and squelch (SQL) controls, a ¼-inch PHONES jack and an eight-pin MICrophone connector.

Rear-Panel Controls and Connectors

On the rear panel are several controls and connectors: SO-239 antenna connector; transverter output (30 mV, phono jack); antenna output (phono jack); receiver antenna input (phono jack); compressor-level adjustment; external speaker (1/8-in phone jack); microphone-tone adjustment; AM carrier-level adjustment; key jack (¼-in, three-conductor phone jack); anti-VOX adjustment; accessory jack 1 (for phone patch or AFSK connections, 8-pin DIN jack); meter switch (power out, set or SWR reading); accessory jack 2 (for connection to ICOM transmatches with automatic bandswitching, 7-pin DIN jack); ALC (phono jack); 6-pin power connector; remote (1/8-in phone jack for computer control of IC 735); send (PTT line, active low); and ground terminal (spring clip).

In addition to the previously mentioned backlight dimmer and AF-tone adjustments, there are cabinet-access holes for sidetone volume and tuning-knob drag adjustments. With the cabinet removed, one can select output power (100 W/ 50 W), 25 kHz marker-

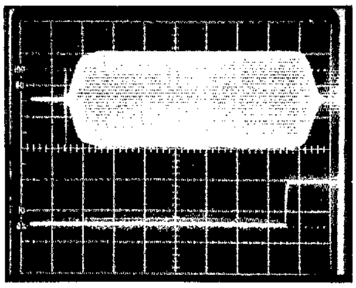


Fig 5—CW keying waveform of the IC-735. The lower trace is the actual key closure; the upper trace is the RF envelope. Each horizontal division is 5 ms. The very faint spike at the beginning of the envelope is discussed in the text.

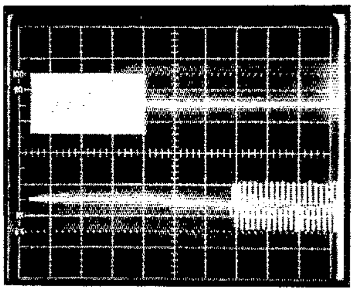


Fig 6—Receiver recovery (turnaround) time. The upper trace shows the key opening; the lower trace shows receiver audio output. Horizontal divisions are each 5 ms. There is an approximate 14-ms delay before receiver recovery.

generator on/off, scan-timer on/off or move a jumper to select fast- or slow-scan rate.

Operation

This radio reminds me of the early days of scientific calculators. The '735's capabilities can be somewhat intimidating, but a few days spent reading the manual and practicing various operations opens new realms of convenience and control. The 46-page instruction manual gives complete explanations for all normal operations. It does not, however, give any information about use of the remote-control capabilities of the IC-735.

I found the VFO and memory controls exceptionally easy to use, and powerful. Each memory has the flexibility of a VFO; essentially, the radio has 14 VFOs. Mode scanning was very helpful during the WØORE/ Challenger space-shuttle flight, when I used this feature to monitor various WA3NAN frequencies for shuttle communications. Normal noise conditions limit the effectiveness of the audio squelch, and therefore the scan operations in the SSB, CW and AM modes (except for the scanning microphone). Under quiet conditions, however, the functions are useful.

The optional IC-EX243 keyer was installed in the test radio. I am very happy with the keyer, but there are two aspects of its operation that are potentially inconvenient. Keyer speed is adjusted by means of the MICrophone GAIN/SPEED control on the front panel. The control is a sliding potentiometer in a recessed compartment. At my normal keying speed (15 to 25 WPM), I found the control somewhat difficult to adjust. Also, those who work both CW and phone must readjust the control each time they switch modes. CW weighting is adjusted during the installation of the keyer. When the keyer is switched off, one paddle may be used to hold the transmitter on while a matching network is adjusted.

My other radios do not offer full-break-in operation. Because the relay closures in those radios do not follow the key action exactly, I normally operate with a long VOX delay that maintains the transmit mode throughout a word. I found break-in operation with the IC-735 a pleasure. The TR relay is very quiet and not at all distracting. Break-in operation is effective up to about 35 WPM, where the space between dots becomes less than the AGC time constant.

A photo of the keying waveform (Fig 5) shows a very faint spike at the beginning of the RF envelope. This could cause a key click of extremely short duration if the spike were present on the air. I asked about clicks during every CW contact and received nothing but excellent reports.

The IC-735 performed flawlessly for me. It is a pleasure to operate. It is a lightweight, but feature-packed rig. The ICOM IC-735 is available from ICOM America, Inc, 2380 116th Ave, NE, Bellevue, WA 98004, tel 206-454-8155. Price class: IC-735, $849; IC-EX243 keyer, $50; FL-32 500-Hz filter, $60.—*Bob Schetgen, KU7G*

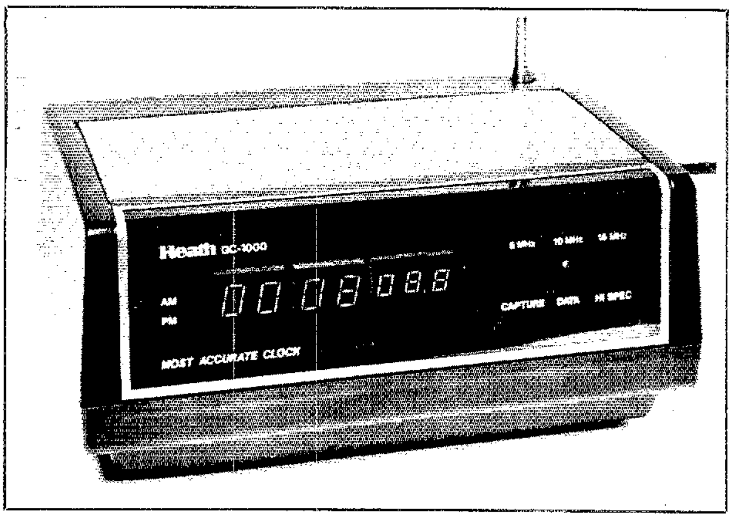
HEATH GC-1000: "MOST ACCURATE CLOCK"

Our lives all revolve around one common element—time. Every day we hear or ask the question, "What time is it?" When asked this question, most of us will glance at a $3.94 mail-order-special timepiece and blurt out some sort of a reply. After such an encounter, do you ever wonder what time it really is?

If you own the Heath GC-1000, you probably will never again have to wonder. Why? Because the GC-1000 automatically sets itself to the National Bureau of Standards time signals whenever a strong signal can be received from WWV on 5, 10 or 15 MHz. The unit is modifiable to use WWVH by changing one resistor and two capacitors during construction. The clock will run on either 117- or 234-V ac. If the power source fails, an external 12-V dc source can keep the clock running accurately. Even if such a source is not available, the GC-1000 will reset itself automatically when power is restored if an adequate WWV signal is received. An optional RS-232-C output is available to supply chronograph information to your computer at speeds between 110 and 9600 bauds.

NBS Time Information

The National Bureau of Standards' stations (WWV in Colorado, WWVH in Hawaii) transmit time signals continuously on frequencies of 5, 10 and 15 MHz. The RF receiver in the clock scans these three frequencies and locks on to the strongest signal. A binary-time code is included in the transmissions. This code consists of one-minute-long strings of binary data made up of several sets of pulses. Each set of pulses represents one digit of informa-



tion. The position of the digit in the code determines whether the digit represents an hour, a minute or a second. Time-code pulses are sent once each second, so that in the one-minute time frame enough information is sent to convey current hour, minute, second and day of the year.[1] Using this mechanism, the GC-1000 automatically calibrates itself to NBS.

Time Display

The most easily observed difference between the GC-1000 and most other digital clocks is in the time display. In addition to hours and minutes, seconds and tenths of seconds are displayed. If the clock has not set itself within the past 24 hours, the tenths-of-seconds display is dimmed. When the clock is running in the standard (12-hour) format, two LEDs indicate whether the time is AM or PM. These LEDs are extinguished in the 24-hour format.

In addition to the actual time display, six status LEDs are situated in two rows of three on the right side of the front panel. The top three LEDs (5, 10, or 15 MHz) indicate which WWV frequency is being monitored. The three lower LEDS indicate: CAPTURE (green), if the receiver is locked on WWV; DATA (amber), signifying that digital time information is being received; or HI SPEC (green) indicating that the clock has just calibrated itself and is accurate to within 10 milliseconds.

The Bottom Panel

Two DIP switches located on the bottom panel are used to: Select the time zone (including Daylight Savings Time); set the 12- or 24-hour format; activate or lock out each of the three WWV frequencies; and set the receiver propagation delay for distances of up to 3600 miles from WWV. In addition, UTC 1 (corrected UTC) can be selected to adjust the clock automatically in 0.1-second increments to make up for the slight variations in the earth's movement. When the variation exceeds 0.7 second, NBS initiates a "leap second," usually on June 30 or December 31, to get things back in line. With the GC-1000, there's no need to reset for a leap second—this is done automatically!

[1]Information on the exact format of the timing code can be obtained from the *NBS Time and Frequency Users Manual*, NBS Special Publication 559. A copy may be purchased from: US Department of Commerce, National Bureau of Standards, Washington, DC 20234.

Documentation

The 91-page manual supplied with the kit is used during assembly, testing and alignment. These instructions lived up to what I have learned to expect from Heath—all steps, from assembly through final testing, are clearly spelled out.

Construction

Most of the components used in the GC-1000 are contained on four PC boards. One of these, the three-channel scanning receiver, is factory assembled, tested and aligned. This board simply plugs into the main circuit board with an edge-type connector. The three remaining subassemblies, (display, tone decoder and main circuit board) must be "stuffed" and soldered. The tone decoder and display boards, like the receiver, plug into the main circuit board. Construction took about 8 hours, with an additional 20 minutes required for initial test and calibration.

Initial Test and Calibration

The internal microprocessor provides three modes to aid in unit calibration. The first mode checks all the LED segments in the time display. The second mode calibrates the 1000-Hz tone decoder used in WWV reception, and the third mode is used to align the 1200-Hz tone decoder used for WWVH reception. Only an insulated screwdriver, supplied with the kit, is required to perform these three adjustments. These constitute the entire calibration for the GC-1000. Four no 6-32 machine screws attach the cabinet to the electronic assembly. Finally, the 54-inch telescoping antenna is attached, and you're ready to tell time.

Operation

The Heath GC-1000 has been in service at W1OD for almost a year now, with no problems. The clock sits atop my transceiver. Although the presence of full-legal-limit RF approximately 6 inches from the unit does prevent the clock from calibrating itself to WWV while I'm operating, the internal 3.6-MHz oscillator keeps the time display accurate. This oscillator is electronically trimmed: Every time the clock aligns itself to WWV, the oscillator "remembers" the correction direction and adjusts its frequency accordingly. The 54-inch telescoping antenna will not provide a reliable WWV signal at my QTH, so an external antenna is used.

If you take pride in knowing what time it really is, the GC-1000 is definitely for you. Available from Heath/Zenith Computers & Electronics. Price class: GC-1000 Most Accurate Clock kit, $230; assembled and tested, $425. GCA-1000-1 RS-232-C Output Accessory, $50.—*Mike Kaczynski, W1OD*

New Books

THE COMMODORE HAM'S COMPANION

by Jim Grubbs, K9EI. Published by QSKY Publishing, PO Box 3042, Springfield, IL 62708. First edition, 1985. Soft-bound volume, 8½ × 5½ inches, 160 pages. $15.95 plus $2.50 for shipping and handling.

Whether you already own a Commodore 64™ or VIC 20™ computer or are thinking of buying one, you're sure to have a need for information on how to use it effectively in your hamshack. The 14 chapters in this book are designed to do just that, as well as provide you with some guidelines concerning the purchase of one of the many Commodore computers. The chapters are brief and cover a lot of territory.

Off the top, the pros and cons of the many Commodore machines are discussed. According to Jim, over 100,000 hams already own either a VIC 20 or a C64. That alone should give you some indication of why Amateur Radio equipment manufacturers and software developers favor those machines. If you don't already have a computer, you might consider this oft-quoted rule: Find the software that'll do the job you want to do, then buy the machine to run the software. (It's usually frustrating to try to do it the other way around.)

The software—communications, log keeping, MSO, FAX, grayline, and so forth—and hardware (RTTY/CW modems and TNCs) for use with the Commodore machines are discussed in several chapters. Other chapters cover computing by telephone and the information services and magazines that are available for Commodore users. A multiple-page listing of Commodore software and/or hardware suppliers is given in an appendix. Two other appendixes provide you with the addresses of about 20 different magazines and a glossary of terms. A bibliography of over 60 magazine articles pertaining to use of the Commodore computers and radio is also included.

Throughout the book are strewn tips and hints and tidbits of information that Commodore users are certain to feast on. Next to the "power on" switch, this is one item ham-oriented Commodore users will want to have.—*Paul K. Pagel, N1FB*

Conducted By Bob Schetgen, KU7G
Assistant Technical Editor

DIPOLES FOR HAND-HELD 2-M TRANSCEIVERS

☐ I have seen several descriptions of portable antennas for 2 meters. Most of them were of the "J" configuration, which seems unnecessarily complicated to me. What is wrong with the "lowly" dipole?

After five years of using the dipole I am about to describe, I have concluded that there is nothing wrong with it. It has traveled from coast to coast and border to border and has always permitted solid contact with at least one repeater (except in the most sparsely populated areas).

The center insulator of my dipole is shown in Fig 1. It is made from a piece of scrap Plexiglas® about ¼ × 1 × 2 in. Make a hole large enough to pass RG-58 cable in the center. Near each end, make a hole somewhat larger than the insulated element wires. (I used my soldering iron to melt the holes through the plastic.) Other center insulators can be used: NØAXK used a plastic milk-bottle cap.

For the elements, I used split "zip" cord. Hook-up wire would also work. Begin with the element wires too long, about 21 inches each, and strip about ½ inch from one end of each element.

Choose a length of coaxial cable for the feed line. Place a connector suitable for your transceiver on one end of the cable. Insert the other end of the coax through the center hole of the insulator. Strip off enough of the cable jacket so that the braid, when fanned out and twisted, can reach from the insulator center hole through one of the end holes, and be looped back to itself. Strip the center conductor to within ¼ inch of the shield. Feed it through the other end hole and loop it back on itself. Feed the stripped ends of the elements through the end holes (from the same side of the insulator as the feed line) and twist them to the coax conductors. Solder all twisted connections.

I support each end of the antenna with a few feet of mason's twine. A couple of half hitches around the element ends supply enough grip so the antenna does not fall down. I usually hang the antenna between a curtain rod and a chair leg.

Adjustment requires a tape measure, wire cutters and an SWR meter. Put the SWR meter between the transmitter and the feed line. Hang the antenna a couple of yards from any conductors. (I wonder if hanging it in an aluminum window frame would be a better approximation of a hotel room window.) Set your transceiver frequency to the center of the band segment you plan to use. Measure the SWR. Then, using the tape measure to assure equal element lengths, cut off about ¼ inch from the end of each element. Continue measuring and pruning until the SWR reaches a minimum.

Take the antenna down, coil it up, tie the bundle with the end support strings and throw it into your suitcase. You are ready to travel!—*Tony Appeiget, KØDCF, Plymouth, Minnesota*

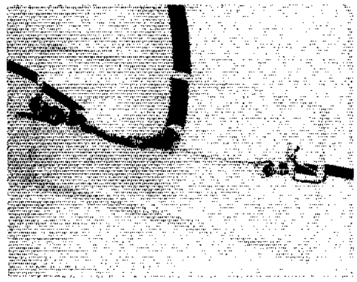


Fig 1—The center insulator of KØDCF's simple, portable, 2-m dipole antenna.

Fig 2—KD7MW's dipole for a 2-m hand-held radio.

☐ When you bring up the subject of antennas for 2-meter hand-helds, you might attract 10 different hams with 20 different opinions! There are many antennas on the market, and each one has its devoted admirers. Each manufacturer presents all sorts of advertising claims.

One simple fact is often overlooked: Many common vertical antennas ($\lambda/4$, $5/8\ \lambda$) require an ideal ground reflector in order to work as we expect. The ground reflector simulates a mirror-image of the radiating element, providing the gain and radiation patterns that we associate with the antenna.

When a rubber duck or whip antenna is used with your hand-held radio, there is no ground reflector. Under such conditions, the theoretical gain we associate with a "textbook" $\lambda/4$ vertical antenna is not available. In fact, the vertical element acts as one half of a dipole, while the radio itself acts as the other half. [An excellent discussion of $5/8$-λ and other vertical antennas appears in *The ARRL Antenna Compendium.*—Ed.] If we add a second resonant $\lambda/4$ element, a center-fed dipole and better performance should result.

I added a $\lambda/4$ wire to my hand-held radio to find out (Fig 2). Attachment of the second wire is simple. First, find an alligator clip large enough to grip the metal jacket of the hand-held-radio antenna connector. (The clip can be found at Radio Shack® or an auto-parts store.) Connect the clip to a piece of wire. (I used 16 AWG, stranded, insulated wire.) Cut the wire so that the entire assembly is 19¾ inches long. Bend the wire down 90° about 4 inches from the clip. Fasten the clip to the top of the antenna connector so that the wire hangs down clear of your hand.

[My TR-2500 has an insulated BNC connector, which prevents use of an alligator clip. I used no 20 wire for the element and formed a loop in the end of the wire. The loop slips over the BNC jack and is pressed into contact when the BNC plug is tightened.—Ed.]

Table 1

Relative Strength Readings for Several Antennas with and without an Added $\lambda/4$ Wire Element

Antenna	*S Units* *Without Element*	*With Element*
Rubber duck	6.5	8.5
$\lambda/4$ no 1	7	9.5
$\lambda/4$ no 2	8	9 + 10 dB
Hot Rod	9 + 10 dB	9 + 10 dB

Does it work? You bet! I tested four antennas: two homebuilt $\lambda/4$ whips, the rubber duck that came with my ICOM 02-AT and an AEA Hot Rod.™ All but the Hot Rod show significant improvement when used with the second element. Received signals are stronger. Relative field-strength measurements are higher and show that the angle of radiation has been lowered. The results of on-the-air tests with another ham, located about five miles away, are shown in Table 1. He measured my signal strength on the S meter of a Yaesu transceiver. The wire boosts the signal strength of the $\lambda/4$ whips and rubber duck by about 2 S units. I have repeated this test with other hams and achieved similar results. With the added wire, the $\lambda/4$ whips performed as well as the Hot Rod, and even the rubber duck puts out a better signal than a $\lambda/4$ whip alone.

Note that the wire has no appreciable effect on the performance of the $\lambda/2$ AEA Hot Rod. This is not surprising since a $\lambda/2$ conductor is already a complete antenna.

I find the Hot Rod a superb hand-held-radio antenna, but it appears to be an end-fed "Zepp" oriented vertically and fed through a matching network. My $\lambda/4$ whip and $\lambda/4$ wire comprise a $\lambda/2$ vertical dipole. As my results show, a $\lambda/2$ antenna radiates equally well, whether it is end or center fed.

Every hand-held-radio antenna is a compromise between radiation efficiency and size considerations. Rubber ducks are very convenient, but not very efficient performers. Longer antennas offer more efficiency and gain, but their length often presents a hazard to objects and people.

For me, the best all-around hand-held-radio antenna is a $\lambda/2$ dipole, consisting of a $\lambda/4$ flexible-steel whip, made from measuring tape, and a single $\lambda/4$ wire. With this configuration, I can walk down a street near my home and talk through a repeater 70 miles away, in Victoria, British Columbia. Except for the Hot Rod, no other antenna I have tried can do that. The measuring-tape antenna is not too long for most indoor use, and it does not damage itself or the surroundings in the event of a collision. The wire dangles down harmlessly beside my hand and rarely gets in the way.

On those occasions when I must use the rubber duck, I attach the λ/4 wire. This allows me to reach repeaters that are normally inaccessible with the duck alone. Under windy conditions that would blow the tape antenna over, I use the Hot Rod.

A heavy-duty dipole could be made using coat-hanger wire or aluminum clothesline. The second element can be made of any insulated wire that is stiff enough to hold its shape during use and flexible enough to roll up and put in your pocket.

Tune the dipole by attaching it to an SWR indicator and carefully pruning for minimum reflected power. (Many SWR indicators designed for HF use give a valid reflected-power null at 2 m, although higher SWR readings may be inaccurate.) Be sure to keep the radio and antenna in the same position relative to your body and nearby objects each time you take a reading; varying proximity effects distort the measurements.

One other tip: Do not touch either element while operating. You may not get an RF burn at low power levels, but you may detune the antenna and attenuate both transmitted and received signals.

The extra wire may look a little odd, but it works very well. To my mind, a 2-S-unit improvement is worth a few snide remarks! In this high-tech age, it is nice to be able to boost your signal so much with such a simple, easily made accessory. It is probably the cheapest 2 S units you will ever gain!—*Peter A. Klein, KD7MW, Seattle, Washington*

PUT YOUR HEATH DX-20 AND VF-1 ON 30 METERS

☐ The Heath DX-20 is a 50-W CW transmitter that covers the 80, 40, 20, 15 and 10-meter amateur bands. It can operate on 30 meters with two simple wiring changes, if 20-m operation is sacrificed. The conversion entails moving a tap on the plate-tank coil of the oscillator/multiplier stage and disconnecting a tap on the pi-output inductor of the final amplifier.

First, move the 20-m tap on the plate inductor of the 6CL6 (oscillator/multiplier) to 12.5 turns from the plate end (three turns toward the ground end from its original position). The new doubler tank tunes from about 9.4 to 15 MHz, so be sure to tune it for peak PA grid currrent near maximum capacitance. Then, disconnect the 20-m tap (from the band switch) on the pi-output inductor of the 6DQ6A final amplifier.

The transmitter can be used with 5-MHz crystals or with a 5-MHz VFO. The Heath VF-1 VFO can provide a 5-MHz signal if we pad the 11-m oscillator (which originally operated from 6.74 to 6.81 MHz). (I connected about 115 pF, NPO, in parallel with the 11-m trimmer.) Adjust the trimmer so that a 5.05- to 5.075-MHz output signal is produced while tuning from 7 to 7.135 MHz on the VF-1 high-frequency dial. Then peak the VF-1 output by adjusting the slug in the HF output coil. Peak VFO output is indicated by a maximum grid-current reading for the 6DQ6A in the DX-20.—*Carl Long, K8OWL, Parkersburg, West Virginia*

THE ETCHED MONIMATCH IS ACTUALLY AN OMNIMATCH

☐ A circuit for an SWR meter appears in "An Etched-Circuit Monimatch . . .", October 1969 *QST*, pp 29-33. The same circuit appears on page 124 of *The ARRL Antenna Anthology* (out of print). I built the circuit without deeply considering its operation. After a while, I became suspicious at the ease with which my antenna tuned (as indicated by the twin meters).

I discovered that, under some conditions, voltage developed by D2 back biases D1, so that unity SWR is indicated regardless of the transmission-line conditions. Since I wish to retain both meters, I quickly installed a dual potentiometer (see Fig 3) and found a vastly different situation concerning the dynamics of the antenna, tuning settings, and so on. —*Kevin C. Parsons, VK2DYW, Turramurra, Australia*

MORE ON RFI TO TOUCH-CONTROLLED LAMPS

☐ I had the same problem as W7OTC (Hints and Kinks, May 1985 *QST*) with a touch-controlled lamp switched on and off by my transmissions (100 W to a roof-mounted vertical, with two radials per band). The problem occurred during operation on the 80- through 15-m bands, but 10-m operation had no effect. A 1-kΩ resistor was not a complete cure in my case.

A 3.3-kΩ resistor in series with the signal input on the lamp helped on all bands except 80 m (an additional 1.8 kΩ prevented the lamp from functioning). When the resistor was replaced with an RF choke (100 μH, 139 mA), the problem abated on all bands except 80 m. On 80 m, the interfering signal was considerably attenuated by the choke, but the lamp still switched. The choke alone may be enough to clear up the problem in some cases.

The final answer turned out to be both the RF choke and a 1.8-kΩ resistor in series with the signal-input lead to the touch-control circuit.—*Colin Hall, G4JPZ/W6, Marina del Rey, California*

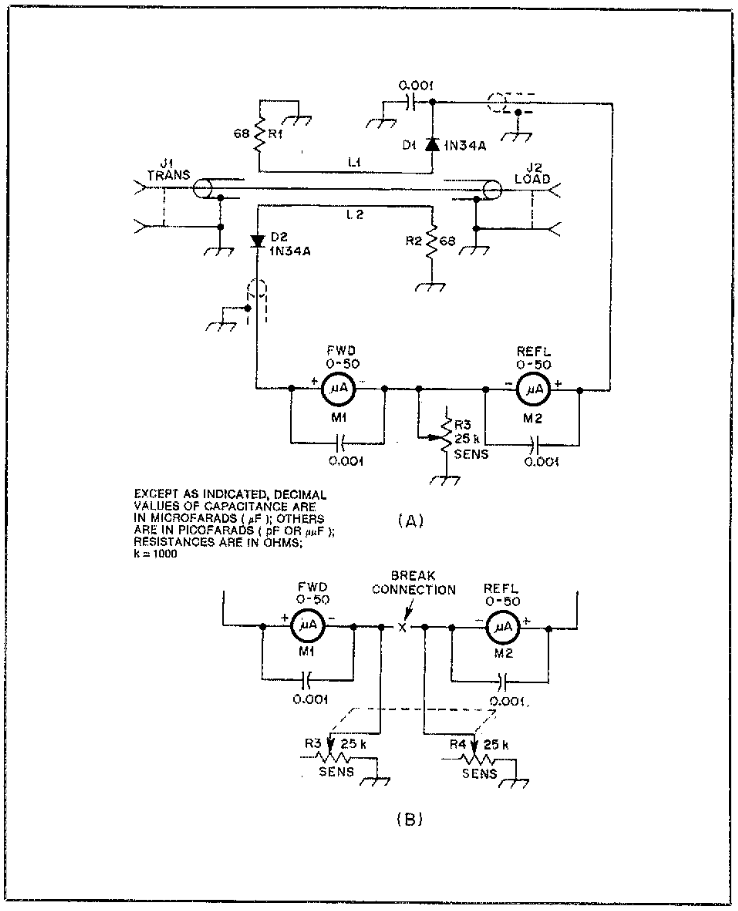


Fig 3—An original (A) and corrected partial schematic (B) of the etched-circuit monimatch. For details of L1 and L2, see *The ARRL Antenna Anthology* or the original *QST* article mentioned in the text.

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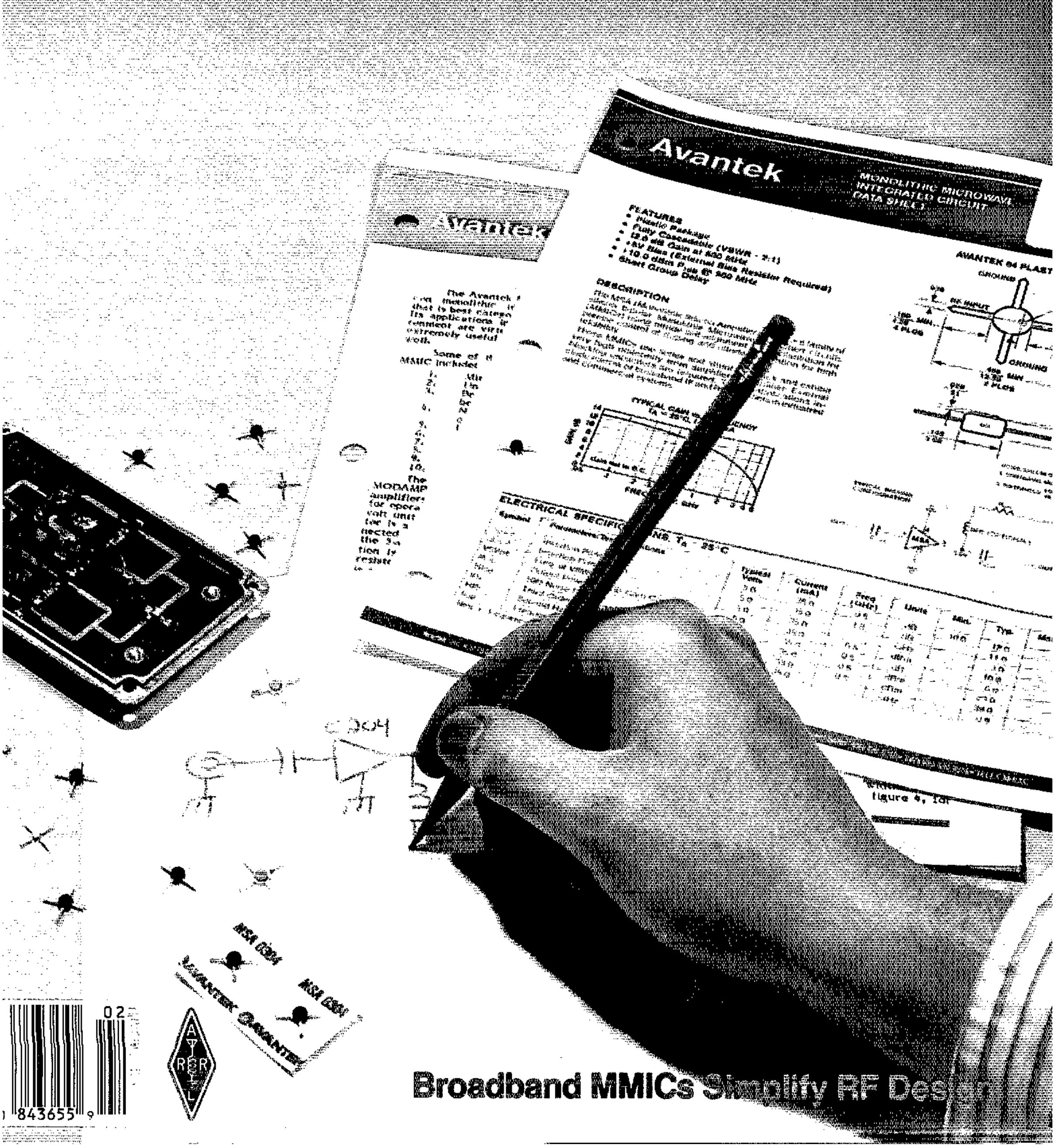

Broadband MMICs Simplify RF Design

February 1987 *Volume LXXI Number 2*

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OUR COVER

Broadband monolithic microwave integrated circuits ((MMICs) are rapidly replacing discrete transistors in many low-level RF amplifier circuits. These low-cost gain blocks work from HF through the microwave region and require no tuned circuits. To learn more about these state-of-the-art devices, turn to page 23. *(cover photograph by Meyers Studio)*

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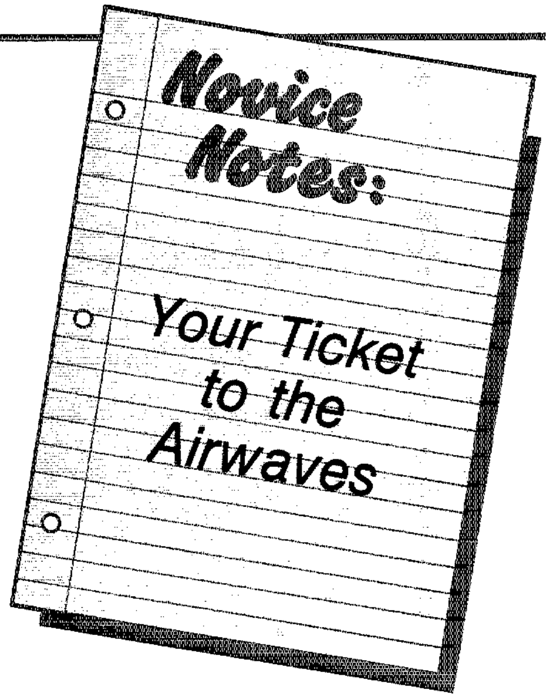


Need a hand putting that Novice ticket to use? Help is as close as your nearest club.

By Lee G. Hayford, AH2W

The chilly bite of this mid-December morning didn't bother Matt as he made his way through the freshly fallen snow. Spotting a coworker, Matt packed a handful of fluffy snow into a ball and threw it at Jack, who was huddled at the bus stop, breathing on his bare hands. The snowball crumbled in midair. Jack hadn't even noticed.

Four weeks ago, Jack had passed both the written and code parts of the Novice test. Carl, a local electronics technician, had given him the test and said the FCC would issue a license in four to six weeks. Though Jack had spent the past month dreaming of making his first contact, he dreaded trying to copy those first code signals through other signals and noise—what Carl called QRM and QRN. Nonetheless, he smiled at the thought of those reams of scrap paper piled in his desk drawers, testimony to the hours he'd spent on code-practice sessions.

"Ground control to Jack," yelled Matt, finally getting his friend's attention.

"Oh, hi, Matt. I was thinking about getting my Novice ticket and what my call sign will be."

"Yeah, I know how you feel. Too bad you don't have an antenna and a rig yet. You won't be able to get on the air when you get your ticket...unless you go over to Carl's shack."

"I know. But what really bothers me is I don't know what antenna would work the best on 15 meters—or even how to put one up. Not to mention finding a radio in my price range. There are so many kinds available."

"How about asking Carl for some help?"

"I've thought of that, but Carl has a tight schedule. Probably doesn't have the time."

"Then why not come over to the club meeting tonight? I'm sure you'll find someone there who'll be glad to lend you a hand putting up an antenna. You gotta admit, it sure would be nice having a station to get on the air with as soon as your license arrives."

"What kinda club is it?"

"A repeater club."

"Will a ham who's into repeaters be willing to help me put up an HF antenna?"

"I don't see why not...but there are plenty of other clubs. Last week, I called the American Radio Relay League and got hold of the Club Services Department. They sent me a computer printout of all the ARRL clubs in my area."

"Yeah?" Jack wondered, stamping his feet to keep warm.

"Sure. They also sent me a list of instructors in my area. I've been putting off upgrading to Advanced, and maybe an instructor will give me the push I need."

"Okay, so I can get a list of ARRL clubs. But why should I join one? All I wanna do is get on the air, have a few QSOs and maybe build up my code speed."

Matt thought for a moment before answering. "There are lots of reasons. You've already said you need help putting up an antenna...and advice on buying a rig. You might even find a club member who has some gear to lend you."

"Hmm," thought Jack, not totally convinced.

"I had a blast at last month's club meeting. Club members gave me a plaque for being ham radio's worst cook. I tried to cook lasagna for a club dinner—and promptly learned that I should stick with contesting. It's nice to be part of the gang. This weekend, I'm using my 2-meter hand-held at a checkpoint in the Christmas parade. Our club always sends a bunch of us to help coordinate communications during a few public-service events each year."

"Okay, okay, I get the idea," said Jack.

"If I join a club, I get all kinds of support and help, make new friends, and have fun while I learn about ham radio and make myself useful in the community. The only way to start is to go to a meeting—and you've just sold me on that idea."

That evening, Jack was roused by the shrill ring of the telephone. Browsing through the *ARRL Operating Manual,* he was looking for tips on making his first on-the-air contact. How will I ever learn all those Q signals, thought Jack. It's hard enough not being nervous about making a mistake during a contact. But Jack's fears gradually gave way to his growing excitement.

Matt's enthusiasm for ham radio spilled through the telephone receiver. "Jack, you comin'?"

"You mean to the club meeting?"

"Yeah. Carl just told me that the club finished putting up a six-element triband beam yesterday, and tonight they have a sked with Pitcairn Island, of *Mutiny on the Bounty* fame."

"Great, Matt. Count me in. You drivin'?"

"Sure, I'll be over in a few minutes to pick you up."

Jack marveled at the large number of people crammed into the tiny electronics workshop at the community college. The buzz of people talking reminded him of the boarding area of a busy airport. He generally didn't like crowds and was about to lose himself in a corner when a hand firmly clasped his back.

"Glad you've come to the meeting, Jack." Carl's pleasant voice eased his nervousness. "The club president usually begins the meeting by introducing all visitors, so don't run away." Jack smiled at the gentle tease.

"Matt told me this is a repeater club, Carl. Why is a DX contact on the agenda?"

"We have a club repeater, sure, but this is really a general-interest club. We're into all kinds of things. For example, Bill over there and a few other club members are working on an intercom system for the hospital in their spare time. Mary and Joe work a lot of the traffic nets, passing messages. The club even has a local net on 10 meters.

Jack was impressed. "Does the club hold classes for people interested in getting a license...or upgrading?"

Carl's eyes wrinkled in a warm smile. "Why, Jack, don't you remember your own introduction to ham radio came when you asked me what that long pole was doing on my roof?"

"I sure do, Carl. But I never thought of you as being a teacher."

"From now on just call me 'Teach,' " whispered Carl as the club president called the meeting to order.

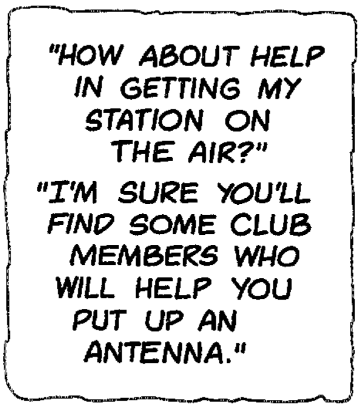
Help Is Just a Phone Call Away

If you're like most Novices and beginners, you'd appreciate a little help putting that new ham license to use. More than likely, you don't have an experienced amateur operator in the family, so you'll have to look elsewhere. A radio club is one of the best sources for help in setting up a station, locating gear, and even when an antenna project goes awry. It's also a good place to learn more about operating: contesting, DXing, handling traffic, repairing equipment, and more. And don't forget fellowship—getting to know the people behind the call signs. Many are the special personal rewards for joining those who have helped you get that Novice ticket, and by helping others in turn.

Radio clubs are as varied in purpose and scope as the members themselves. There are repeater, school, DX, general-interest, contest, VHF and public service clubs, to name a few. Finding the club that matches your interests is easy to do, and will greatly increase your enjoyment of Amateur Radio. As a newcomer, you can bring enthusiasm and a new perspective to any club—and add to the collective strength of the Amateur Service.

Well, what are you waiting for? There are nearly 1800 clubs across the country that are actively affiliated with the ARRL. Why not call or write to the Club Services Department, 225 Main St, Newington, CT 06111, tel 203-666-1541. We'd like to put you in touch with a club near you today.

Lee Hayford, AH2W, is the ARRL Club Program Manager.



• *Under Construction*

Understanding and Constructing RF Chokes

Part 16: RF chokes shouldn't be taken for granted. They can become hot, burn out or work perfectly. Some simple rules for ensuring good performance are given here.

By Doug DeMaw, W1FB
ARRL Contributing Editor
PO Box 250, Luther, MI 49656

Where can I buy a plate choke for my homemade linear amplifier? Can I construct my own choke? How much inductance do I need? These common queries are sometimes heard while monitoring the ham bands, or read when answering my mail. I think more needs to be known about RF chokes by those who are new to Amateur Radio, or those who haven't taken the time to learn how RF chokes operate. This article is aimed especially at those of you who want to know how to choose or build an RF choke for best performance.

Types of RF Chokes

Fig 1 shows three common formats for RF chokes. A single-layer or solenoidal choke is shown at A. A pi-wound choke is shown at B, and a solenoidal toroid RF choke is depicted at C. Each of these chokes can do the same job if they are designed and applied correctly.

Chokes A and B of Fig 1 may be air wound or on insulating, nonmagnetic forms, such as ceramic or high-dielectric plastic. When a large amount of inductance is needed, versus choke physical size, we may use ferrite or powdered-iron forms to increase the inductance over that which will occur with an air-core coil of equal turns and size. The pi-wound choke of Fig 1B also provides a means by which greater inductance (many wire turns per pi) can be obtained.

RF chokes come in many sizes and shapes (Fig 2). Some are encapsulated to protect the windings from abrasion, dirt and moisture. Others are simply dipped in glyptol or similar varnish, while many chokes are without any exterior protective coating. Some chokes are wound with Litz wire (several strands of fine enameled wire in a silk or cotton outer sheath), and others

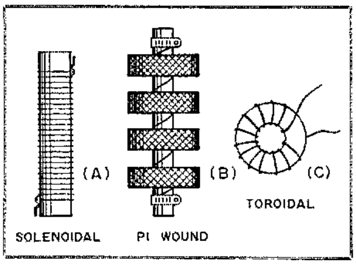


Fig 1—Formats for RF chokes. A single-layer, solenoidal winding is shown at A. Chokes with multilayer pi windings appear as shown at B. Toroidal RF chokes (C) are also suitable, and offer a self-shielding property that is helpful in discouraging circuit instability.

contain plain enameled, single-strand copper wire. Generally, the Litz-wire chokes exhibit a higher Q when many turns are required. Some RF chokes are self-supporting, air-core devices. These are made from heavy gauge enameled wire (solenoidal wound), and require no solid coil form to help them retain their shape. This type of choke is used at VHF and UHF, where small values of inductance are common.

What Does an RF Choke Do?

The word "choke" is self-explanatory. But, what does an RF choke hold back? The answer is "RF energy." If we have a signal path to which dc must be added, we do not want the RF energy to become misrouted to the dc voltage source. Rather, the RF energy must be allowed to continue on its intended course. An RF choke permits the flow of dc, but will block the flow of ac or RF energy. Not any RF choke will provide this service: It must be of the correct inductance and current-carrying capability. This depends upon the type of circuit in which it is used.

Basically, an RF choke may be regarded as a resistance (impedance) against ac energy. The only dc resistance through the choke is the ohmic value of the wire in the winding. The higher the inductance (impedance) of the choke, the more effective it is for blocking the flow of ac or RF energy.

Circuit Examples

Two typical examples where RF chokes are used appear in Fig 3. Example A is for a transistor class-C amplifier. An RF choke is found in the collector circuit of Q1. It allows the RF current to flow into the pi-section filter, but not to the power supply via the V_{CC} line. However, the dc voltage will reach the collector via RFC1. A similar set of circumstances is found at B of Fig 3, where a vacuum-tube RF power amplifier is illustrated.

Choose the Right Choke Inductance

There is no universal RF choke that we may buy or build for circuits such as those in Fig 3. First, the choke must be able to handle the direct current that flows through it when the amplifier is conducting. The current should flow with minimum voltage drop, which means the choke should have the least dc resistance possible. Check the current rating of the choke you buy, or use a large enough wire gauge to handle the current if you wind your own RF choke. The wire table in *The ARRL Handbook* may be consulted for gauge versus current rating. Always select a current rating that exceeds the expected current by at least 20%.

Choke inductance is dependent on the

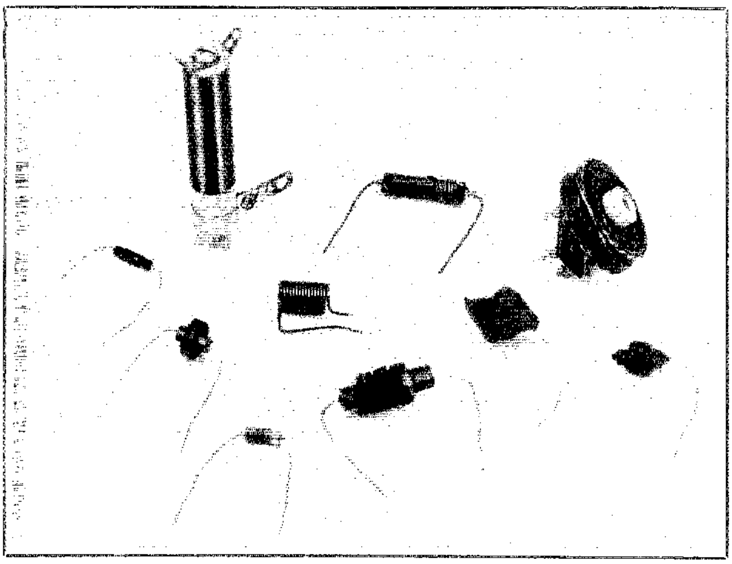


Fig 2—A collection of manufactured RF chokes to illustrate the many formats used in choke construction.

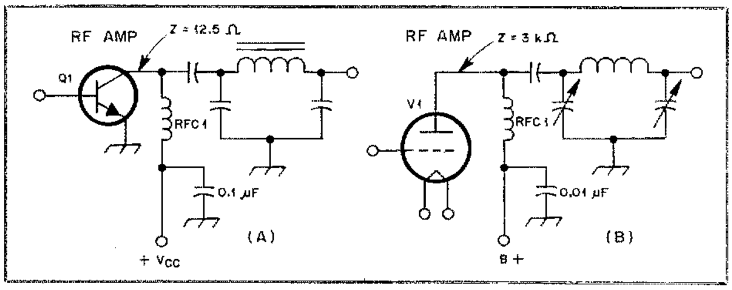


Fig 3—Circuit examples that show RF chokes as collector (A) and plate (B) impedances to allow the flow of dc while blocking the passage of RF current.

characteristic impedance of the circuit in which it is used. An industrial guideline for solid-state circuits calls for a choke reactance (X_L in ohms) that is approximately four times the impedance of the circuit to which it connects. Fig 3A indicates a collector impedance of 12.5 ohms. This means that the RF choke should have an X_L of 50 ohms at the lowest planned operating frequency. Assume that our amplifier will be used on 3.5 MHz. How may we find the required inductance for RFC1? Here is how it is done:

$$L\ (\mu H) = \frac{X_L}{2\pi f\ (MHz)} \qquad \text{(Eq 1)}$$

$$L\ (\mu H) = \frac{50}{6.28 \times 3.5} = 2.27\ \mu H$$

You may be asking, "How do I learn the transistor collector impedance?" That is also a simple procedure:

$$Z\ (coll) \approx (V_{CE})^2/2P_o \qquad \text{(Eq 2)}$$

where
Z is in ohms
V_{CE} is the collector-to-emitter voltage
P_o is the output power in watts

Thus, if Q1 of Fig 3 has a 12-V supply and 5¾ watts of output, the collector Z is 12.5 ohms, as shown.

The situation at B of Fig 3 is about the same as for A of the same figure. In this example, we find an arbitrary 3000-ohm plate impedance. Assume that our lowest operating frequency is 28 MHz. If we were to use the ×4 rule for reactance stated earlier, the ideal choke inductance will be based on 12,000 ohms of choke reactance. This equates to an inductance of 65.8 μH at 29 MHz, using the procedure in Eq 1. However, it is more practical to use a different procedure for vacuum-tube choke design. More on this later.

What if the Inductance Is too Low?

We must keep in mind that an RF choke is in parallel with the characteristic impedance of the circuit with which it is used. This can be thought of as two resistors in parallel, wherein the combined value will always be less than that of the smallest value. If the RF choke reactance is too low, say, a 5-ohm X_L in parallel with a 25-ohm collector impedance, the choke is not effective at blocking the flow of RF current, and some RF energy will reach the power-supply line. Also, this low choke reactance will cause a mismatch at the collector circuit if fixed-value networks are used. This will prevent proper power transfer from the amplifier to its load. In this undesirable situation, the choke will have to accommodate some RF current along with the dc current that flows through it. Choke heating or destruction can result.

RF chokes come in many sizes and shapes

It becomes impractical to follow the ×4 rule with tube types of amplifiers, owing to the high plate-impedance values. Most commercial high-power amplifiers contain plate chokes of fairly low reactance, respective to the plate impedance. The designers tend to adopt a different rule than is used in the semiconductor industry. The effective *parallel resistance* of the choke is the matter of concern rather than the X_L. A mismatch caused by low choke reactance can be tuned out by the adjustable network in a vacuum-tube amplifier. High-Q plate chokes are chosen to provide an acceptable parallel resistance. This characteristic can be measured with a laboratory instrument called an RX meter. A choke with a parallel resistance of 100 kΩ or greater would be suitable for use in the circuit of Fig 3B. Such a choke might have only 100 μH of inductance for use at 1.8 MHz. Multilayer pi-wound plate chokes were once used in place of solenoidal ones. This was done to obtain high values of choke inductance. Typically, a 1-mH choke was used for 80-m amplifiers. Pi-wound chokes can cause problems (more on this later).

Another example of an RF-choke application is shown in Fig 4. RFC1 permits the base of Q1 to have a dc return to ground, but it prevents RF energy from being lost to ground. A typical RF power transistor, when excited, has a base impedance of less than 10 ohms. Therefore, the RF choke may be of very low inductance. Let's assume the transistor in Fig 4 has a base impedance of 5 ohms. The operating frequency is 7 MHz. Knowing

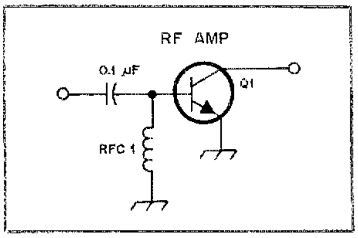


Fig 4—RFC1 is used as a base impedance for Q1. This provides a dc return for the base circuit while keeping the RF energy above ground.

these facts we find that Eq 1 calls for a minimum choke inductance of 0.45 µH. Therefore, a very small solenoidal choke may be used.

Problems with Series Resonance

If you're an old-timer, I'm sure you recall the shock of turning on, for the first time, a homemade RF power amplifier, only to hear a loud bang and see tendrils of smoke rise from the RF plate choke! On inspection you discovered that two or more of the multilayer pi coils of the choke had turned dark and slammed together with a shotgun-blast sound. Why did this happen? The culprit is called "series resonance." Fig 5A shows an RF choke across which some parasitic capacitance exists. All inductors are affected by stray capacitance across the turns. This sets up a self-resonant condition, such as that shown at Fig 5B. This parallel resonance can be troublesome at certain frequencies, especially in a broadband amplifier; the frequency response of the circuit will not be flat, as desired.

We are not concerned so much with parallel resonance in our narrow-band RF amplifier circuits, but *series resonance* in an RF choke can quickly cause choke destruction (shotgun effect mentioned earlier). A good RF choke will not exhibit a series resonance at any amateur frequency within the operating range of the amplifier. You may test your RF choke for series resonances by placing a shorting wire across the choke terminals (keep the wire short), then checking the choke with a dip meter. If the resonances fall outside the ham bands, no problems should be encountered.

A series resonance within or near a ham band will allow the RF current to rush through the choke to ground, via the bypass capacitor at the B+ end of the choke. This will heat the choke and set up a field that can cause the pi windings to slam together with a bang! A solenoidal RF choke, on the other hand, may end up with a blackened, sagging winding. I have known amateurs that blamed this type of malady on parasitics. It's true that high-magnitude parasitic oscillations can cause a choke to burn up, but only if the choke happens to be series-resonant at or near the frequency of the parasitic. The rule is to make sure that (1) your amplifier is stable, and (2) that the

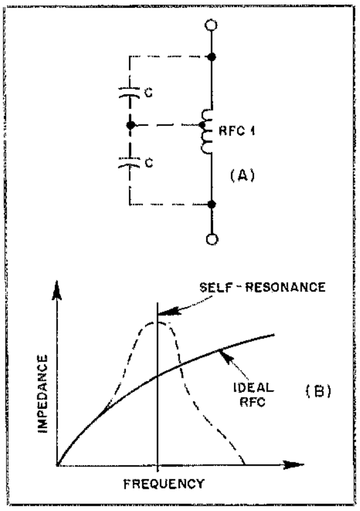


Fig 5—Stray capacitance exists across any coil winding, as shown at A. This can cause an unwanted parallel resonance for RF chokes (self-resonance) as indicated by the dashed curve at B.

plate RF choke has no series resonances at any planned operating frequency.

Other Choke Problems

Under some conditions, the RF chokes in an amplifier can set up an unwanted self-oscillation event. Fig 6A shows a circuit in which this might occur. RFC1 and RFC2 have relatively high Q values. Furthermore, they are of the same inductive value. These chokes, in combination with stray circuit capacitances, happen to be resonant (Fig 5B) at the same frequency. Here we have a perfect tuned-base, tuned-collector situation. Although the amplifier may be designed for 3.5-MHz operation, self-oscillation takes place at, for example, 800 kHz. The frequency of oscillation may be anywhere in the spectrum, depending on the parallel resonance of the chokes. If the self-oscillation is strong enough, it may destroy the transistor because of high peak voltages and currents.

How might we prevent this dangerous situation from existing? First, chokes of different inductance values should be used. Secondly, we can spoil the Q of one of the chokes (Fig 6B) by placing a low-value resistor in parallel with the choke, or by using an 850-mu ferrite bead in series with the RF choke. A resistor could be bridged across RFC2 of Fig 6B to lower the Q, but part of the amplifier power would be dissipated in the resistor. This is not an efficient road to travel.

Some Practical Homemade Chokes

Should we buy or build our RF chokes? Being the tightwad I am, and generally wanting "instant delivery" of component parts when I place an order, I prefer to make my own chokes. Certainly, a home-built RF choke is simple and inexpensive to fabricate. Let's examine first a high-power plate choke for a tube type of RF amplifier, such as two 3-500Zs in parallel for 2 kW PEP.

The photograph of Fig 7 shows an RF choke that I developed for my personal use. Several attempts were made to design a

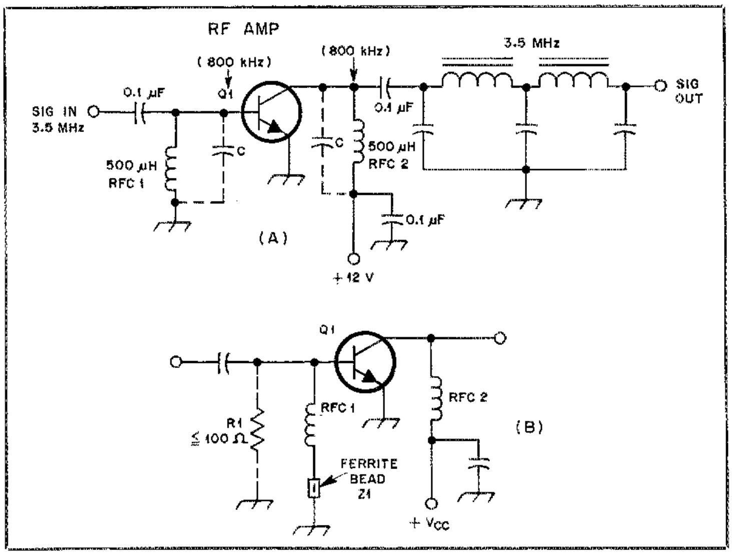


Fig 6—Unwanted parallel resonance of RFC1 and RFC2 at A can cause a tuned-base tuned-collector self-oscillation that may destroy a transistor. The circuit at B includes some Q-spoiling devices (R1 and Z1) that aid in preventing self-oscillation and the peaking response of self-resonance (see text).

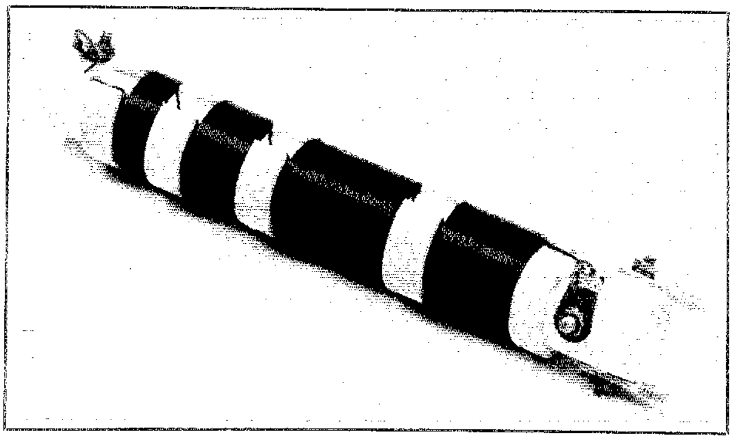


Fig 7—Photograph of the W1FB high-power RF plate choke. Unwanted parasitic capacitance is reduced by adding spacers along the coil winding.

Table 1
Homemade RF Plate Choke Performance

Freq (MHz)	*Parallel Resistance (kilohms)*	*RX Meter Reading*
28.0	100	X_L = 3
24.9	125	X_L = 2
21.0	125	X_L = 1.5
18.0	100	X = 0
10.1	100	X_C = 1
7.0	125	X_C = 6
3.5	100	X_C = 30

These values were measured by means of a Boonton Radio Corp 250-A RX meter. X_L is a plus reactance and X_C is a minus reactance. Series resonances for this RF choke are approximately 36, 43 and 64 MHz. The choke inductance is 65 μH and the Q_L (unloaded Q) is 120. Although the RF choke shows a parallel resistance of approximately 100 kΩ at 1.8 MHz, the capacitive reactance was off scale at this frequency. Therefore, the data were not included in the table. The choke should, however, perform satisfactorily at 160 meters.

choke that had no series resonances in or near any of the HF-band amateur frequencies. The 12-meter band presented the major problem in this effort: Series resonances kept popping up in a range from 23 to 27 MHz while working with a continuously wound solenoidal choke. I was able to increase the frequency of the unwanted resonance by making the choke winding smaller, but this sacrificed performance at 3.5 MHz. Finally, I reverted to the old method of placing individual single-layer windings on the coil form (see Fig 7) to break up the distributed capacitance. I knew this would raise the series-resonant frequencies of the choke. As indicated in Table 1, the resonances did indeed move higher (36, 43 and 64 MHz, as checked with my dip meter after placing a shorting strap across the RF choke). When the resonance existed at 26 or 27 MHz, the effective parallel resistance of the choke was only 5000 Ω at 24.9 MHz.

I chose no. 22 enameled wire for the choke winding. This size wire will handle up to 900 mA of current if it is not confined in a transformer case or other hot environment. We may assume that our RF chokes will be located where there is a flow of air (cooling fans) in a linear amplifier.

Fig 8 shows a small bobbin-wound choke that has an inductance of 3 mH. I wound this unit on an Amidon B-72 ferrite bobbin (permeability = 2000). The bobbin is filled with no. 30 enameled wire, scramble wound. The unloaded Q is 50 at 250 kHz. The parallel resistance is 125 kΩ at 500 kHz, and 100 kΩ at 1.9 MHz. These bobbins are ¾ inch long and have an OD of 3/8 inch. A collar is located at each end of the bobbin, and this makes it easy to scramble-wind and contain the wire. A wire pigtail protrudes from each end of the coil form to permit attachment of the coil winding. This choke was wound mainly to illustrate how easy it is to wind your own high-inductance RF chokes. Smaller ferrite forms (with pigtails) are also available for winding homemade VHF and UHF RF chokes.

Practical Aspects of the RF Plate Choke

Fig 9 shows the winding data for the plate RF choke of Fig 7. In practice, the number of turns per separate winding is not especially critical. Normally, I use progressively larger windings per section, but the lower winding of this choke had to be pruned in order to resolve the series-resonance problem mentioned earlier. Otherwise, there would be more than 36 turns on the bottom winding.

My coil form is a 5½-inch piece of high-impact polystyrene tubing with an OD of ¾ inch. The dividers between the winding sections are ¼-inch slices of ¾-inch PVC tubing. Each divider is cut with a hacksaw to provide an expansion gap when the dividers are mounted on the coil form. The resulting slots in the rings allow the wire to be routed through them to the succeeding winding. One length of wire is used for the entire choke.

No. 4 screws and nuts are used to affix the two solder lugs, and a pair of no. 6 spade bolts at the bottom of the coil form. The spade bolts may be used for attaching the RF choke to a chassis. A generous coating of polyurethane varnish is applied to the coil winding and divider rings. This protects the winding from abrasion while

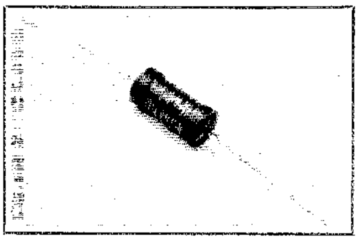


Fig 8—Photograph of a homemade 3-mH RF choke that is wound on an Amidon ferrite bobbin (see text).

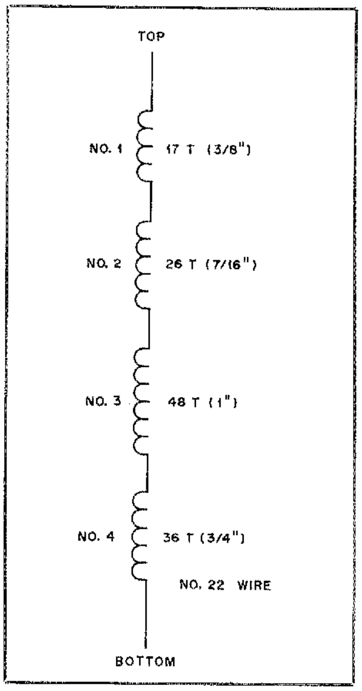


Fig 9—Details of the plate RF choke shown photographically in Fig 7. A continuous winding is broken up into four sections to reduce the effects of stray capacitance. Dimensions are included for the lengths of the four close-wound windings.

(continued on page 22)

Using *QSTs* to Choose an Old HF Rig

Want to buy a used HF transceiver? *QST's* Product Reviews can be a big help.

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The Product Reviews in old *QSTs* are invaluable in selecting a used HF transceiver. Product Reviews replaced the previous Recent Equipment articles beginning in January 1976. The change in the column title accompanied a change to more extensive laboratory testing in that year. The laboratory testing of Amateur Radio equipment is a highly beneficial service performed by ARRL for members. Although the "experts" may differ over the best method of testing, the approach used in the ARRL Lab has the virtue of being a standard procedure. It has been applied to most of the HF transceivers introduced in the last 10 years.

In preparing this article, Product Reviews appearing over the last 10 years were analyzed. Table 1 digests the information appearing in those reviews.

No transmitter data are given. The ARRL tests show that all transmitters complied with existing FCC regulations on spurious and harmonic emissions. However, in some cases modifications were necessary. A problem that is sometimes encountered in transmitters is distortion. SSB transmitters are not noted for high fidelity. Some transmissions are difficult to understand, and this may be complicated by phase distortion from a synthesized local oscillator. Read the laboratory testing portion of the Product Review and the on-the-air comments. Probably the best way to evaluate transmitter distortion is to listen on the air. A transmitter that sounds good when used by others usually will sound good when you use it, if used correctly. Try to choose a rig that is relatively distortion free.

In addition, such features as passband tuning, IF shift, notch filters, dual VFOs, digital readout, memory, scan capability, FM and FSK have not been included. Generally, later equipment and higher prices indicate more features. The review equipment may or may not have included options. Specific information about a particular rig can be obtained by reading the review.

Table 1 Format

Make and Model

The first column lists the make and model of 44 HF transceivers reviewed in *QST* from January 1976 through October 1986. The equipment is listed in the order that the reviews appeared—earliest review first, latest review last. All units generate a nominal output power of approximately 100 W, unless noted otherwise. Exceptions are the low-power transceivers produced by Heath (HW-8 and HW-9) and by Ten-Tec (Argosy, Century 21, Century 22). All the reviewed transceivers are solid-state designs, unless noted. The all-solid-state rigs have the advantage of easy tune-up and band changing. In addition, mobile or portable operation may be facilitated. The disadvantages are an optional power supply is usually required, and an antenna matching network of some type may be necessary.

QST Issue

This column lists the issue of *QST* in which the review appears. This information is the most significant information presented in this article. If you are considering purchase of a particular used rig, read its review carefully. Then check the next few months of the Technical Correspondence and Hints and Kinks columns for additional information (Feedback or updates). If you have a problem in locating the particular issue, try radio clubs, or the local public or university library. Many hams have saved all issues over a long time—try them, or check the flea market at your next hamfest. Also, the ARRL will furnish a back issue or a copy of the review for a nominal charge.

Bands and Modes

All of the transceivers cover the 80- through 10-meter amateur bands. This column shows any exceptions. Most of the transceivers are capable of CW and SSB operation. The Heath HW-8 and HW-9 transmit and receive CW only, and the Ten-Tec Century 21 and 22 transmit CW only. This column also shows additional bands and modes, such as 160 meters, WARC bands, general coverage capability and AM operation.

Receiver Performance

Three columns are devoted to describing the performance characteristics of the receiver sections. The tests performed in the ARRL Lab are patterned after those described by Hayward and covered in some detail in the *ARRL Handbook*.[1] A recent *QST* article describes the Product Review process, and the procedures that ARRL uses to maintain the integrity of the process.[2] Unless otherwise noted, the column heading 80 m-20 m indicates the test results that were obtained on 80 meters and 20 meters, respectively.

Minimum Discernible Signal

Minimum discernible signal (MDS), or noise floor, is the lowest level signal that can be detected by the receiver. It is the signal level equal to the internally generated noise in the receiver. Seven of the units contain preamplifiers that can be switched in or out of the signal chain. In six cases, the data were obtained with the preamplifier activated. In the testing of the Yaesu FT-102, the preamplifier was inactive. Preamplifiers reduce the MDS. The values in the table range from −144 to −125 dBm. (The lower-level values generally indicate better performance: −144 dBm is better than −125 dBm.) The lower values of MDS only improve performance up to a point, however. In the bands from 160 through 20 meters, reductions below about −132 dBm do not

[1]Notes appear on page 22.

Table 1
Summary of HF Transceiver Product Reviews

Make and Model	*QST Issue*	*Bands and Modes*	*Noise Floor (dBm)*		*Receiver Performance Blocking Dynamic Range (dB)*		*IMD Dynamic Range (dB)*	
			80 m	*20 m*	*80 m*	*20 m*	*80 m*	*20 m*
Heath HW-8	Apr 76	No 10m	—	—	—	—	—	—
Kenwood TS-820*	Sep 76	160	—	−136	—	114	—	85
Yaesu FT-101E*	Sep 76	160, AM	—	−141	—	108	—	81
Heath HW-104	Dec 76		—	−125	—	94	—	71
Yaesu FT-301D	Oct 77	160, AM	—	−133	—	100	—	75
Ten-Tec Cent 21	Dec 77	—	—	—	—	—	—	—
Kenwood TS-520S*	May 78	160	—	−133	—	104	—	69
Yaesu FT-901DM*	Nov 78	160, AM	−137	−137	114	118	85	90
ICOM IC-701	Apr 79	160	−133	−133	120	120	89	87
Drake TR-7/DR-7	May 79	GC, AM, 160	−133	−133	120	120	84	90
Swan 100MX	Jun 79	—	—	—	—	—	—	—
Ten-Tec 554	Jul 79	—	—	—	—	—	—	—
Yaesu FT-101ZD*	Dec 79	160	—	−139	—	112	—	78
Ten-Tec Omni D	Jan 80	160	−128	−139	115	125	94	90
Kenwood TS-120S	Feb 80	—	−139	—	108	—	75	—
Yaesu FT-7B	Mar 80	AM	—	—	—	—	—	—
Kenwood TS-180S	May 80	160,W	−139	−139	112	114	82	83
Swan Astro 150	Jul 80	—	−127	−131	114	118	84	86
Yaesu FT-107M	Apr 81	160,W, AM	−133	−133	NL	NL	82	90
Kenwood TS-830S*	May 81	160,W	−136	−136	129	NL	83	82
Yaesu FT-707	Jun 81	W, AM	−126	−127	NL	NL	76	80
Kenwood TS-130S	Jul 81	W	−138	−138	109	110	79	78
Cubic Ast 102BXA	Dec 81	160,W	−125	−129	NL	NL	90	84
Kenwood TS-530S*	Mar 82	160,W	−135	−136	112	120	88	90
ICOM IC-720A	Aug 82	GC, AM, 160	−132	−132	NL	NL	97	92
Collins KWM-380	Oct 82	GC, AM, 160, W	−131	−131	NL	NL	NL	NL
Ten-Tec Argosy	Oct 82	(10 MHz)	−133	−133	99	98	64	64
ICOM IC-730	Dec 82	W, AM	−140	−140	NL	NL	NL	96
Yaesu FT-One	Aug 83	GC, AM, W	−133	−138	NL	NL	NL	NL
ICOM IC-740	Sep 83	W, 160	−141	—	125	—	94	—
Yaesu FT-102*	Oct 83	160,W	−127	−127	NL	NL	97	97
Yaesu FT-77	Nov 83	W	−139	−139	99	99	92	94
Kenwood TS-930S	Jan 84	GC, AM,W	−139	−139	NL	NL	88	87
Heath SS-9000	Feb 84	160	−138	−140	119	118	88	91
Kenwood TS-430S	Mar 84	GC, AM,W	−138	−137	NL	NL	95	90
Heath HW-5400	Oct 84	W	−135	−133	110	112	82	90
Yaesu FT-980	Nov 84	GC, AM, W	−138	−138	NL	NL	NL	NL
Yaesu FT-757GX	Dec 84	GC, AM, W	−140	−137	NL	NL	90	89
ICOM IC-751	Jan 85	GC, AM, 160	−142	−138	NL	NL	91	93
Ten-Tec Cent 22	May 85	W(10 MHz)	−131	−128	112	109	82	81
Heath HW-9/HWA-9	Jul 85	W	−130	−128	124	122	99	88
ICOM IC-745	Sep 85	GC, AM, W, 160	−140	−144	115	116	92	94
ICOM IC-735	Jan 86	GC, AM, W, 160	−134	−133	NL	NL	92	88
Kenwood TS-940S	Feb 86	GC, AM, W, 160	−140	−139	141	138	93	97

*Indicates solid-state design with tube final amplifiers. 160 = 1.8-2.0 MHz. W = WARC bands. GC = General coverage. AM = Amplitude Modulation. NL = Noise limited. IC-730, IC-740, IC-751, IC-745, IC-735 and FT-757GX data are with preamplifiers active. FT-102 data are with preamplifier inactive. Test bands for HW-104, FT-301D and IC-740 are not given.

provide better performance because the natural atmospheric noise dominates. Lowering the noise floor in these bands may actually complicate other facets in the design. However, on 10 and 15 meters, lowering these values does indeed help.

Blocking Dynamic Range

Blocking dynamic range is a measure of the receiver's ability to copy a weak signal in the presence of a nearby, strong signal. (By nearby, we mean close in frequency.) The receiver is tuned to a weak signal, (typically −110 dBm), and another signal, 20 kHz away, is fed into the receiver input. The level of the close by signal is increased until the original audio output signal drops by 1 dB, indicating the onset of the collapse of the receiver's ability to process the original weak signal. The strength of the blocking signal is then referenced to the MDS to derive the blocking dynamic range. Thus, if a blocking signal is −25 dBm, and the MDS is −133 dBm, the difference between the two is the blocking dynamic range: 108 dB. The higher this figure is, the better.

Six tests were conducted with the preamplifiers in, and one with it out. Turning on the preamplifiers generally changes the values by −2 dB. The blocking dynamic range values in Table 1 run from 94 dB to 141 dB.

Sixteen of the transceivers show that blocking dynamic range is "noise limited." This is a problem that has arisen with the advent of synthesized local oscillators used in the newer equipment. A synthesized local oscillator operates by sampling the output of a voltage-controlled oscillator. The sample is fed to a frequency divider. This is a digital integrated circuit that divides by a number, N, chosen by the operator. Thus, a subharmonic is generated. The subharmonic is compared with the output of a crystal oscillator in a phase/frequency detector. Depending on whether the subharmonic is too low or too high, a dc signal is produced that regulates the voltage-controlled oscillator that generates the oscillator output. Filters are also incorporated. The net result is that the output frequency is N times the frequency of the reference crystal. Detailed descriptions of these phase-locked loops can be found in Helfrick, Williams and in recent editions of the *ARRL Handbook*.[3,4]

Synthesized circuits provide excellent frequency stability on the average. However, they tend to *hunt* for the proper frequency and generate what is referred to as "phase noise". In attempting to perform the ARRL blocking tests, loud noise sometimes occurs long before the 1-dB compression drop is obtained. It is sometimes referred to as phase noise, as hash, or as reciprocal mixing. The problem is discussed in the reviews of the FT-101ZD, FT-107M, TS-930S and KWM-380.

Thousands of the transceivers that are noise limited in the blocking tests have been purchased and are in use. This noise is a potential problem that buyers should be aware of. It points out the importance of thoroughly reading the reviews and testing equipment on the air.

Intermodulation Distortion

The intermodulation distortion (IMD) test determines to what extent two nearby signals can combine and produce energy in the passband of the receiver. In these tests, signal generators produce two fundamental signals that are of equal strength and 20 kHz apart. The two signals are fed simultaneously into the input of a receiver in the CW mode, and incorporating CW filters. When these two signals encounter nonlinear devices, or more specifically, mixer stages, various combinations of the signals are generated at discrete frequencies. The "third-order" frequencies are troublesome to the receiver because they are very close to the fundamental test signals. A detailed description of the phenomenon is given by Kerwin.[5]

The frequencies of the two third-order terms are determined by subtracting one fundamental frequency from twice the other fundamental. The example given in recent editions of the *Handbook* uses two fundamental frequencies at 14.040 and 14.060 MHz. These two frequencies yield third-order products at 14.020 and 14.080 MHz. During testing, the receiver is tuned to one of the third-order frequencies, for example 14.080 MHz, and then the two nearby, equal-strength signals at 14.040 and 14.060 MHz are increased from a very weak level while the audio output from the receiver is monitored. The strength of the two signals is recorded at the point where the audio output rises 3 dB above the internally generated noise. This level is referenced to the noise floor, and is defined as the IMD dynamic range. The higher the dynamic range, the better the receiver.

Again, six tests were conducted with activated preamplifiers and one without. The preamplifiers generally alter the results by 2 dB. Tests with two transceivers were noise limited because of the synthesized local oscillators. Values of IMD dynamic range in Table 1 vary from 64 dB to 99 dB.

Anomalies

Another consideration, not indicated in Table 1, is that of anomalies. About 20% of the equipment tested exhibited some sort of malfunction. Most were minor, but some were quite significant. Admittedly, most of the units tested were among the first off the production line. Most of their problems have been corrected, no doubt. Nevertheless, anomalies are a matter of concern. In buying a used rig, a warranty covering some time period is desirable. If that isn't feasible, checking the rig out at your QTH is a good idea. Using the rig at the seller's QTH is another alternative. At any rate, be aware that anomalies do exist and protect yourself as well as you can.

Prices

How much should you pay for a used rig? When you read the Product Reviews, check that issue of *QST* for advertised new prices. Remember that the transceiver was current-production equipment at that time. This will give you a good base to compare the relative values of two or more different rigs. Look through the used-equipment ads that appear in the current issues of *QST*—they'll give you an idea of values at present. Remember that most advertised prices do not include options—try to determine the value of such things as CW filters, built-in or optional power supplies, and so forth. They should be factored into your cost-value decision.

Conclusion

There is a lot of good, used equipment available. People have worked the world with all sorts of equipment. You first need to decide whether you must have an all-solid-state rig or will settle for tube finals. Decide what features you need, or will probably use. Check the noise floor, blocking dynamic range and IMD dynamic range of your candidate rigs. Remember that these figures come from tests on just one production item. There can be a variance among units in the same or different production lots. Next, take a look at price considerations. This process should narrow your choices.

From this point on, read Product Reviews, Technical Correspondence and Hints and Kinks. Listen on the air and find out how your candidates sound. Then, when you have located *your* rig, see what warranty or on-the-air testing you can arrange. Bear in mind that anomalies could be a potential problem.

Remember that there is no substitute for doing your homework. Following these procedures should provide you with an excellent used HF rig at a very reasonable price.

Notes

[1]W. Hayward, "Defining and Measuring Receiver Dynamic Range," *QST*, Jul 1975, pp 15-21.
[2]Bruce O. Williams, "The Product Review Process," *QST*, Dec 1985, pp 22-24.
[3]A. Helfrick, "The Universal Synthesizer," *QST*, Sep 1981, pp 18-23.
[4]F. Williams, "A Digital Frequency Synthesizer," *QST*, Apr 1984, pp 24-30.
[5]K. Kerwin, "Intermodulation Distortion: A Mystery Solved," *QST*, Jan 1984, pp 26-29.

RF Chokes

(continued from page 19)

it secures the wire and the dividers to the main coil form.

Polystyrene tubing will melt and become deformed in the presence of excessive heat.

PVC tubing* should not *be used as the main coil form, owing to its poor RF properties.

Therefore, this choke should be used only in a cooled amplifier compartment. Locate the choke at least 3 inches from the power-tube envelope. A piece of Delrin® rod can provide a more heat-resistant coil form (check with your local plastics dealer for this material). PVC tubing *should not* be used as the main coil form, owing to its poor RF properties.

In Closing

All too often I hear amateurs complaining about being unable to locate a commercially made RF choke of some specified value. Not only does it take time to find sources of supply for specific chokes, but the chokes can cost a fair amount of money. We can often build a good plate choke for under a dollar, whereas we might spend upwards of $10 (material plus shipping) to buy a commercial equivalent. Homebuilt RF chokes are not only less expensive, they can be made in a single evening!

One more tip is in order: Do not use a metal clamp at each end of the choke winding for attaching the coil wires. A closed conductor of that type is equivalent to a shorted coil turn. This will destroy the coil Q. I checked to learn the actual effect of a shorted turn on the plate choke of Fig 7. The unloaded Q dropped from 120 to 30 with only one closed conductor at the top end of the RF choke. A metal clamp can be used, provided it is not a complete conductor. That is, it can be circular to, say, 300 degrees. A nonconductive screw and nut are then used to compress the clamp for a tight fit on the coil form.

Monolithic Microwave Integrated Circuits

Part 1: Wait! Even if you're not interested in microwaves, you can still use these low-level gain blocks in your next RF project. They work from dc to nearly daylight!

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Monolithic microwave integrated circuits (MMICs) are sure to revolutionize receiver and transmitter design, just as low-noise GaAsFET devices did 10 years ago. Just what is an MMIC? The field is expanding so rapidly that the answer to that question changes every month. In this article, I will concentrate on low-level amplifier MMICs, useful in many ham projects, that are available in small quantities to individuals. This type of MMIC is a chip that contains a single-stage, Darlington-connected bipolar transistor pair with internal biasing. A combination of series and shunt feedback establishes input and output impedance, sets the device gain and ensures stability. The chip is contained in one of a variety of standard low-power, stripline transistor packages.

The state of the art is progressing rapidly in the fabrication of single-package RF ICs, and the term MMIC applies to devices other than single-stage amplifiers as well. Manufacturers have demonstrated that complete receiver front-end assemblies—including RF amplifier, mixer and even the local oscillator—are possible on a single chip. With current technology, MMICs are usable to 18 GHz!

The MMICs that I've used in my projects are from a family of silicon MODAMP™ MMICs manufactured by Avantek. Similar devices are available from NEC, Siemens (MSC) and others. The MODAMP is a modular gain-block amplifier with nominal 50-ohm input and output impedance. With the exception of one special series, these devices are unconditionally stable. Some versions provide usable broadband gain at frequencies above 4 GHz. Low-frequency performance is limited only by the value of the series blocking capacitors used at the input and output of the device.

An MMIC chip can replace an entire amplifier stage that uses the standard hybrid approach with discrete transistors, capacitors and resistors. Size is reduced dramatically, as is manufacturing assembly time. An MMIC chip is merely mounted to the case housing, and small bond wires tie the input and output to the appropriate pins on the device case. Since inductive elements and large bias decoupling capacitors are sometimes best done "off chip" because of their physical size, these are generally the only additional components needed to build a complete MMIC amplifier stage.

A Typical Circuit

The schematic of a typical MMIC amplifier stage is shown in Fig 1. A circuit like this is usable with most MMICs over a frequency range from dc to 3 or 4 GHz. The only thing that changes with frequency is the value of C1, C2 and RFC1.

Everything inside the shaded lines is contained inside the MMIC package! Series and shunt feedback resistors are shown as R_E and R_B, respectively. R1 and R2 are used in addition to R_E and R_B to set the quiescent operating point of each device.

The standard MODAMP MMIC requires an external resistor, R3, to complete the bias network for the device. An external RF choke, RFC1, is often used to isolate R3 from the RF path. Some versions of the MODAMP MMIC include R3 inside the device. While at first this may seem convenient, the external resistor/RF choke combination offers greater bandwidth and gain capability.

Choosing the right values for RFC1 and R3 is important to obtain maximum gain and power output from the MMIC. The combination of RFC1 and R3 should have a high reactance, greater than 500 ohms, at the frequency of operation. Carbon resistors work fine for R3. The RF choke is important—depending on the value of R3, amplifier gain can drop as much as 1 dB if RFC1 is eliminated. This is caused by the parallel loading of the resistor across the nominal 50-ohm output impedance of the MMIC.

The value of R3 can be calculated from a simple equation:

$$R3 = \frac{V_{cc} - V_{MMIC}}{I_{MMIC}} \qquad \text{(Eq 1)}$$

where V_{cc} is the available supply voltage.

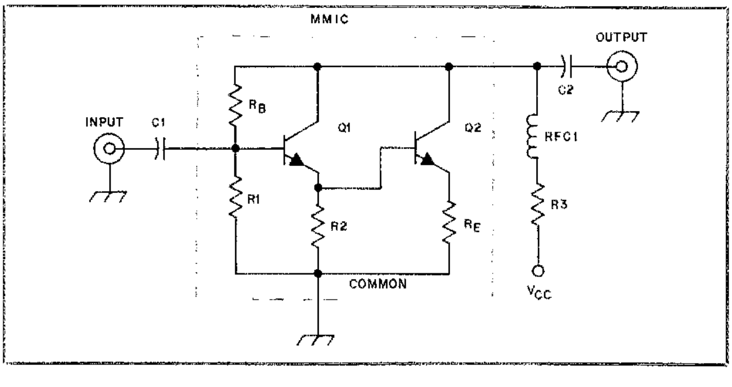

Fig 1—A complete MMIC amplifier stage uses only a few parts and no tuned circuits. Everything inside the shaded lines is contained inside the MMIC package.

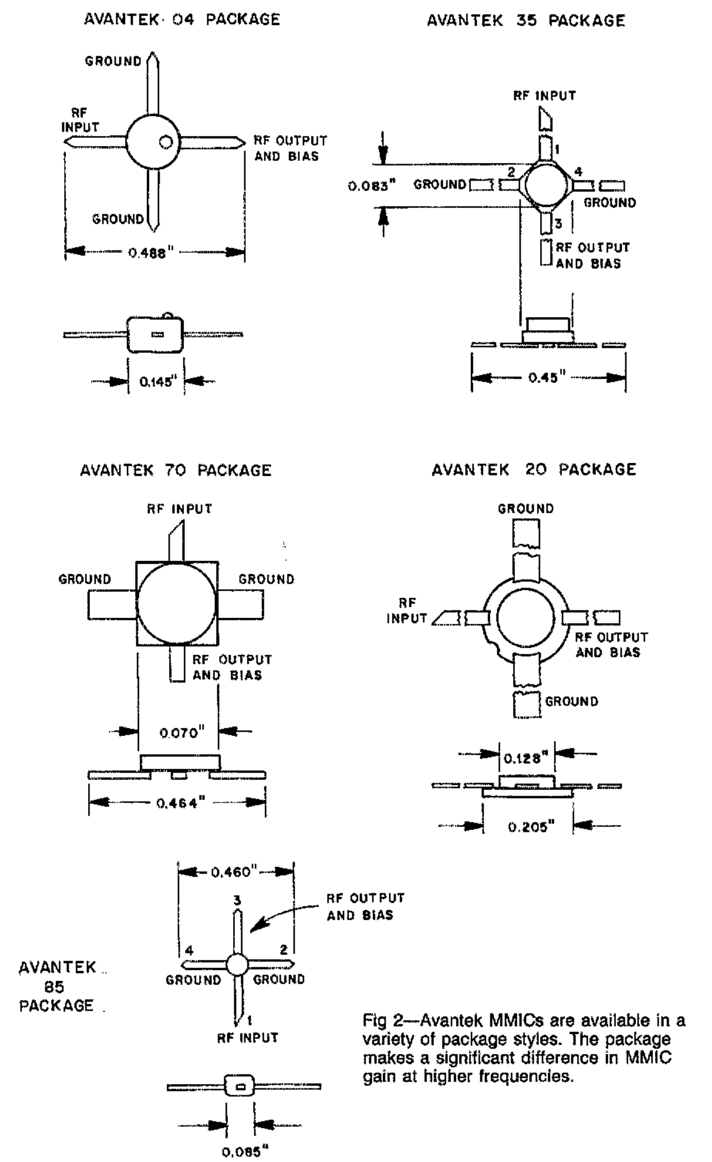

Fig 2—Avantek MMICs are available in a variety of package styles. The package makes a significant difference in MMIC gain at higher frequencies.

V_{MMIC} and I_{MMIC} are specified on the data sheet for the specific device being used.

As Eq 1 indicates, the higher the supply voltage, the higher the value for R3. This is advantageous from the standpoint that a higher value for R3 will load the output of the MMIC less and allow the MMIC to produce greater gain.

R3 also serves as a temperature-compensating element for the MMIC. As the device beta (β) increases with temperature, collector current will increase. Increased collector current causes an increased voltage drop across R3, which tends to decrease the voltage to the MMIC. This in turn decreases MMIC current. An additional advantage of using an external carbon resistor is that the carbon resistor has a positive temperature coefficient, whereas an MMIC with the internal resistor for R3 has a negative temperature coefficient. (A positive-temperature-coefficient resistor is one whose value increases with temperature.)

The manufacturer suggests a 2-V differential between the MMIC operating voltage and the supply voltage for best gain performance over a wide range of temperatures. If V_{cc} was applied directly to the MMIC, with R3 equal to 0, the device would self-destruct when the ambient temperature was increased to +100°C. Even though a 2-V differential is optimum, a differential of up to 7 V is still acceptable, especially when you consider the relatively narrow temperature range over which typical amateur equipment operates.

The only other components needed to complete the amplifier circuit are C1 and C2, which act as dc blocking capacitors. C1 and C2 should be chosen for low reactance at the frequency of operation, preferably several ohms. For an HF or VHF MMIC amplifier, silver-mica capacitors will work fine. For frequencies above 1 GHz, however, good low-loss ceramic chip capacitors are a must.

MMIC Device Families

The part numbers established by Avantek categorize MODAMP devices by performance. A typical Avantek MMIC has a part number like this: MSA-AABB-CD. Table 1 shows the various Avantek device types and explains how MMIC characteristics are given by the part number.

Outline drawings for some popular Avantek MMIC packages are shown in Fig 2. Generally, the plastic 04 package may be most desirable for commercial or amateur applications where temperature extremes vary from −25°C to +75°C. The "micro-x" 35 package is an industry standard for microwave transistors. It is hermetically sealed and offers acceptable performance over a wider temperature range (−55°C to +125°C). The "micro-x" package also offers improved RF performance above 2 GHz because the package parasitics are lower than those of the plastic 04 package. Recently introduced by Avantek, the 85 "micro-plastic" package combines the low cost advantages of the 04 package with the high-frequency advantages of the 35 package. The thermal resistance, θ_{jc} (the ability of the device to dissipate power), is rated at 200°C/W for the 04 package and 140°C/W for the "micro-x" package. For the 85 package, θ_{jc} is rated at 150°C/W. Single-unit prices are in the \$8, \$3 and \$4 price range for the 35, 04 and 85 packages, respectively.

For more rugged environments that require military screening, the Avantek 0.200-inch-square disc package (type 20 package) or the 70-mil stripline package (type 70) are available. The 20 package has a θ_{jc} of 65°C/W, making it capable of greater power dissipation and hence greater power output than the other package types. For the 70 package, θ_{jc} is 130°C/W. Prices for these "high rel" parts start at \$30, so they are generally not used for amateur applications.

Another new release that probably won't see much amateur use is the 86 style package. This one takes advantage of

Table 1
MMIC Nomenclature

The Avantek MODAMP MMICs each have a part number like the following: MSA-AABB-CD. The part number gives some important information about the device. Here's a guide to some characteristics of the various device families.

The number designated by AA defines which MODAMP die is used. The primary differences among the die types are maximum power output, gain and noise figure (NF). The performance numbers given here are approximate and will vary with package style and frequency. Presently there are six available types:

Type	*Characteristics*
01	Low power (+1 dBm), high gain (18 dB) and moderate NF (5 dB)
02	Medium power (+4 dBm), medium gain (10 dB) and moderate NF (6 dB)
03	High power (+10 dBm), medium gain (10 dB) and moderate NF (5.5 dB)
04	Highest power (up to +17 dBm), low gain (8 dB) and moderate NF (6 dB)
07	Similar to 02 except lower operating voltage and lower NF (4.5 dB)
08	Highest gain (30 dB at 100 MHz), medium power (+12 dBm) and low noise figure (3 dB) (Note: This device is not unconditionally stable and care must be given to bias decoupling design.)

BB designates package configuration. Presently there are five available package options.

Style	*Package*	*Comments*
04	Plastic	145-mil-diameter package, low cost; reduction in high-frequency performance
20	BeO	200-mil-square beryllium-oxide package (ceramic); excellent thermal conductivity for higher power applications
35	Micro-x	100-mil-square, economical glass-sealed package with excellent high-frequency performance
70	Stripline	70-mil-square, gold-plated package for "high rel" applications
85	Micro-plastic	85-mil-diameter, low-cost package with excellent high-frequency performance; similar to the micro-x package
86	Surface-mount	Version of 85 package with leads formed for surface-mounting techniques; decreased high-frequency performance

Options

Some of the ceramic-style MMIC families have a suffix (-CD) tacked on to the end of the part number. An example is the MSA-0335-21. A -1 for the first number of the suffix indicates that the series-bias resistor (R3 of Fig 1) is built in. The -1 series require an operating voltage of about 12 V. A -2 indicates that an external bias resistor is required, and the operating voltage is typically 5 to 6 V. In the -1 series with the built-in bias resistor, one of the common leads is a V_{cc} terminal. In the -2 style, there are two ground leads.

The second digit of the suffix is used to designate a premium part which typically has a better high-frequency response. For example, the gain of the MSA-0235-11 is 1 dB less at 1 GHz than it is at 100 MHz. For the MSA-0235-12, however, the frequency at which the gain is 1 dB lower is 800 MHz. This is quite a difference in performance!

These options apply to the 01, 02 and 03 geometries in the 35 and 70 packages. The 04 series (for example, the MSA-0470 or MSA-0435) has no bias or frequency-response options and therefore no suffix.

The 04 and 85 package styles are designed such that both common leads are grounded for best high-frequency performance. Dc is then fed in via the bias network arrangement discussed earlier, and there is no internal-bias-resistor option. This is the standard arrangement, so these styles have no suffix after the package style (for example, MSA-0104).

surface-mount technology, but generally requires mounting to a ceramic substrate to attain adequate heat sinking.

For most amateur applications the 04, 35 and 85 packages are most appropriate. Later in this article I will describe amplifiers that use the 04 and 85 packages since they are the least expensive and are readily available from local distributors in any quantity desired.

MMIC Manufacturing Processes

MMIC chip manufacturing processes are very similar to those for silicon bipolar transistors. An excellent series on these manufacturing processes appeared in *QEX*.[1] The technology necessary for building MMIC chips didn't exist until a few years ago. For example, state-of-the-art nitride self-alignment and ion-implantation techniques are used for precise doping control. This guarantees a high degree of uniformity among wafers of MMIC chips. Nitride passivation assures high reliability by minimizing oxidation buildup on the chip. Precision thin-film resistors are fabricated directly onto the chip so that on most versions only one external resistor is needed to set the bias point. The small reactances associated with the internal feedback resistors enhance the high-frequency characteristics of the MMIC. All of these factors result in high-volume production and low manufacturing cost.

[1]Notes appear on page 32.

Performance

There are so many different MMIC versions that sometimes it's not easy to decide which to use for a given application. In Tables 2 through 4, I have summarized typical gain and 1-dB-gain-compression performance data for the various MMIC families. The data, which covers popular amateur frequencies, was obtained from Avantek specification sheets and represents performance at optimum current for continuous operation.

Performance figures for the popular MSA-0104 through MSA-0404 plastic-package MMICs are shown in Table 2. Since it's often necessary to cascade or parallel units for additional gain or power output, I've included information on various combinations as well.

Table 3 shows performance data for several of the "micro-X" 35 versions. By comparing these figures with those of Table 2, it is evident that the microwave packages do offer superior performance above 2 GHz and should even be considered for work in the 1296-MHz band.

Table 4, for devices with the 85-type package, shows that this series is a good compromise between price and performance at higher frequencies. It's readily apparent that gain above 902 MHz is approximately 1 to 2 dB greater with the 85 package than the 04 package. The 85 and 35 packages offer similar gain above 902 MHz. The 85 package is certainly the choice for economy, yet it still retains the high-frequency performance of the 35 package style.

Input and output SWR is typically less than 2:1 for all of the MMICs. Noise figure ranges from about 5 to 7.5 dB for the 01 through 04 series, with the 01 having the lower noise figure. The 08 series devices have minimal internal feedback and therefore have a lower noise figure—typically 3 to 4 dB up to 3 GHz. Gain of the 08 series is the highest of any of the MODAMP MMICs, but care must be taken in the layout and bias network design since this series is not unconditionally stable. This point will be covered in the practical construction section.

Applications

These MMICs can find many uses in receiving and transmitting equipment in both the RF and IF sections. Since they require no tuned circuits and the 01 through 04 series are unconditionally stable, MMIC amplifiers can be built quickly and easily in a minimum of space. In a test setup, for example, an MMIC can be used as a broadband scope or counter preamplifier when low-level gain is needed. In a receiver, MMICs can be used as RF and IF amplifi-

Table 2

Typical Gain and 1-dB Compression Point (P_{1dB}) Performance for 04 Style Avantek MMICs

Type (MSA-)	*30*	*50*	*144*	*220*	*432*	*902*	*1296*	*2304*	*3456*	
				Frequency (MHz)						
0104	19	19	19	18	17	14	12	9	6	dB Gain
	+8	+8	+7	+6	+4	†	†	†	†	dBm P_{1dB}
0204	13	13	13	13	12	11	10	8	6	dB Gain
	> +7	> +7	> +7	> +7	+7	+5	+4	+2	†	dBm P_{1dB}
0304	13	13	13	13	12	11	10	8	6	dB Gain
	> +13	> +13	> +13	> +13	+13	+11	+10	+5	†	dBm P_{1dB}
0404	8	8	8	8	8	8	7	6	5	dB Gain
	> +13	> +13	> +13	> +13	> +13	+13	+13	+13	†	dBm P_{1dB}
For Cascaded 04 Type Devices:										
02/03	26	26	26	26	24	22	20	16	12	dB Gain
	> +13	> +13	> +13	> +13	+13	+11	+10	+5	†	dBm P_{1dB}
02/03/04	34	34	34	34	32	30	28	††	17	dB Gain
	> +13	> +13	> +13	> +13	+13	+13	+13	††	†	dBm P_{1dB}
03/04/04	†††	†††	†††	†††	†††	†††	†††	22	16	dB Gain
	†††	†††	†††	†††	†††	†††	†††	+13	†	dBm P_{1dB}
For Four 0404 Devices in Parallel:										
4-0404	> +19	> +19	> +19	> +19	> +19	+19	+19	+19	†	dBm P_{1dB}

†Not specified.
††Not recommended for 2304 MHz because of compression of the 03 stage.
†††Not analyzed.
Note: This information was obtained from Avantek data sheets and represents typical performance at the current specified for continuous operation.

Table 3

Typical Gain and 1-dB Compression Point (P_{1dB}) Performance For 35 Style Avantek MMICs

Type (MSA-)	*902*	*1296*	*2304*	*3456*	
		Frequency (MHz)			
0135	17	15	11	9	dB Gain
	†	†	†	†	dBm P_{1dB}
0235	12	11	10	8	dB Gain
	+11	+9	+6	†	dBm P_{1dB}
0335	12	12	10	7	dB Gain
	+12	+10	+6	†	dBm P_{1dB}
0435	8	8	7	5	dB Gain
	+12	+10	+6	+5	dBm P_{1dB}
0835	24	20	15	12	dB Gain
	+13	+14	+12	+10	dBm P_{1dB}

†Not specified.
Note: This information was obtained from Avantek data sheets and represents typical performance at the current specified for continuous operation.

ers. For applications where a low noise figure is not critical, an MMIC can be used as a front end. In transmitters, MMICs can be used for all low-level stages up to 50 mW or so, depending on the device chosen.

Practical Construction

This part of the article is for those of you who have a practical application for an MMIC amplifier or just want to experiment to see how they really behave. Here, I will describe the construction of single and cascaded MMIC amplifiers and show the measured performance of several popular combinations.

Since there are so few parts in an MMIC amplifier, it won't take too long to gather them and it won't break the bank either. Study Tables 2 through 4 and pick the MMIC best suited for the frequency range and power level you need. For most appli-

Table 4

Typical Gain and 1-dB Compression Point (P_{1dB}) Performance for 85 Style Avantek MMICs

Type (MSA-)	*30*	*50*	*144*	*220*	*432*	*902*	*1296*	*2304*	*3456*	
				Frequency (MHz)						
0185	18	18	18	17	17	15	14	10	7	dB Gain
	> +7	> +7	+7	+5	+4	+3	+2	†	†	dBm P_{1dB}
0285	12	12	12	12	12	12	11	10	8	dB Gain
	> +9	> +9	+9	+7	+5	+5	+5	†	†	dBm P_{1dB}
0385	12	12	12	12	12	12	11	10	7	dB Gain
0485	8	8	8	8	8	8	8	7	6	dB Gain

†Not specified.
Note: This information was obtained from Avantek data sheets and represents typical performance at the current specified for continuous operation.

cations, I'd recommend the 85 series because they work well and cost only a few dollars each. Avantek components are available through a number of distributors nationwide. Contact Avantek for the name and address of the distributor for your area.[2] You should have no trouble buying MMICs in small quantities from any distributor.

You'll also need some small-diameter wire, around no. 26 or 28, to make the RF chokes. For the external bias resistor, you'll need an assortment of ¼- and ½-W resistors with values of up to about 400 ohms. The circuit also contains a few capacitors for bypassing and dc blocking. The dc blocking capacitors can be good-quality silver-mica or ceramic units for frequencies through the VHF range. Ceramic chip capacitors are highly recommended for UHF work and above, though. One source of ceramic chips in small quantities is Microwave Components of Michigan.[3] Last, you'll need to decide what type of connectors to use to mate your amplifier to the outside world. I prefer SMA connectors because they are small and they work well at 900 MHz and above, where I do most of my experimenting these days. You can put the finished unit in an enclosure if you wish.

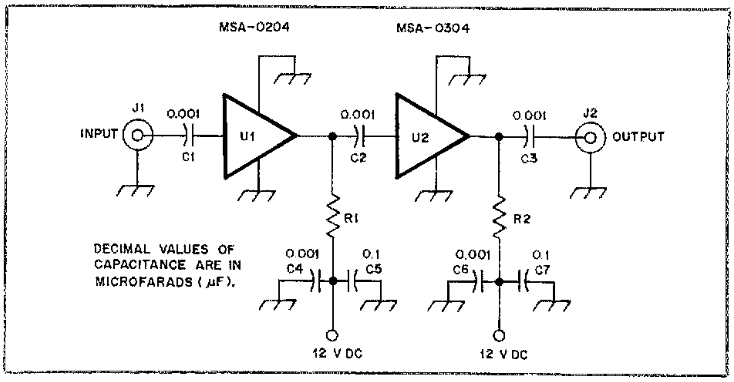

Fig 3—Schematic diagram of the simple HF and VHF MMIC amplifier. Capacitors are silver-mica or ceramic types, and values are expressed in μF. The resistors are ½-W carbon units.

J1, J2—Female, chassis-mount BNC connector.

U1—Avantek MSA-0204.
U3—Avantek MSA-0304.

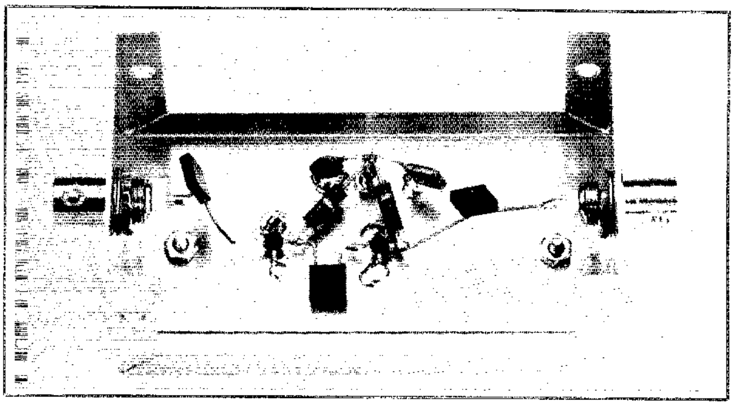

Fig 4—The amplifier of Fig 3 is built on a brass sheet inside a small aluminum box. All ground points are soldered to the brass sheet.

A Simple VHF Amplifier

A simple VHF test amplifier using an MSA-0204 and MSA-0304 can be built from the schematic of Fig 3. C1 through C7 are all common silver-mica or miniature-ceramic capacitors. The 0.1-μF capacitors are used along with the 0.001-μF bypass capacitors to suppress low-frequency oscillations occurring in the bias decoupling network. Remember that the MMICs have a significant amount of low-frequency gain, so good bypassing is a must.

R1 and R2 are ½-W carbon types. The exact value will depend on the type of device used. Table 5 shows typical bias-resistor values (for a 12-V supply) for popular MMICs. These values assume continuous operation at the specified current level. If you use a different supply voltage, you can calculate the resistor value from Eq 1. The optional RFC for each MMIC was not used in this circuit.

I built one version of the amplifier on a piece of 0.015-inch-thick hobby brass bolted to the inside of a standard aluminum box, as shown in Fig 4. Both MMIC common leads are soldered directly to the brass ground plane.

Another version was built using a scrap piece of double-sided, 0.062-inch-thick, glass-epoxy circuit-board material instead of the brass sheet. To assure a good ground for the MMIC common leads, drill a hole in the board and solder them to the ground plane side (which is pressed flat against the case ground). The best way to do this is to use the lead of a 1-W resistor as a bending fixture so that the leads don't break off.

Table 5
Bias Resistor Information For Various Avantek MMICS

Type (MSA-)	*Optimum Current (mA)*	*Resistor Value for V_{CC} = 12V dc (Ohms)*	*Resistor Dissipation (Watts)*
0104	20	330	0.13
0204	30	220	0.20
0304	40	180	0.29
0404	50	130	0.33
0135	22	270	0.13
0235	40	150	0.24
0335	50	120	0.30
0435	50	130	0.33
0835	35	120	0.15
0185	17	410	0.12
0285	25	280	0.18
0385	35	200	0.25
0485	50	140	0.35

Bend the common leads down and then away from the package so the device will lay flat when soldering to the groundplane. See Fig 5. Other construction details are the same as for the amplifier shown in Fig 4.

The gain plots in Fig 6 show that both versions have usable gain well above 1 GHz. Measurements were made on a swept network analyzer. Curve A is for the brass-sheet amplifier, while curve B is for the PC-board version. Lead lengths were purposely made longer on the brass-sheet version (3/8 inch versus 1/4 inch) to see the effect on high-frequency performance.

Since the swept network analyzer plots only characterized the amplifier down to 50 MHz, additional point-by-point data was taken to evaluate performance at specific HF frequencies. This data is shown in Table 6. The 0.001-μF blocking capacitors begin to roll off the gain below about 7 MHz. For improved gain performance at

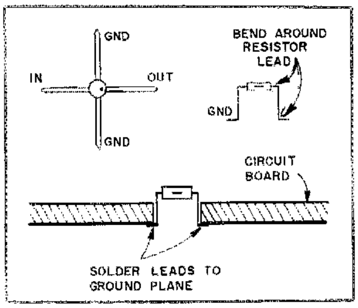

Fig 5—Mounting details for the MMIC. Double-sided PC board material is used instead of brass sheet for the amplifier of Fig 4.

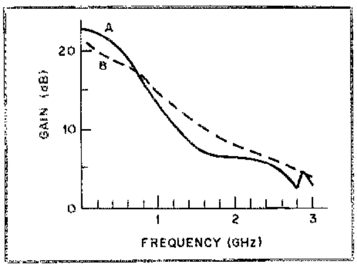

Fig 6—Gain versus frequency for the simple VHF MMIC amplifier. The curve at A is for an amplifier built with brass sheet for the ground plane, while curve B is for the PC-board version. See text.

low frequencies, the blocking capacitors were changed to 0.1 µF. Calculations predict a 1-dB gain reduction to occur at a frequency below about 100 kHz when using 0.1-µF capacitors. High-frequency performance above 50 MHz may suffer, depending on capacitor parasitics.

The basic test amplifier will find many uses around the amateur station. Some possibilities include use as an IF amplifier for a converter or receiver or as an IF amplifier for an automatic noise figure meter. With the 0204/0304 combination, noise figure will be around 6 dB below 1 GHz and 1-dB gain compression at the output will typically be + 10 dBm or greater.

Techniques for Using MMICs at UHF and Above

To realize the total gain potential of MMICs at frequencies above 902 MHz, microstripline techniques are required. A cross-sectional view of a microstrip transmission line is shown in Fig 7. The actual impedance of the microstripline depends on the line width (W), the height of the line above the ground plane (h), and the dielectric constant (ϵ_r) of the material separating the line from the ground plane. Microstripline impedance calculations are beyond the scope of this article, but you can learn more about them from several good articles that have appeared in the amateur literature.[4-6]

The microstripline PC board can be etched, or you can use a sharp knife and hot soldering iron to create isolated pads on any piece of scrap board. Common glass-epoxy material is fine for most applications below 2 or 3 GHz; we'll cover this in detail later.

An amplifier built on microstripline is shown in Figs 8, 9 and 10. Standard 0.062-inch-thick, double-sided, glass-epoxy PC-board material has a dielectric constant about 5.0. A microstripline with a characteristic impedance of 50 ohms is about 0.10 inch wide on this material. The line lengths needed for an MMIC amplifier are short enough that the loss of glass-epoxy material is acceptable, even at 3456 MHz.

The board layout shown in Figs 9 and 10 lends itself rather nicely to using 2- or 4-hole flange-mount SMA-type connectors. Gold-plated SMA connectors can be easily soldered to the bottom ground plane. Remember to clear away a circle of copper 0.150 inch in diameter around each SMA center pin on the ground-plane side of the board. This will prevent the center pin from shorting to the ground plane and also ensures a smooth RF transition between the connector and the board.

To ensure a low-loss, low-inductance path to ground for the common leads of the MMIC, pieces of thin copper or brass foil (preferably no greater than 0.005 inch thick) are used to tie the ground areas on the top of the board to the bottom ground plane. First wrap the edges of the board. Then drill a hole where the MMIC mounts that is big enough to wrap a piece of this foil under the common leads, through the hole, down to the ground plane. Solder the foil on both sides of the board. Alternatively, drill a small hole through the board under the ground leads of each device. Bend the leads down, through the small holes, and solder them to the top and bottom ground areas.

In the UHF amplifier, good-quality 0.050-inch- or 0.100-inch-square ceramic-chip capacitors are used as dc blocks. These capacitors are necessary for good gain performance at frequencies around 1 GHz and higher. Use a 15-W soldering iron when installing the chip capacitors to avoid removing the metallization during assembly. An excellent article on the selection and use of chip capacitors appeared in *QEX*.[7]

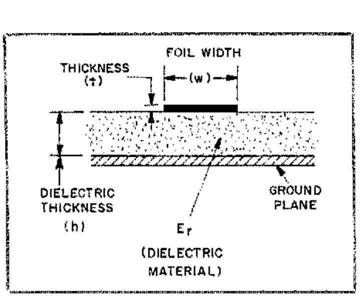

Fig 7—Cross-sectional view of typical microstripline construction.

Table 6
MMIC Amplifier Performance at HF

With 0.001-µF Blocking Capacitors:

Frequency (MHz)	*Gain (dB)*
28	21.4
7	20.6
3.5	19.0
1.2	19.0

With 0.1-µF Blocking Capacitors:

Frequency (MHz)	*Gain (dB)*
28	21.7
7	21.4
3.5	21.5
1.2	22.0

Table 7
Performance of Various Microstripline MMIC Amplifiers

MMICs Used (MSA-)	*Frequency (MHz)*	*Gain (dB)*
0104/0104	500	30.42
	900	28.07
	1300	24.75
	2300	16.65
	3400	11.25
	4000	7.15
0204/0304	500	22.70
	900	21.52
	1300	19.50
	2300	14.40
	3400	10.00
	4000	8.49
0404/0404	500	14.45
	900	14.48
	1300	12.46
	2300	10.80
	3400	6.65
	4000	5.79

RFC1 and RFC 2 are made from no. 26 or 28 enameled wire. The chokes offer a high impedance to RF at UHF and microwave frequencies. At lower VHF frequencies, the reactance of the RF chokes is rather small, and R1 and R2 appear as terminations for low frequencies.

Bypassing is similar to that used in the VHF amplifier. The 0.1-µF capacitors can be used to reduce low-frequency oscillations in the bias decoupling network. When cascading two or more MMICs in a typical receiver or transmitter strip, it may be advantageous to use additional decoupling. Remember that MMICs, especially the 01 and 08 series, have significant gain at low frequencies (several megahertz). If the bias decoupling is not adequate, the amplifier may oscillate from feedback in the bias network. If you experience low-frequency oscillations, try adding a 1-µH RF choke in series between V_{cc} and each bias resistor, and then bypassing each end of the 1-µH choke with a 0.001-µF capacitor.

I built several amplifiers with combina-

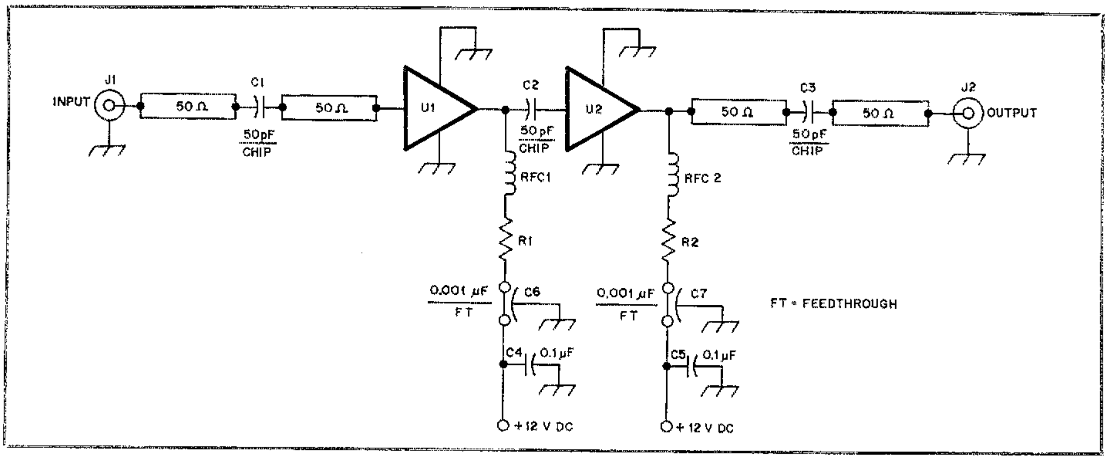

Fig 8—Schematic diagram of the microstripline MMIC amplifier.

C1-C3—50- to 100-pF ceramic chip capacitor. Good quality, 50-mil- or 100-mil-square units are preferred. See text.
C4, C5—0.1-μF, 25-V ceramic disc.
C6, C7—470- to 1000-pF feedthrough capacitor.
J1, J2—Female, flange-mount SMA connector.
R1, R2—Carbon bias resistors. See text and Table 5 for values.
RFC1, RFC2—4 turns no. 26 or 28 enam wire, 0.125-in ID, spaced 1 wire diam.
U1, U2—Avantek 04 series MMIC. See text.

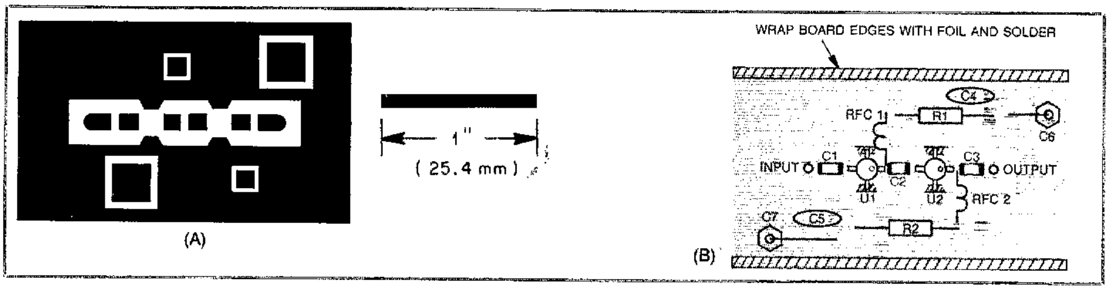

Fig 9—Etching pattern and PC-board layout information for the microstripline MMIC amplifier of Fig 8. All components mount on the circuit-trace side of the board. A PC board can be etched from the pattern shown at A, or a sharp knife and hot soldering iron can be used to clear away unwanted copper. Black areas represent unetched copper.

tions of the 04 series MMICs and measured the performance of each. The configurations are: (1) 0104 driving 0104; (2) 0204 driving 0304; and (3) 0404 driving 0404. Gain for these amplifiers is shown in Table 7.

Notice the vastly improved performance of the microstrip 02/03 combination as compared to the VHF version shown in Fig 3. This is because the 50-ohm transmission lines match the MMIC to its 50-ohm source and load. The gain obtained was slightly less than advertised in the data sheets, but is probably caused in part by the use of lossy glass-epoxy material. It is possible to enhance the high-frequency performance above 2 GHz by using low-loss, Rogers® 5880 circuit-board material. For 0.031-inch-thick board with a dielectric constant of 2.17, a 50-ohm line would be about 0.10 inch wide. For 0.062-inch-thick board, a 50-ohm line is about 0.20 inch wide.

Some gain reduction can be attributed to mismatch loss caused by SWR interactions between the output port of one MMIC and the input port of the second MMIC. This effect is more pronounced at higher frequencies where SWR is typically higher. This subject will be covered in Part 2 of this article.

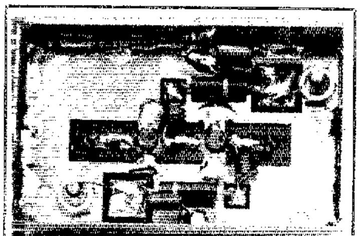

Fig 10—Here is the completed MMIC amplifier, ready for testing. If desired, it can be mounted in an enclosure such as an aluminum box, or you could solder together side and bottom plates made from scrap circuit-board stock or from sheet brass.

Noise figure for the 0104/0104 configuration was measured at 4.7 dB at 1296 MHz and 5.3 dB at 2304 MHz. Noise figure below 1296 MHz will typically be 4.5 dB. The 1-dB-gain-compression point of the 02/03 combination was measured at +10 dBm at 1296 MHz and +5 dBm at 2304 MHz, referenced to the output port. For the 04/04 combination, the 1-dB-gain-compression point was +13 dBm at 1296 MHz and +12 dBm for 2304 MHz. Slightly improved gain performance can be expected by using the 85 package style MMICs.

A High-Gain, Low-Noise MMIC Amplifier

A similar microstripline test amplifier was built using a single MSA-0835 MMIC. Since this particular series is not unconditionally stable, there are a few special considerations. I chose a 200-ohm, ½-W carbon resistor to bias the MMIC at 25 mA for the lowest possible noise figure.

(continued on page 32)

The Miniaturized, Simplified London Tone Alert

If you thought the original control decoder was an innovative project, try this modified version!

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After my article on the London Tone Alert appeared in *QST*, the correspondence I received seemed to dictate a need for a small, easy-to-build pocket-sized tone alert.[1] Using the basic idea described in the original text, I have developed a simple unit that works with a single DTMF (dual-tone, multi-frequency) audio tone, is not subject to falsing, is built on one board and can fit into a tiny box. Other features, such as visual indicators to display that the unit is operating correctly, can be added. This information is offered in my first article.

[1]Notes appear on page 32.

The London Tone Alert

The London Tone Alert is a special circuit that plugs into a 2-m transceiver. It is one of the most important tools a civil-emergency-preparedness group can use during an emergency. When such a situation arises, the responsible group member presses an assigned numerical button on the transceiver's DTMF pad for two seconds. In turn, this procedure enables the tone alert to sound in those members' 2-m transceivers that have been silently monitoring the frequency. The group is now alerted

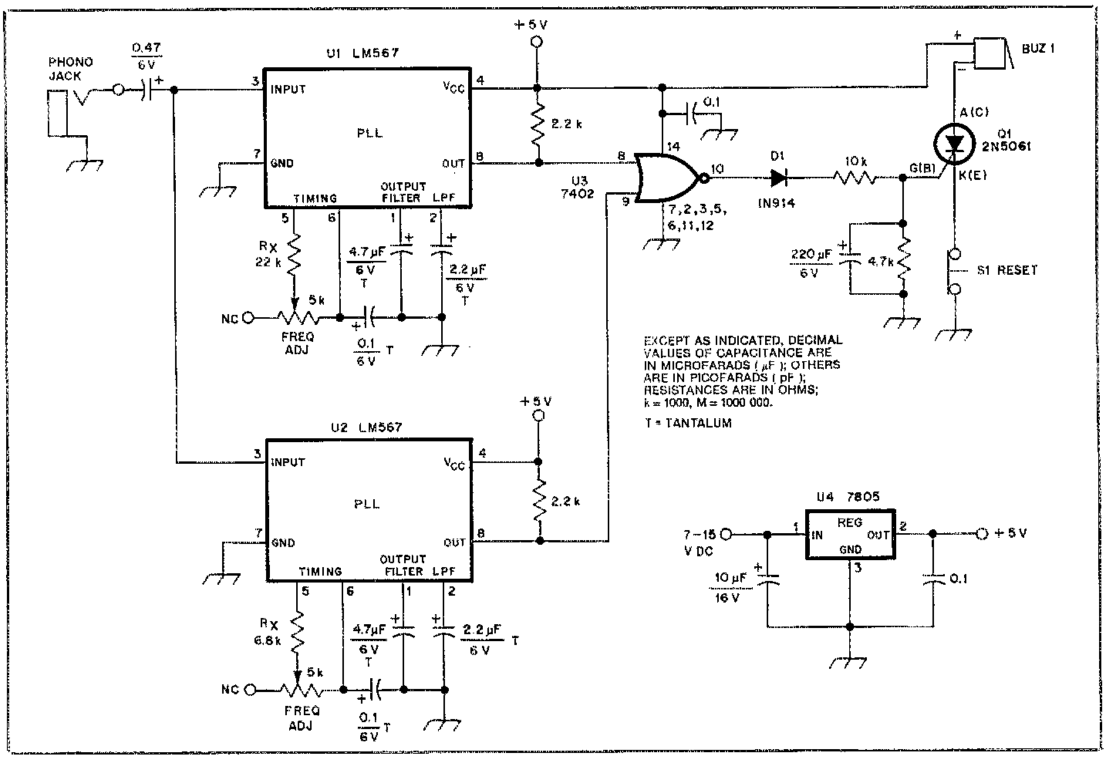


Fig 1—The schematic for the simplified, miniaturized London Tone Alert. All resistors are ¼-W, 5% carbon types.

D1—Diode, 1N914.
LS—6-V buzzer (RS part no. 273-054 or equiv).
Q1—SCR, 2N5061.
S1—Normally closed push-button switch.
U1, U2—Tone decoder, LM567.
U3—Quad 2-input NOR gate, 7402.
U4—Voltage regulator, 7805.

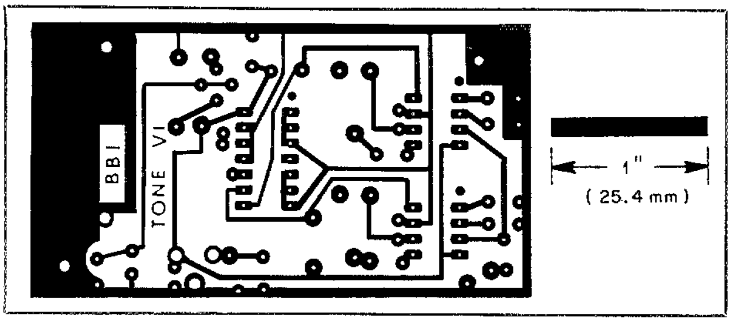


Fig 2—Circuit-board etching pattern for the Mini London Tone Alert. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil.

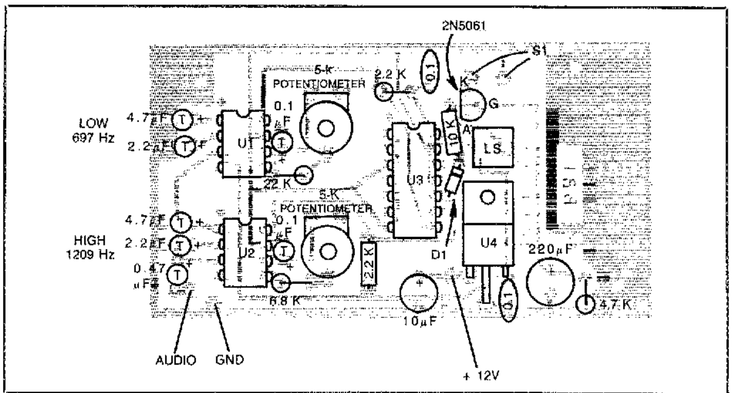


Fig 3—Parts-placement guide for the Mini London Tone Alert. Parts are placed on the nonfoil side of the board; the shaded areas represent an X-ray view of the copper pattern. Gray areas represent unetched copper.

that help is needed and voice communications can commence.

How the Unit Works

A three-wire cable plugs into the accessory socket of the 2-m transceiver. Here, the cable connects to the + 12 V line, ground and the audio output. (Using this connection configuration, the transceiver's speaker is not disabled.) The cable enters the small box that will hold your circuit; the box should have a normally open push-button switch on its top, and side holes to pass the sound of the buzzer.

When a remote station senses an emergency situation, button no. 1 on the 2-m rig's DTMF pad is pressed for 2 seconds or more to activate the buzzer in the tone-alert circuit. The sound is loud enough to be heard throughout the house. Then, by simply pushing the button on the box top, the buzzer is disabled and the device is reset. The circuit continuously monitors for an alert tone when it is plugged into an activated receiver.

When the decoder is tuned to the no. 1 tone, it serves as a personal alert and also responds to the general tone alert, which is 1-4-7 in London. In each case, a delay is incorporated in the first digit to eliminate falsing. My circuit has been in operation for several months and it continues to work fine.

The Mini-London Tone Alert's main function is to alert individuals in times of emergency or emergency-preparedness tests. But, we may not be using the device to its full potential. Imagine a group of friends who commonly share an interest in ATV. Each member could be assigned a personal calling number and alerted individually when operating conditions are just right. There are many possibilities, limited only by the imagination.

How the Circuit Works

Fig 1 is the schematic diagram of the London Tone Alert. The speaker output of a receiver is fed into the audio input jack that connects to the input terminals (pin 3) of the two LM567 PLLs. Valid tones are detected by two 567 PLLs, producing a logic "low" at their outputs (pin 8). When this level is applied to U3, a positive pulse appears at the output. This signal is directed through a diode and resistor to the gate of the 2N5061 SCR which immediately conducts to sound the buzzer. (An NPN transistor can be substituted in place of the SCR for a short-burst tone alert. More on this later.) To prevent the SCR from being triggered by voice transients, a short delay is introduced by the 220-μF capacitor. This means that the transmitted tone must last for two seconds or more. Each button on the DTMF pad produces two tones. Though we are interested in using only one tone, both tones help to prevent falsing. The 4.7-kΩ resistor between the SCR's gate and ground stabilizes the circuit, further preventing false triggering.

Note that only one of the four sections available in the 7402 is used. The other three sections are connected to ground. These include pins 2, 3, 5, 6, 7, 11 and 12 and are shown on the schematic.

By using a 7805 voltage regulator, input voltages from 8 to 14 can be used. The voltage, of course, depends on what your equipment can supply. A 9-V battery can also be used, but is not recommended for extended periods of operation. The regulator can be eliminated if a 5-V power supply is available. The buzzer is disabled by pressing the reset button (S1).

Construction

Use ¼-W resistors; stand them on end, if necessary, to conserve board space. Low-voltage capacitors can be used which need not be rated at more than 6 V. Tantalum capacitors are used throughout the circuit because they are small and very stable. The buzzer is from Radio Shack (273-054) and is suitable for this application. Fig 2 shows the circuit board from the foil side; Fig 3 is the parts placement diagram.[2] Use no. 3-48 × ¼-inch machine screws for mounting the board in an enclosure.

I found a carton of small plastic boxes with sliding tops at a local surplus store. My find proved ideal for this project and each cost less than $1. Metal boxes were used for several other tone-alert circuits I built—the boxes were unique and also inexpensive.

Tuning

Every tone produced by a single key press on a DTMF pad is actually composed of two tone frequencies; it is necessary to detect both. I used two LM567 decoders, one for each note, that must be tuned to respond to the required frequencies.

My unit responds to DTMF pad button no. 1 and uses the frequencies shown on the diagram in *The 1987 ARRL Handbook* (697 and 1209 Hz).[3] The frequencies assigned to the other pad buttons may also be found there.

To tune an LM567 to the desired frequency, apply power and connect a frequency counter to pin 6, or to the appropriate end of the 5-kΩ potentiometer. Another 2-m rig can be used as the signal source. Turn the potentiometer from one end to the other to determine if it covers

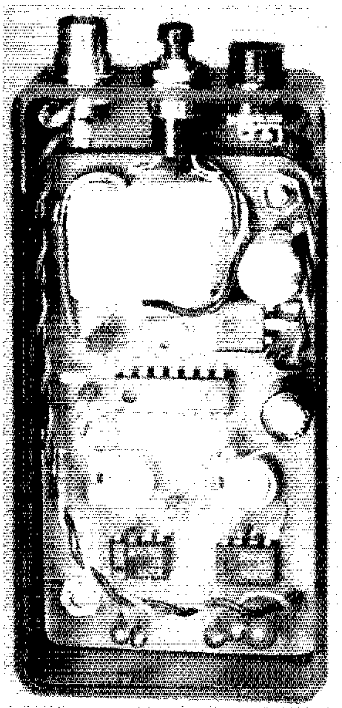


Fig 4—An internal view of the Tone Alert's circuit board.

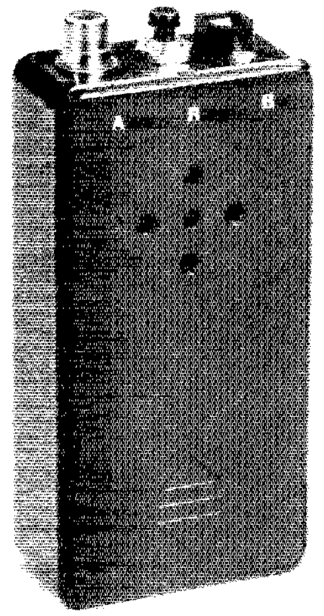


Fig 5—The completed circuit board is housed in a 2- × 4-inch plastic enclosure. The letters A, R and B label the audio socket, reset button and battery plug.

the frequency you want. Then, set the potentiometer accurately. Once this is done, tune the second 5-kΩ potentiometer to the other desired frequency in the same manner.

If the frequency you want does not lie within the potentiometer's range, R_x must be changed. Use a higher resistor value to lower the frequency and a lower value to raise it.

Testing

When the PC board is complete, but not yet mounted in its enclosure, connect the power and the audio input from the jack on your 2-m transceiver. On the base-station transceiver, transmit the tone you are tuned to. After 2 seconds, the buzzer in your circuit should sound. If nothing happens, check that the push button is connected—it is necessary to complete the circuit.

Further checks could be done with an ordinary 20-kΩ/V voltmeter on the 5- or 10-V scale. A positive voltage should be present on pin 8 of each LM567, with the reading dropping to nearly zero when the tone is applied. Now connect the meter to pin 10 of U3; a positive voltage (about 5 V) should appear whenever the tone is applied. If the diode is connected properly, this positive voltage should trigger the SCR and sound the buzzer.

Conclusion

Fig 4 is a photograph of the completed PC board. Fig 5 shows the board mounted in a 2- × 4-inch plastic enclosure. Several throughholes in the casing allow for passage of the buzzer's sound. The letters A, R and B label the audio socket, reset button and battery plug.

Suppose you want the buzzer to utter a short burst, rather than remain activated until the reset button is pushed. Simply change the SCR to an NPN transistor and mount it so that the base mounts in place of the SCR's gate; the collector resides in place of the anode and the emitter rests where the cathode would be. The buzzer will now stop as soon as the transmitted tone subsides. No reset button is necessary. About a 2-second delay still remains to discourage falsing.

Here's an idea for you to work on: See if you can eliminate one of the LM567s and the SN7402 and their associated parts, and still have the circuit work! It can be done, but you will find that it responds to any one of four button tones. Incidentally, this change makes room for a 9-V battery and the complete device fits in a shirt pocket! I would be interested to hear about other novel uses this project suggests.

Notes

[1]T. C. Tanner, "The London Tone Alert," *QST*, Nov 1983, p 35.

[2]The author will supply circuit boards for $5, US funds, plus $1 shipping and handling. The ARRL and *QST* in no way warrant this offer.

[3]M. Wilson, ed, *The 1987 ARRL Handbook* (Newington: ARRL, 1986), p 34-3.

Monolithic Circuits

(continued from page 29)

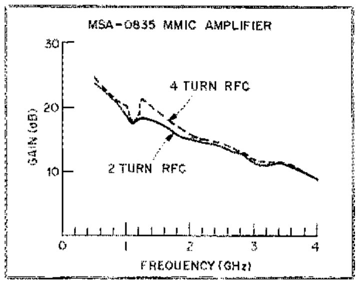


Fig 11—This graph compares the gain of a single-stage MSA-0835 amplifier with 2-turn and 4-turn RFCs. Although the use of a 4-turn choke enhances gain, a 2-turn choke is preferred for amplifier stability.

The RF choke was made from 2 turns of no. 28 wire, 0.125-inch ID, spaced one wire diameter. When the 2-turn RF choke was added in series with the bias resistor, the amplifier exhibited a slight increase in gain in the 500-2500 MHz frequency range without compromising stability. Experimentation with up to 6-turn RF chokes yielded greater gain, but stability was marginal. The 2-turn choke is a good compromise for maximum gain and stability. Depending on the inductance of the bias resistor, the series RF choke may need to be deleted to ensure stability under all circuit conditions.

Actual measured gain response with 2-turn and 4-turn RF chokes in place is shown in Fig 11. Gain (for a single device!) is 24 dB at 500 MHz, while the gain at 3500 MHz drops to 9 dB. Gain was not measured above 3500 MHz. Noise figure as measured at 2304 MHz is in the vicinity of 4 dB with an associated gain of 13 dB—not bad for an untuned microwave amplifier using glass-epoxy PC board material! Gain performance comparable to that shown in Table 3 may be achieved if a lower-loss dielectric material such as Rogers Duroid® were used.

In Part 2 of this article, I will show how to combine MMICs in parallel for increased power output. I will also discuss important parameters such as gain, compression point, third-order IMD products and noise figure and how they should be considered when designing MMICs into your next project.

Notes

[1]B. Olson, ">50: Focus on Technology above 50 MHz," *QEX*, Apr 1986, pp 12-15; May 1986, pp 12-14; June 1986, pp 10-11.

[2]Avantek, 3175 Bowers Ave, Santa Clara, CA 95051, tel 408-727-0700.

[3]Microwave Components of Michigan, 11216 Cape Cod, Taylor, MI 48180, tel 313-941-8469 (evenings).

[4]D. Mitchell, "Microstrip Impedance Program," *Ham Radio*, Dec 1984, pp 84-86.

[5]J. Fisk, "Simple Formulas for Microstrip Impedance," *Ham Radio*, Dec 1977, p 72.

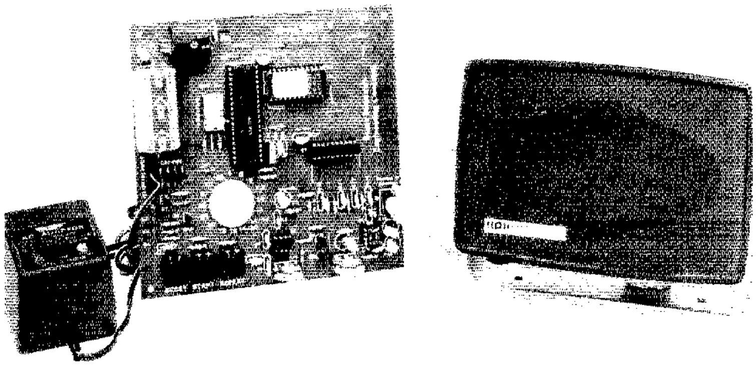
[6]J. Fisk, "Microstrip Transmission Line," *Ham Radio*, Jan 1978, pp 28-37.

[7]B. Olson, ">50: Chip Capacitors," *QEX*, Sep 1986, pp 14-15.

Build the Morsemaster II

Learning Morse code can be difficult. This deluxe code trainer will help prepare you for the VE code exams from Novice through Amateur Extra.

By Mike Huddleston, KJ4LN
5440 O'Quinn Ct
Stone Mountain, GA 30088



We hams are proud of our demonstrated ability to use Morse code for communicating. Often criticized as anachronistic in today's world of automatic high-speed digital communication, our use of Morse code remains the single outstanding feature that distinguishes us from most other users of the airways.

On the other hand, the code requirement is also given as the reason many would-be hams never get licensed. It's also the reason so many of us seem to be frozen in the Technician class.

The first Morsemaster was built so that I might, after numerous tries, finally struggle past the 5-WPM code test and get a ham ticket. After getting the Novice license and joining the local club, I realized that lots of people have the same problem with the code. The Morsemaster got passed around. With its help many hams upgraded, and offered many worthwhile suggestions and criticisms that were incorporated into the Morsemaster II. It combines virtually every feature desirable in a Morse-code trainer, and can be built for a modest cost.

The Morsemaster II is self-contained. You can keep it in your desk drawer at the office to practice your code during lunch or other breaks. The pleasant audio quality makes practice sessions less tedious. A virtually endless reservoir of pseudorandom lessons is available—13,107 in each of 15 lesson types. Lessons can be selected for the beginner as well as for the Amateur Extra candidate at crystal-controlled speeds of 4 to 33 WPM. The lesson can be stopped at any time and repeated exactly, even at a slower speed, so you can verify your copy. A built-in printer interface can print out each character as it is sent, and a built-in iambic keyer trainer permits sending practice. And the best part is that you can build it yourself in a few hours from readily available parts—and for less than $50!

Theory Behind the Morsemaster II

Dots and Dashes

The timing of Morse code is based on the dot as the shortest time element. Given that a dot has a certain duration, proper code will have a dash duration three times that of the dot. I personally use "dit" and "dah" in preference to the better-known "dot" and "dash" because the former method mimics the actual sounds of the elements better. Learning the code is a process of identifying the sounds of the characters, and it is important to speak of, and think of, the characters in terms of their sound.

A dot or a dash is called an "element." The space, in time, between successive elements in a character is one dot duration. The spacing between characters is three dot periods, and the spacing between words is seven dot periods. This is the timing you can expect on the 13- and 20-WPM Volunteer Examiner (VE) tests.

The Novice test, however, differs. The characters are generally sent at a rate of about 13 WPM, but the spacing between them is stretched so that only five words are sent in one minute. The reasoning is that characters sent at less than 13 WPM sound artificially long and drawn out. And the good part is that you only need to be able to recognize characters at 13 WPM to get through both the 5- and the 13-WPM code tests. For this reason, the Morsemaster uses 13-WPM characters for every speed from 4 to 13 WPM, and from 14 to 20 WPM it uses 20-WPM characters, adjusting the spacing between them to achieve the 14, 16 and 18-WPM rates. In this manner, the student need only be able to recognize Morse characters at two rates—13 and 20 WPM—to be able to pass all code tests up to Amateur Extra.

Timing and Speed

A Morse-code word consists of five characters. If we choose our characters randomly from the English alphabet and numbers, we will find that there is an average of 60 dot periods, including spacing, in our hypothetical word. On the other hand, if we choose our word content based on commonly used letters and characters, we find only 50 dot periods. This is because the Morse alphabet uses its shortest possible characters for the most common letters. For example, the letter "E," the most frequent in English usage, is the shortest Morse character, being only a single dot. And so on, for most of the characters. The word "Paris" is taken to be a representative common-usage five-character word for timing Morse transmissions. It has 50 dot periods, including spaces. This is the basis for FCC and VE testing for code speed. The word "Codex," with 60 dot periods, is representative of random letters and numbers, with no regard for usage frequency.

The Morsemaster bases its timing on the "Paris" word, as do the amateur code tests. For example, at 13 WPM, the word "Paris" could be sent 13 times in a single minute. In this minute, then, would be 13 $\times$ 50 = 650 dot periods. No matter what characters are sent, this is their rate. When the Morsemaster sends code at a rate of less than 13 WPM, the 650 dots/minute rate is preserved for the characters themselves, but the spacings between them are elongated.

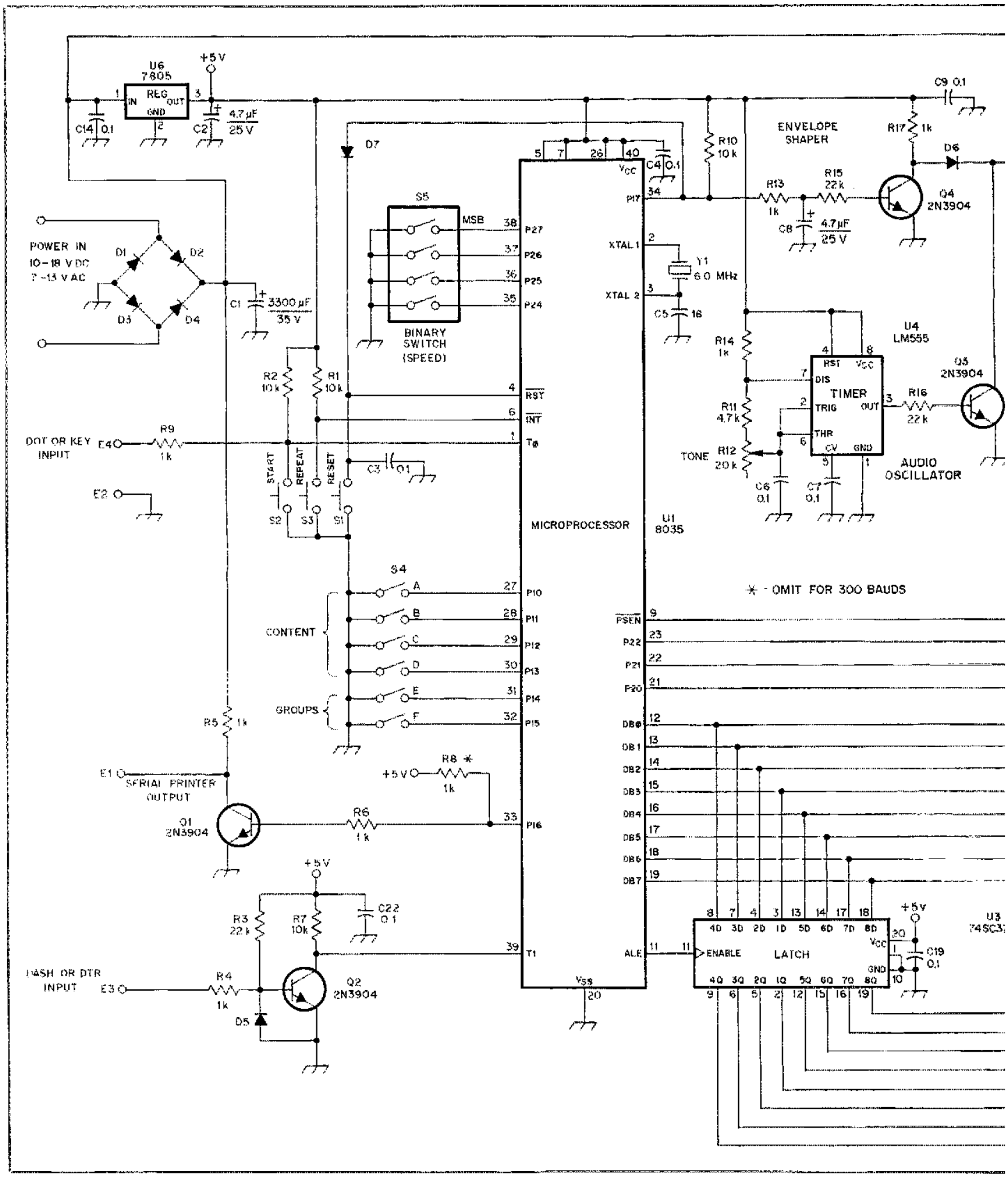
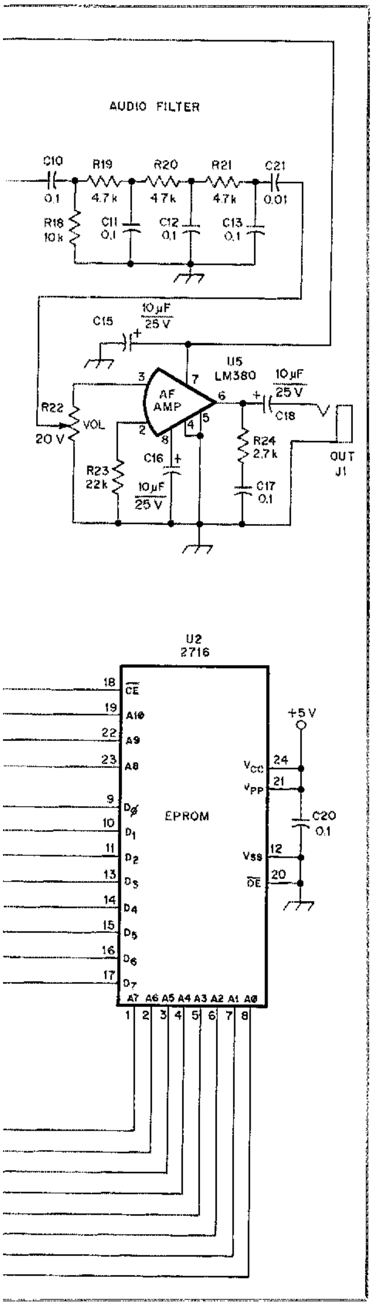


Fig 1—Schematic diagram of the Morsemaster II. Parts source identification: RS is Radio Shack, DK is Digi-key, AMP is AMP Inc.[2,3]

D1-D4, incl—1N4001 rectifier diodes.
D5-D7, incl—1N914 diodes.
J1—3.5-mm miniature phone jack, RS 274-297.
Q1-Q4, incl—2N3904 NPN transistors.
S1-S3, incl—PC-mount push-button switches, DK PN P9951.
S4—Six-pole DIP switch, DK PN CT2086.
S5—16-position BCD rotary switch, AMP PN 1-435167-1.
U1—8035 family microprocessor, DK INS8035LN-6.
U2—2716 EPROM. (Programmed device available; see note 2.)
U3—74SC373, 74HCT373 or 74LS373 latch, DK 74LS373N.
U4—LM555 timer, DK LM555CN.
U5—LM380N-8 audio amplifier, DK LM380N-8.
U6—LM7805T 5-V voltage regulator, DK LM7805CT.
Y1—6.0-MHz series resonant crystal, DK X026.

Miscellaneous

40-pin DIP socket, DK C8940.
24-pin DIP socket, DK C8924.
20-pin DIP socket, DK C8920
8-pin DIP socket, DK C8908 (2 req).
Heat sink for U6, DK HS111.



In all cases, however, the 3:7 ratio of intercharacter spacing to interword spacing is retained.

A further note on code speed is in order. The Morsemaster uses a crystal-controlled microprocessor to provide the critical timing necessary for accurate code-speed settings. Code-speed selection is not infinitely variable, but only those speed settings required for the most efficient learning process are made available. This is not a disadvantage; rather, you as the student are assured of "textbook" code rates—to better than 1% accuracy. These are the same rates and weightings used by Volunteer Examiners for amateur code testing.

Circuit Operation

Refer to Fig 1. The heart of the Morsemaster II is an 8035 single-chip microcomputer. The device has its own internal read/write memory, and supports external program memory in the form of a 2716 (2048 × 8) EPROM. The 74SC373 is used as an address latch for the multiplexed address/data bus. Additional information on this configuration may be obtained by consulting an 8035 data book.

The microprocessor decodes the switch inputs and generates the Morse output. This output, at pin 34, is an inverted-voltage Morse signal that turns on Q4 when there is no tone output, and turns it off when there is. The combination of C8, R10 and R13 provide the 5-ms rise and fall times for the Morse signal, reducing low-frequency "thumping." Increasing the value of C8 will increase the rise/fall time of the tone, and vice versa. The LM555 audio oscillator, U4, runs all the time. Its square-wave output is gated by the smoothed Morse signal through Q4 and D6, and then applied to a conventional passive filter. The low-pass portion of the filter consists of R19, C11, R20, C12, R21 and C13; it removes the harmonics of the square wave produced by U4. The high-pass portion of the filter consists of C10, R18, C21 and R22; its job is to eliminate any low frequency thumping which C8 didn't completely remove. This process is illustrated in the oscilloscope traces in Figs 2 and 3.

As soon as the Morsemaster II is powered up, it begins generating 16-bit pseudorandom numbers at the rate of one new number every 100 microseconds. It continues this until the START button is pressed, at which time it transfers the latest number into a storage register, and begins to output the pseudorandom code sequence called for by the programming switches. After each code character is output, five new numbers are generated, and the last is used for the next character. This allows a total of 32 possible choices for the next character in the sequence of 13,107 characters for each lesson type.

At the completion of a lesson, or if the RESET switch is pressed, code output ceases and the microprocessor resumes its pseudorandom number calculations. If the START switch is then again pressed, the activity described above again takes place. If the REPEAT button is pressed, the microprocessor retrieves the old number it stored the last time the START button was pressed, and uses it to start this new lesson. In this manner, the REPEAT button causes the last lesson to be replayed, while the START button begins an entirely new one.

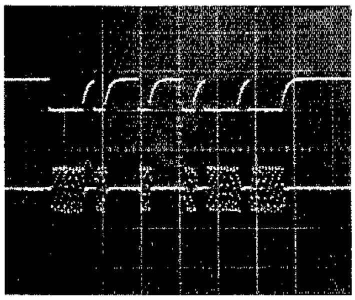


Fig 2—Storage oscilloscope trace of the Morsemaster II sending the character sequence NEW at 33 WPM. Horizontal divisions are 200 ms each. The top trace, at 5 V/div, shows the output of the microprocessor at pin 34 and the lower trace shows the audio output to the speaker at 500 mV/div. The spots on the lower trace are the digital aliases of the audio signal.

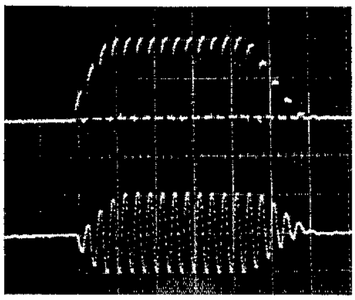


Fig 3—Storage oscilloscope trace of Morsemaster II sending a single dot at 50 WPM. Horizontal divisions are 5 ms each. The top trace shows the gated square wave at the collector of Q3 at 2 V/div. The lower trace shows the same signal at the audio output at 200 mV/div. The approximate 5-ms rise and fall times are evident in each trace. Note the nearly sinusoidal output in the lower trace.

The LM380N-8 audio amplifier is straightforward. It uses a smaller-than-usual output capacitor, C18, to act as another high-pass filter. To use the Morsemaster for maximum audio-output power, the value of C18 can be increased up to about 150 μF, and power output will increase somewhat proportionally. Since increasing the value of C18 will also enhance low-frequency response, some thumping may be heard. If this is the case, C8 may be increased up to about 10 μF, to eliminate the thumping.

Q1 and Q2 are used solely for the printer option. One of the jobs of the microprocessor is to provide a serial character to a printer or CRT after each corresponding Morse transmission. The ASCII character corresponding to each Morse character is output on pin 33, where Q1 inverts the data and swings its output between about 0.2 and 8.0 volts. Q2 is used as a buffer for the printer's Data Terminal Ready (DTR) line, if one is used. R4 and D5 keep the DTR line from damaging Q2 if it should swing beyond maximum RS-232-C levels.

In most cases, the printer or CRT you elect to use will not require a DTR line, especially at the relatively low data rates of 300 to 600 bauds. However, if your printer does, be aware that it may cause some degradation of the Morsemaster's performance, as the Morsemaster must stop what it is doing to wait for the printer to get ready. If you plan to use a printer with the DTR line, time two identical Morse transmissions (using the REPEAT key); one with the printer attached and one without. In all likelihood there will be no difference, but if there is, you should adjust your Morse data rates to accommodate the lower data rate.

The power supply is thoroughly conventional, using a bridge rectifier input so ac or dc (of either polarity) may be used to power the unit. Permissible input voltages are from 7 to 13 V ac or 10 to 18 V dc. A large filter capacitor is employed, as is a 7805 5-V regulator.

Putting It Together

There's nothing at all critical about assembling the Morsemaster II. All of the parts are readily available and just about any construction technique may be used. If you want to go from scratch, a printed-circuit board or perfboard will be fine. A full-size PC-board pattern, with a parts-placement diagram is available, as well as a hexadecimal program for the EPROM.[1] You may either program your own EPROM (U2), or purchase one already programmed from the source mentioned in the parts list.

Because there are no "tweaks" or restrictions on parts placement, the Morsemaster II should work as soon as you have put it together, providing you used reasonable care in building it. The use of sockets for ICs is recommended, as long as you use good ones. A low-wattage soldering iron, rosin-core solder and care in handling the metal-oxide-semiconductor (MOS) ICs (U1, U2, U3) are essential. If you use the PC board, pay special attention to avoiding solder bridging across runs when you solder a connection. Finding these bridges later is tough, and they are infamous for killing an otherwise perfect project.

The lead spacing for all the resistors, diodes and jumpers on the PC board is 0.4 inch. A neat, professional appearance will result from preforming these leads around U6, the 7805 regulator, which is very close to the exact 0.4-in spacing. Be sure to observe polarity on the electrolytic capacitors, diodes, transistors and ICs. Polarity of these components is shown on the parts-placement diagram and is silk-screened on the PC board (if you elect to buy one).

The recommended order of assembly (again on the PC board) is the following: IC sockets; switches; phone jack; transistors; diodes; crystal; potentiometers; resistors; jumpers; capacitors; U6; and, finally, the power transformer. Before inserting the ICs into their sockets, plug the unit in and check the following voltages with respect to the negative lead of C1: U1, 5 V at pins 5, 7, 26 and 40; U2, 5 V at pins 21 and 24; U3, 5 V at pin 20; U4, 5 V at pins 4 and 8; and 8 to 15 V at U5, pin 7. If any voltage is more than 5% from the specified value, remove power and look for the problem. It will probably be either a cold solder joint, a solder bridge or a forgotten jumper. An unusually high voltage in the 5-V circuit may indicate that U6 is defective. An unusually low voltage in the 8- to 15-V circuit may indicate that one of the rectifier diodes (D1-D4) is defective or installed backwards. Whatever it is, find it before proceeding.

Finally, remove power and install U1, U2 and U3. All three are static-sensitive devices, so use proper antistatic precautions when inserting them. Do not touch their pins. Any problems encountered now will be in the vicinity of U1, U2 and U3, and the long circuit runs connecting them. Be especially on the lookout for any solder bridges or cold joints.

That's about it for assembly. An experienced kit builder should have it together and working in less than two hours, while a newcomer might spend an entire evening. In any event, take your time with assembly and the Morsemaster will still be working years after you've gotten your Amateur Extra ticket.

Using the Morsemaster II

In order to get going with the Morsemaster, you'll need either a speaker or a set of headphones. The headphones or speaker must be terminated with a standard miniature (3.5-mm) plug. The phone or speaker socket is located on the lower-right side of the Morsemaster circuit board. Speaker or headphone impedance is not critical, so just about anything hanging around the house will work. The power supply should be connected to the two terminals marked AC OR DC INPUT on the left center of the circuit board. Any 7 to 13 V ac supply, or a 10 to 18 V dc supply will work fine, as long as it can supply the 150 mA needed by the circuit. Suitable choices are the commonly available plug-in ac adapters offered by literally dozens of mail-order houses and electronics retailers. If you want to use your Morsemaster in the car, a cigarette lighter plug can be used. Since the unit uses a bridge-rectifier input circuit, polarity of the dc supply makes no difference.

The Morsemaster's microprocessor generates low-energy discrete harmonics of 0.4, 2 and 6 MHz. When operated near AM radios or TVs tuned to low VHF channels, interference may occur. The best solution is to move to another room, although a metal case shielding the Morsemaster can be used if desired.

Controlling the Controls

The numerous switches and controls of the Morsemaster II are simple to understand and use. The VOLUME control and the TONE control are self-explanatory. The rest are used as follows:

RESET—This button stops an operation in progress, and readies the Morsemaster for the next command. As long as this button is held down, a steady tone is heard.

START—Pressing START begins the selected Morse lesson. When pressed, it turns on the tone for 0.3 seconds, waits one second, then starts outputting the selected Morse lesson.

REPEAT—Pressing this button repeats the previous lesson, whether it was completed or was terminated by the RESET button. You will find this feature a tremendous help in every phase of your learning process, whether just starting or preparing for the 20-WPM test. When you can hear the same lesson twice, you not only are reinforced, but can verify the accuracy of your work. When the REPEAT button is pressed, the Morsemaster beeps and pauses, as with the START button, then sends the previous lesson over again.

SPEED—The large rotary switch in the lower left of the circuit board controls the code speed, as shown in Table 1. The speed control may be changed at any time, even in the midst of a character being sent. With the Morsemaster, Morse code is never sent at a character rate less than 13 WPM, so this is the slowest speed rate allowed by the keyer function. Of course, the user may space the characters as appropriate for the lower rates.

DIP SWITCHES—The set of six DIP switches located to the immediate left of the microprocessor is used to select the lesson and the number of characters to be

Table 1

Rotary Speed-Control Switch Selections

Position	Characters (WPM)	Words (WPM)	Keyer (WPM)
0	13	4	13
1	13	5	15
2	13	6	17.5
3	13	7.5	20
4	13	10	22.5
5	13	13	25
6	14	14	27.5
7	20	14	30
8	20	16	32.5
9	20	18	35
10	20	20	37.5
11	22	22	40
12	25	25	42.5
13	27	27	45
14	30	30	47.5
15	33	33	50

[1]Notes appear on page 38.

Table 2
Lesson Selection
(DIP Switches A, B, C and D)

Lesson No.	*Switch Positions* A B C D	*Lesson Description*
1	off off off off	Characters E I S T M O A N W
2	on off off off	Characters B C D G Q X Y Z 0
3	off on off off	Balanced review
4	on on off off	Characters F H J K L P R U V
5	off off on off	Weighted review
6	on off on off	Balanced review
7	off on on off	Characters 1 2 3 4 5 6 7 8 9
8	on on on off	Weighted review
9	off off off on	Balanced review
10	on off off on	Punctuation . , ? / $\overline{AR}$ $\overline{SK}$ $\overline{BT}$
11	off on off on	Weighted review
12	on on off on	Trouble characters B 6 H 5 V 4
13	off off on on	Weighted review
14	on off on on	Balanced review of all characters
15	off on on on	Approximate "Paris" review
16	on on on on	Iambic or conventional keyer

Table 3
Lesson Length Selection
(DIP Switches E and F)

Switch Position	*Length*
E off F off	Generate 1 five-character word
E off F on	Generate 5 five-character words
E on F off	Generate 10 five-character words
E on F on	Generate 25 five-character words

sent. The six switches are labeled A through F on the schematic and on the circuit board (see Tables 2 and 3). The bottommost two switches, E and F, select the number of code words to be generated from the choices of 1, 5, 10 or 25. The upper four switches, labeled A through D, select the lesson content. Referring to Table 2, Lessons 1, 2, 4, 7 and 10 are the only ones that introduce new characters. These groupings are used by the US Army training program described in *Army Technical Manual TM 11-459*, except for Lesson 10. Lesson 10 contains punctuation and procedural characters not used by the military—it is added to complete the set required of Amateur Radio licensees. Review Lessons 3, 5, 6, 8, 9, 11 and 13 are of extreme benefit when used following a lesson with new characters. They review all characters learned to that point, and Lessons 5, 8, 11 and 13 emphasize the most recent lesson. This is accomplished by generating half the characters from the most recent new-character group, and half from all the rest of the past groups.

As noted in the Army manual, and confirmed by personal experience, the characters most confused by code listeners are given in a special lesson (12) and review (13). Lessons 14 and 15 are the drill lessons. Once the characters themselves are learned, these lessons are used for speed improvement. Lesson 14 gives equal weighting for all characters—there are as many "Xs" as "Es," for example. This lesson should be used if the training lessons have been completed and the student still has some problems with the less common letters. Lesson 15 approximates English language-letter usage frequency. There are four times as many "Es" as "Xs," for example. Since the more common letters are also the shortest in terms of Morse elements, this lesson runs faster than Lesson 14. Use Lesson 15 for speed improvement after you are comfortable with all the characters.

Lesson 16, the keyer mode, differs from the rest. In the first place, the printer output is disabled. Secondly, RESET must first be pressed to leave the keyer mode, once entered. When the keyer mode is entered by selection on the DIP switch, the iambic or paddle mode is automatically selected. To use a straight key or bug, the REPEAT key must be held down while the RESET key is struck and released. The mode thus selected will remain in operation until an alternate mode is selected on the DIP switch and the RESET key is pressed. Thirdly, the code rates are different. They start at 13 WPM, include 20 WPM, and go all the way to 50 WPM. These are shown in Table 1.

Learning the Code

Generally speaking, the Morsemaster II can teach Morse code effectively with only the addition of an earphone and a power supply. A key is a great help, if you have one, as is a printer. Either or both will save you time when first learning the code.

Novice Training

For the person just starting to learn the code, there are several things to keep in mind. First, forget everything you ever learned about visual dots and dashes. Mastering Morse code is based on the concept of hearing *characters,* not elements, as they are sent. Every character has a distinct sound, and it is this that you should learn.

Beginners often make the mistake of learning the dots and dashes; then when they hear code, they must listen for these separate elements, and stop and translate them to letters. This is a two-step process, while recognizing the letters by their sound is only a single step. Frankly, either approach will work on the 5-WPM code test, but the two-step method simply will not work at 13 WPM and beyond. It is best to start out on the right foot by learning the characters by sound.

The second thing to keep in mind is that everyone gets frustrated at first. After all, Morse is a new language, and it takes some time. The good news is that if you stick with it, you *will* learn it. The Army manual says that the average student will get up to the 5-WPM plateau in 18 hours of practice. The top 5% of students learn it in about five hours, while the lowest 5% may take as long as 27 hours. The important thing is to practice every day. If you can schedule an hour a day, you are pretty well guaranteed to be able to pass your Novice code test at the end of a month, and probably much sooner.

Your first lesson should be from Lesson 1, and from there you should follow the lessons in numerical order through Lesson 15. Don't leave a lesson until you are comfortable with it. Work at 5 WPM, and revert to 4 WPM only if a particular lesson is giving you trouble. Start out each new character lesson with only one word at a time selected (DIP switch sections E and F both off). Press the START button and listen to the characters. Look at a list of Morse characters and identify the ones you have heard. Use the REPEAT button and listen to them again. Write them down as you hear them. Continue REPEATing the same group, and writing each character down until you can recognize them. Now, press the START button again for a new set from this group. Continue in this manner until you have heard all the characters of this group several times, then change the switch settings to five words. Try to copy the entire transmission. At its end, press REPEAT and write the new letters directly below the last ones. Do this as many times as it takes until you are sure you've gotten them all. Don't leave this lesson until you can copy 10 words without an error on the first try!

Use this method on each lesson with new characters in it. On review lessons, you may feel comfortable with starting out with five words per transmission, or just one. In every case, use the REPEAT button to verify your work.

At the beginning of each practice session, use the first five or ten minutes to review the last lesson learned, before starting a new one. Try to complete a lesson at each session.

Once the new character lessons have been learned, lessons 14 and 15 should be used for practice and to improve your speed. It is a good idea to be able to copy at 6 WPM for the 5-WPM test. That extra one-word buffer gives the confidence to overcome any stage fright on test day. Always go back and repeat lessons whenever you feel the need to do so.

General Code Test

The Army code manual does not give expected learning times for exactly 13 WPM, but interpolating their data shows the average student hitting 13 WPM after about 65 hours of practice. My personal experience bears this out. The student practicing for this test should concentrate on Lesson 15, and use the keyer provision as much as possible. The review lessons will also prove helpful, as well as providing a break from Lesson 15 alone. Of course, the introductory lessons and techniques described in the Novice section may be used as well. A special speed—14-WPM characters and 14-WPM speed—is provided to give the student a little extra confidence on the code exam. Obviously, code at 14 WPM will sound slightly different than the test material, so do the bulk of your work at 13 WPM. Remember, the sound of the characters is all-important.

The Biggie: 20 WPM

The Amateur Extra is called the "expert" license, as well it should. While the 20-WPM code test has been passed by students using only the Morsemaster, this is not the recommended procedure. Once you pass the 13-WPM General (or Advanced) code test, if you haven't done so already, buy a rig and get on the air. Work CW. Learn the content of QSOs and get relaxed with code. Use your Morsemaster to augment and improve your code ability. Learn to "copy behind." This technique, the ability to write code two or three characters behind the one you are hearing, is embraced by nearly all serious high-speed CW operators. It may be helpful to repeat the Novice lesson sequence at 14 WPM to get accustomed to the different sound of 20-WPM code, then gradually increase speed. The key is to do whatever works for you. The Morsemaster's versatility will provide the means.

Using the Options

While the Morsemaster by itself is a complete Morse trainer, there are provisions for two options that can be used to enhance learning. The first permits the use of a telegraph key so that you may practice sending as well as receiving. Morsemaster II has a built-in iambic keyer, similar to those included in many of today's popular transceivers, or sold as add-ons. If you already own a key, whether it be a simple straight key, a semiautomatic bug or a squeeze paddle, by all means use it with your Morsemaster. If you plan to buy one in the near future, you may want to go ahead and get it to help in your learning. The student can often get "unstuck" on a particularly troublesome character by sending it repeatedly and listening to it. To connect a straight key or bug, merely connect one of the key's terminals to the E4 connection on the Morsemaster, and connect the other to E2. To connect a paddle key for iambic operation, connect its common leg to E2, its dot terminal to E4 and its dash terminal to E3.

The second available option is a printer output. The Morsemaster II includes a serial output that interfaces to a printer or a computer terminal, and prints out every character that it sends. While particularly helpful for beginners learning the code, printers are expensive, and unless you already own one or can borrow one, the additional help it will provide in learning the code is not worth the expense.

The printer output is serial "quasi-RS-232-C." True RS-232-C uses both positive and negative voltages, but the Morsemaster only uses positive. The majority of RS-232-C printers and terminals will accept this with no problem. I've used a Radio Shack TP-10 printer, a DecWriter terminal and a Hazeltine CRT, and they all work fine. If you do buy a printer for your Morsemaster, be sure to check it out beforehand. As delivered, the Morsemaster operates at 600 bauds, sends eight data bits and two stop bits, and no parity. It may be converted to 300-baud operation by simply removing R8 from the circuit board. Additionally, the printer must be able to generate its own line feed when it receives a carriage return. Most printers do this automatically. To connect a printer, only three lines are necessary, and perhaps only two, depending on the printer. The printer's common connection goes to E2, and its data input to E1. If it has a Data Terminal Ready (DTR) line, connect it to E3. The Radio Shack TP-10 uses a 4-pin DIN plug, with common on pin 3, data on pin 4, and DTR on pin 2.

Conclusion

The Morsemaster is an effective Morse code trainer, as proven by my personal success and that of many other hams in my area. Once you decide that you want to upgrade, and can set aside some time each day to work on the code, the Morsemaster will help you make the most efficient use of that time.

***MORSE CODE: The Essential Language*—and You**

As configured for this article, the Morsemaster II's EPROM-driven Morse lessons are based for the most part on the letter groupings in *US Army Technical Manual TM 11-459*. This learning method has proven highly successful. That's why the Army uses it—and why the Morsemaster II uses it as well.

You and your Morsemaster aren't restricted to lessons based on the Army method, however. ARRL's popular new publication about the code, *MORSE CODE: The Essential Language* by L. Peter Carron, Jr, W3DKV, offers a Morse learning plan based on letter groupings differing from those in the Army method. Your Morsemaster can provide you with code lessons based on the Carron book if you use an appropriately programmed EPROM. Here's how to accomplish this: If you're ordering the Morsemaster II data package mentioned in Note 1 of this article, you're all set: The package includes hexadecimal listings and DIP switch settings for the ARRL *and* Army learning methods.

A *preprogrammed* ARRL Lesson EPROM and a sheet explaining revised DIP switch settings and lesson content are available from Stone Mountain Engineering in addition to the Army Lesson EPROM. The price is the same as that shown for the Army Lesson EPROM mentioned in Note 2 of this article. Be sure to specify that you want the ARRL Lesson EPROM when ordering. In addition, purchasers of full sets of Morsemaster II parts may request that Stone Mountain Engineering substitute the ARRL lesson EPROM for the Army EPROM in their kits. Contact Stone Mountain Engineering for additional details at the address given in Note 2. (This offer includes an instruction sheet showing DIP switch settings and lesson content for the ARRL Lesson EPROM. It *does not* include a copy of the *MORSE CODE: The Essential Language* book. Because the detailed code lesson documentation in Stone Mountain Engineering Morsemaster kits is otherwise based on the Army method, you must depend on your copy of *MORSE CODE: The Essential Language* to round out your documentation on the code lessons contained in the ARRL Lesson EPROM.)

If you're unfamiliar with *MORSE CODE: The Essential Language*, take a peek at the advertisement on page 142, this issue. CW hounds and code students alike, this book is for you! Who says the code is dead? Morse code is alive and well—and living in *your* fingers.—Ed.

Notes

[1]A Morsemaster II data package is available from ARRL at no cost. It includes a full-sized PC-board template, a parts-placement diagram and a hexadecimal listing for programming the EPROM. Send an SASE to: ARRL Technical Dept, 225 Main St, Newington, CT 06111, and ask for the "Morsemaster II."

[2]Parts substitutions may be made if desired. Transistors and diodes may be substituted with units of higher ratings, and capacitor working voltages may be increased. The 8035-series microprocessor may be any one of the following types: 8035, 8039, 8048, 8049, 8050, 80C35, 80C39, 80C48, 80C49, 80C50, 8748 or 8749. A complete parts kit, including wall transformer and step-by-step instructions, is available from Stone Mountain Engineering, PO Box 1573, Stone Mountain, GA 30086; tel 404-879-0241 price $46.95; complete unit, wired and tested, $69.95; programmed 2716 EPROM, $5; silk-screened PC board, $12. All orders must include $2.50 shipping and handling, and applicable sales tax if shipped to a Georgia address.

[3]Digi-key Corp, Box 677, Thief River Falls, MN 56701.

AMP Inc, Harrisburg, PA, tel 717-564-0100 (call for nearest distributor).

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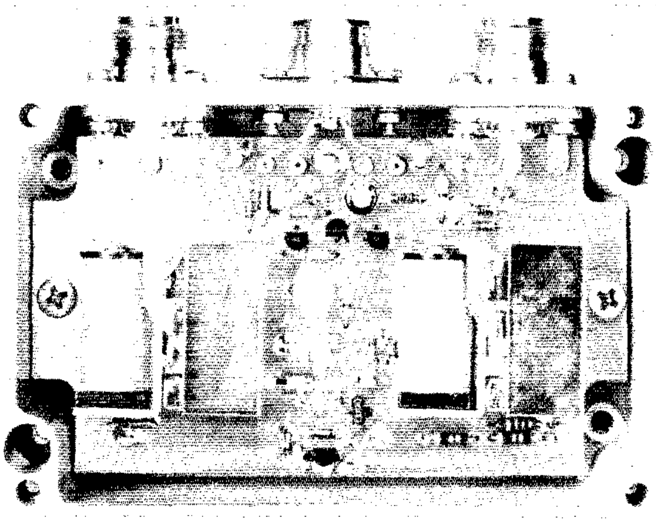
Conducted By Bruce O. Williams, WA6IVC
Assistant Technical Editor

Advanced Receiver Research MML144VDG and MM144VDG Mast-Mounted Preamplifiers and TRS04VD TR Sequencer

Serious VHF and UHF operators have long realized that the best performance can be extracted from a GaAsFET or other low-noise preamplifier only if that preamplifier is mounted at the antenna, ahead of the loss introduced by the feed line. Any loss adds directly to the noise figure of the receiver. While it's possible to operate EME or use OSCAR satellites with the preamplifier located in the station, the lowest noise figure and best results occur when the preamplifier is mounted near the antenna.

Not too long ago, mounting equipment outdoors on the tower was for diehards only. You had to find a suitable low-noise preamplifier and high-quality coaxial relays, come up with a weatherproof mounting system, and design control circuitry to switch everything around. Thanks to Advanced Receiver Research, getting the most from your low-noise receiving system is now as easy as picking up the telephone.

Three separate ARR units are reviewed here. The MML144VDG is a 2-m GaAsFET preamplifier with switching relays that will handle up to 160 W. Its big brother, the MM144VDG, is rated for 1 kW. ARR offers similar preamplifiers for 50, 220 and 432 MHz, as well. The TRS04VD provides sequentially keyed outputs to control the timing of system TR switching to protect the preamplifier and relays from accidental damage. The TRS04VD works with any of the ARR mast-mounted preamplifiers.



MML144VDG Description

The MML144VDG is housed in a rugged diecast aluminum enclosure. A rubber gasket seals the lid so the unit is both RF-tight and weatherproof. Type N female receptacles are provided for connection to transceiver and antenna. A locking DIN receptacle handles the dc connections. All connectors are located on one side of the enclosure, and the unit is installed with this side positioned toward the ground to prevent water from building up around the connectors. An aluminum and stainless-steel clamp assembly secures the enclosure to masts of 1 to 2-1/8 inches OD.

High quality components and construction techniques are evident throughout the MML144VDG. A single PC board holds all the components. A pair of Tohtsu® CX-120P PC-board-mount, RF-type relays dominate the board. The other preamplifier components are located between the relays, with the control circuitry located near the DIN connector.

The preamplifier circuitry is essentially the same as other ARR GaAsFET products. A Mitsubishi MGF-1402 is the active device. The input is tuned with an L network, while the output is matched by a broadband ferrite transformer.

The CX-120P relays are SPDT types. They are connected so that they must be energized to place the preamplifier in the line for receive, and deenergized to bypass it during transmit. There are several advantages to this system. Any time the station is not in use, the preamplifier is switched out of the line to protect it from possible damage from nearby lightning strikes. Also, should the preamplifier break or not be needed, it can be switched off and normal operation can continue as though the transceiver is connected directly to the antenna.

The control circuitry is well thought out, so the MML144VDG is essentially idiot proof. There are three options for keying the unit for transmit. The easiest is automatic RF switching. When the transmitter is keyed, this circuitry senses the presence of RF at the input to the MML144VDG and deenergizes the relays to bypass the preamplifier. It requires at least 5 W at the input to make the unit switch to transmit. This circuitry is similar to the RF-activated switching found in many solid-state VHF and UHF amplifiers. What could be simpler?

If you prefer to have more control over your TR switching, you can provide a command signal from the station to "hard key" the preamplifier. To accommodate the many different rigs on the market, you have the choice of providing a ground-for-transmit or positive-voltage-for-transmit (+5 to 16 V) command. The ARR instructions stress that to prevent preamplifier failures, you must have some type of TR-relay sequencing if you use hard keying. The TRS04VD sequencer described later in this review is ideal for that job.

The control cable from the station has, as a minimum, two conductors for + V dc and ground. A third conductor is necessary if you wish to use either of the hard keying options. The ARR instructions highly recommend the use of shielded cable for the control lead. An unshielded cable can act as an antenna, picking up sufficient induced voltage spikes from nearby lightning strikes to damage the preamplifier.

With low-noise GaAsFET preamplifiers, it is essential to have the right equipment to make meaningful noise-figure measurements. We tested the preamplifiers with a state-of-the-art HP8970A Noise Figure Meter and HP346A Noise Source recently donated to the ARRL Lab by Hewlett Packard. Gain and noise-figure performance for the MML144VDG is summarized in Table 1. With a gain of 22 dB and a noise figure around 0.5 dB, this preamplifier is more than adequate for weak-signal work at 2 meters. Power handling capability is 160 W, so this device is usable with any of the solid-state "brick" amplifiers currently on the market. We tested the review unit with a 150-W Mirage brick without incident.

The review unit was from the initial production run, and there was a minor problem with it. We noticed that low-level harmonics of any 2-meter signal transmitted

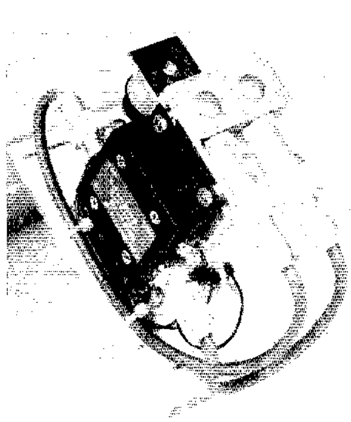
Table 1
ARR MML144VDG 2-M GaAsFET Preamplifier

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 144-MHz band, 1-dB bandwidth is 7 MHz.	As specified
Noise Figure: Less than 0.55 dB.	144 MHz, 0.49 dB; 146 MHz, 0.52 dB; 148 MHz, 0.53 dB.
Gain: 22 dB.	144 MHz, 22.25 dB; 146 MHz, 22.01 dB; 148 MHz, 21.76 dB.
Compression point (1 dB): +12 dBm.	+ 5 dBm.
Power requirements: 11 to 16 V dc at 10 mA, max (transmit) and 180 mA max (receive)	At 13 V, 25 mA (transmit), 150 mA (receive).
Power handling (transmit): 160 W.	As specified.
Through-mode SWR: 1.25:1 max.	1.15:1.
Through-mode attenuation: 0.5 dB, max.	0.2 dB.
Minimum power input to activate RF-sensed switching circuitry: 5 W.	3 W
Size: 5-1/2 × 4-7/8 × 3-5/8 in (HWD), including mounting bracket and connectors.	
Weight: 1 lb 13 oz.	

through the unit appeared at the output. These harmonics were not evident when the transceiver was operated without the preamplifier. One of the harmonics was about 55 dB below the amplitude of the fundamental signal. FCC regulations require that, at 2 meters, all harmonics and spurious emissions be 60 dB below the fundamental, or lower. ARR quickly rectified this problem by changing a capacitor in the RF-activated switching circuitry. The problem did not affect operation of the unit in any way, and has been corrected in current production models.

MM144VDG Description

The MM144VDG preamplifier/relay system is definitely for the serious operator. Although it is much simpler in appearance than the MML144VDG, it's an elegant, rugged piece. The switching scheme is similar to the MML144VDG. The relay is a DPDT transfer type that switches the preamplifier in series with a single feed line between station and antenna during receiving periods, and out of the line during transmitting periods. The preamplifier and relay must be energized to receive, so the preamplifier is switched out of the line any time the station is not in use. It may also be left turned off if operation without the preamplifier is desired.



The preamplifier/relay enclosure is a custom-made two-piece affair. The relay and preamplifier are mounted to brackets that are bolted to a piece of 1/8-inch-thick aluminum plate that is bent into an inverted L shape. The mast clamp accommodates pipes of up to 2-inches OD and also mounts to this plate. The preamplifier top cover is made from aluminum sheet. All seams are welded, so there is no entry point for moisture. Four machine screws secure the cover to the main support bracket.

Three connectors protrude from the bottom of the enclosure. Two Type-N connectors that are actually part of the coaxial relay handle connections for the feed lines from the station to the antenna. The control/power connection is made through an F connector (commonly used in 75-ohm TV systems). Inexpensive RG-59 shielded cable is recommended for the control/power line. To ensure good long-term performance, all RF connectors are silver plated. The cables that connect the relay and preamplifier are made from durable RG-142B coaxial cable with silver-plated conductors and Teflon® dielectric.

The preamplifier itself is one of the standard nonswitched ARR GaAsFET units that is self-contained in its own compact, black aluminum enclosure. At the low end of the 2-m band, gain is about 25 dB and the noise figure is about 0.5 dB, as measured on the HP8970A/HP346A setup (see Table 2). These measurements were made with the relay in the line and energized, as it would be in normal operation.

The relay, custom-made for this application by Dow Key/Kilovac, is a modified type 260. The normally closed contacts are connected together internally so that the station feed line is connected straight through to the antenna when power is not applied. More significant, the normally open contacts (those used to route the signal through the preamplifier for receive) are grounded when not in use. The result is an impressive 100-dB isolation. Even during full-power transmissions the amount of RF that can leak through the relay to the preamplifier input is tens of decibels below the level that would cause damage to the GaAsFET device.

The instructions stress the point that some type of sequencing must be used with this preamplifier/relay system. Unlike the MML144VDG, there is no RF-switched keying option. You *must* provide a 12- to 14-V signal to turn the unit on for receive (this signal energizes the relay coil and supplies

Table 2
ARR MM144VDG 2-M GaAsFET Preamplifier

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency range: 144-MHz band.	As specified.
Noise figure: Less than 0.55 dB.	144 MHz, 0.45 dB; 146 MHz, 0.43 dB; 148 MHz, 0.41 dB.
Gain: 24 dB.	144 MHz, 24.95 dB; 146 MHz, 24.66 dB; 148 MHz, 24.28 dB.
Compression point (1 dB): +12 dBm.	+10 dBm.
Power requirements: 12-V dc at 280 mA.	12-V dc at 270 mA (receive), and 10 mA (transmit).
Power handling (transmit): 1 kW.	Not tested at 1 kW power level, for lack of equipment. Operated at 500-W+ level for extended period.
Through-mode SWR: 1.15:1 max.	1.1:1.
Maximum insertion loss: 0.1 dB.	Insertion loss not detectable.
Operate time at 20°C: 25 ms.	31 ms, including 5 ms of bounce.
Size: 7-1/8 × 4 × 5 in (HWD), including mounting bracket.	
Weight: 2 lb 8 oz.	

power for the preamplifier), and you must remove this signal for transmit. The TRS04VD sequencer described later can be used to ensure that the preamplifier relay is keyed first, before the transmitter and power amplifier are keyed.

The MM144VDG is impressive because it does so much with so few parts. Operation couldn't be simpler—apply or remove 12 V. The relay will handle high power levels as long as it is not hot switched, and the preamplifier performance is fine for terrestrial, satellite or EME operation.

The weatherproof enclosure is designed so that chances of water getting into the unit are extremely remote. We purchased the unit for use on the OSCAR-10 satellite array at W1INF, the ARRL HQ station. We used it for a year before publishing this review. The performance measurements reported herein were made after the unit had been out on the tower for a year. When I removed the unit from the tower for testing, there was no trace of water in the box. The blue paint on the top cover wasn't quite as bright as when it was new and there was some oxidation on the unpainted aluminum mounting bracket, but otherwise the unit appeared and performed as it did when it was new.

Operation of the MM144VDG at W1INF was primarily for satellite work. The antenna is a KLM 22C cross-polarized Yagi fed with more than 100 feet of Belden 9913 coaxial cable. The preamplifier made a noticeable difference in reception of weak satellite downlink signals on a Kenwood TS-700S transceiver. On some signals, the preamplifier made the difference between hearing and not hearing the station.

TRS04VD TR Sequencer

The TRS04VD TR control board is important for the long life of a remotely mounted preamplifier. It provides sequentially keyed outputs to control the timing of all system TR changeovers. If you simply tie everything together and key your rig, power amplifier and relay simultaneously, you will probably start transmitting before the preamplifier relay contacts have finished switching and bouncing. When this happens, there is a good probability of arcing and ruining the relay contacts, as well as applying some transmitter power to the preamplifier.

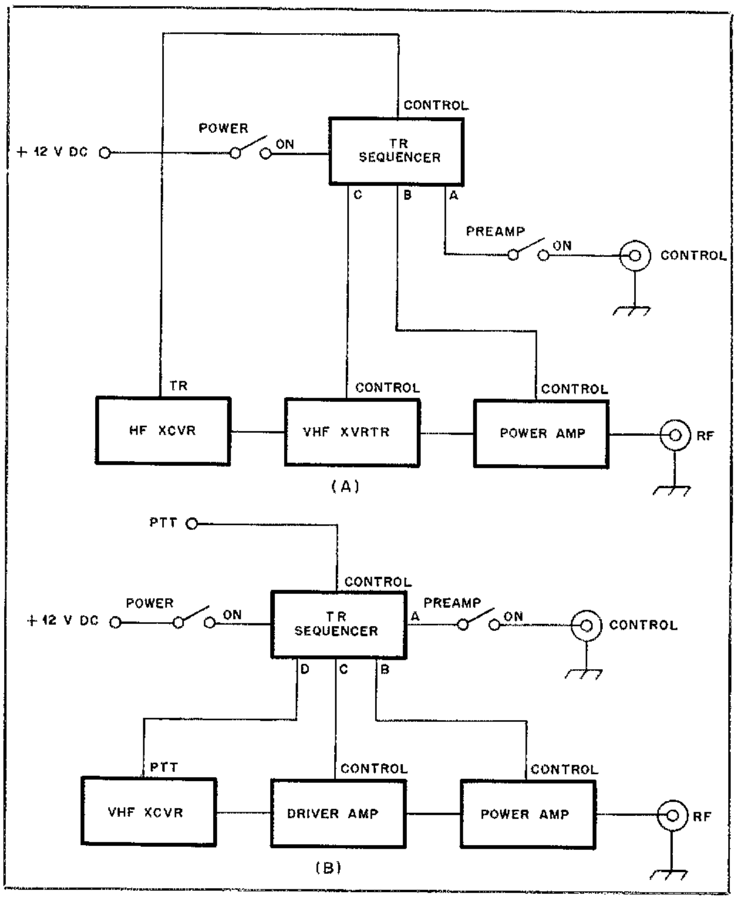
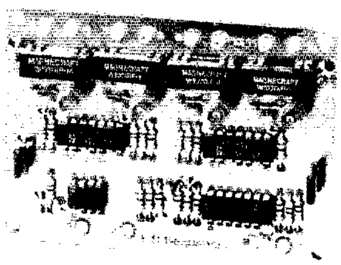


Fig 1—Two typical preamplifier/relay hookup schemes utilizing a TR sequencer.



Operation of the TRS04VD is straightforward. Once you apply the "master" TR command from your transceiver, the sequencer takes over and switches the other components in the system. The TR command can be either a ground-to-transmit or a positive-voltage-to-transmit signal. The one you choose will depend on your particular rig.

There are four keyed outputs that can be used in several ways. Two common hookups are shown in Fig 1. For a system including an HF transceiver, VHF transverter, driver amplifier and high-power amplifier, a typical sequence of events would be something like this: Approximately 8 ms after the TR command is given, the first sequencer output is keyed, switching the mast-mounted preamplifier/relay to the transmit position. About 30 ms later, the power amplifier is keyed, and 30 ms after that the driver amplifier is keyed. Another 30 ms go by and the VHF transverter is keyed, applying RF after everything else in the system is keyed and ready to go. The whole sequence takes about 100 ms, and is reversed to get from transmit back to receive (see Table 3).

All of the TRS04VD components mount on a double-sided PC board. No cabinet is supplied, so the board can be mounted in its own enclosure or even inside a radio or amplifier. Output switching is accomplished with reed relays. Depending on your particular application, you can order the unit with any combination of relays with contacts that are normally open, normally closed or mercury wetted (for high-voltage or high-current applications).

If you want to dig a little deeper into the noise on your favorite VHF or UHF band, ARR probably has a switched preamplifier to suit your needs. Manufacturer: Advanced Receiver Research, Box 1242, Burlington, CT 06013, tel 203-582-9409. Price class: MML144VDG, $180; MM144VDG, $280; TRS04VD, $50.—*Mark Wilson, AA2Z*

Table 3

ARR TRS04VD TR Sequencer Switching Times

	Delay From Initial TR Command Until Output Relays Operate (ms)	
Output	*Key Down*	*Key Up*
A	8	170
B	41	140
C	72	109
D	104	79

SIGNAL GENERATOR POWER CONTROL

☐ I built the signal generator described in Jan 1986 *QST* and found it to be generally a nice addition to my collection of homemade test gear.[1] There was one detail, however, that was less than satisfactory: power control. As DeMaw states, the circuit presented in Fig 3 of that article (shown here as Fig 1) leaves much to be desired.

While thinking about the problem, I came up with a simple circuit that works quite well; see Fig 2. The idea is simple, but I haven't seen it published. It's basically a slightly modified pi-section attenuator. Its advantage over the original circuit is that it preserves the source impedance of the generator near 50 ohms over the full range of power control. My calculations show that the SWR of the source output port remains less than 2:1 for the sample circuit presented here.

Although the concept of source match is not familiar to everyone, preservation of the output impedance of a generator is often very important. This is especially true when precision measurement (even in the amateur context) of gain, attenuation, return loss, and so on, of devices that are sensitive to impedance matching (filters, antennas, amplifiers, for instance), is made. Errors on the order of several decibels or more can accrue easily unless the source impedance is maintained near Z_0, 50 ohms in this case.

My basic idea is to absorb the power variation control, the potentiometer (R3), within a pi-section attenuator. That will allow varying the generator power output without wide excursions of generator output impedance. As is usually the case, however, there is a compromise. To do the job effectively, the attenuation must be fairly large, on the order of 5 to 10 dB. Larger values of attenuation are required for larger variations in output power. (See Table 1.) If you are satisfied with approximately 10 dB of variation, for example, a modified 6-dB attenuator will keep the output SWR at less than 1.6:1.

[1]D. DeMaw, "Build a Homemade Signal Generator," *QST*, Jan 1986, pp 40-43.

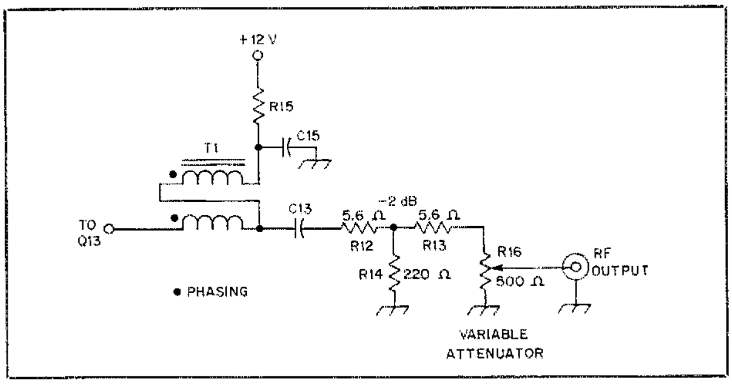


Fig 1—Original generator output-circuit suggestion.

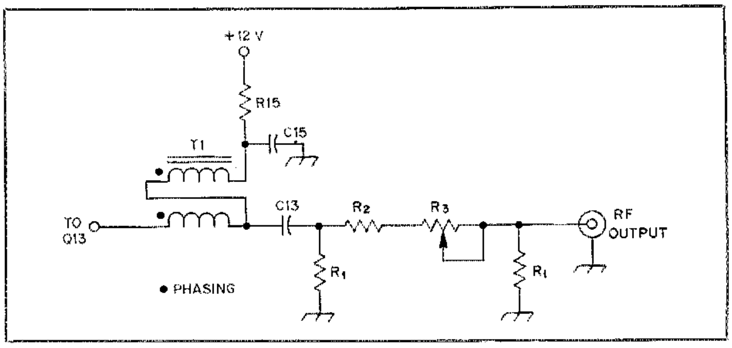


Fig 2—Schematic diagram of the adjustable power control. See Table 1 for resistor values.

Table 1

Power Control Resistor Values

Power Variation (Decibels)	*R1 (Ohms)*	*R2 (Ohms)*	*R3 (Ohms)*	*Source SWR*
10	147	39	100	1.6
20	100	39	1 k	1.8
45	100	39	10 k	2.0

Note: Power variation and source SWR are approximate values.

If you need a 45-dB range, however, you will need a modified 9-dB (or so) attenuator to maintain SWR at less than 2:1.

The circuit in the accompanying figure was breadboarded and the power variations measured by a homemade power meter. Values for the shunt resistors were chosen near values for 6 to 9 dB attenuators, but the series resistor need not be exact, since we're using a potentiometer anyway. SWR was calculated based on a generator impedance of 50 ohms before the attenuator.—*Ralph H. Fowler, N6YC, Rt 1, Box 253R, Pearl River, LA 70452*

ATARI WEFAX

☐ Atari® computer owners who also have an interest in WEFAX reception should obtain a copy of the September 1986 issue of Antic.® (This magazine is devoted entirely to Atari computer subjects.) That issue contains a few articles about WEFAX operation. Included are construction details for a PLL WEFAX demodulator, and software for the 8-bit and 16-bit computer models. If you can't locate a copy of the magazine locally, contact Antic at PO Box 1919, Marion, OH 43306, tel 614-383-314; you may be able to get a back issue or reprint.—*Paul K. Pagel, N1FB, ARRL HQ*

GOODBYE, TVI

☐ Here are a couple of experiences that may be of benefit to others. With an antenna attached to my three-band scanner, my transmitter caused TVI when operating on the 10, 15 and 20-meter bands with as little as 20-W output. There is no TVI with the scanner's antenna disconnected and using 1 kW.

I lined the inside of my TV cabinet with aluminum foil secured with staples. Spray adhesive secured the foil to the cabinet rear. Vent holes were poked through the foil. I installed an ac-line filter and a high-pass filter grounded to the foil. This cured TVI on 80 and 40 meters.

As an added benefit, horizontal oscillator "birdies" that were S9 on 160 and 80 meters are now undetectable.—*Rick Darwicki, N6PE, 17775 Elmhurst Cir, Yorba Linda, CA 92686*

MORE ON THE 160-M SLOPER

☐ A better match (with a subsequent increase in bandwidth) can usually be had with the 160-m sloper described in my article if a quarter-wave Q section is used.[2] It appears that the feedpoint impedance approaches 100 ohms, particularly when the tower is grounded.

The Q section is made of 75-ohm coaxial cable such as RG-59 or RG-11. For solid dielectric cable with a velocity factor of 0.66, an 88-foot length of cable is used. Foam dielectric cable, with a velocity factor of 0.80, requires a 110-foot cable length. The Q section is attached directly to the antenna feed point in place of the 50-ohm feeder, and if long enough, run to the operating position. If additional feeder length is required, it should be made of 50-ohm coaxial cable attached to the Q section by means of a barrel connector.

I am still using the antenna and am very pleased with it. I have heard from others who have used it with success.—*Deane J. Yungling, KI6O, 7932 Sunset Ave, Suite J, Fair Oaks, CA 95628*

TOUCH-LAMP TRANSCEIVER

☐ When my wife told me she had bought a three-way lamp that switched on and off at the touch of any of its metallic parts, I did not realize she had purchased a transceiver! I found that my transmitted signal would cause the lamp to operate exactly as if I touched its metal parts. Later I discovered a raspy, S8 signal at 1875 kHz—it was coming from the lamp, which was located three rooms away and on a different ac circuit. The lamp signal is present at frequencies from 40 meters down. At frequencies from 20 meters up, my operation is undisturbed.

A box inside the lamp contains a circuit board through which ac line voltage is routed and which has a wire connected to the metal base of the lamp. When the lamp is plugged in, the lamp signal is present at all times, regardless of whether the lamp is on or off. In my attempts to eliminate the interference, I tried a commercial ac filter, coiling the lamp cord on some ferrite material and other such approaches without success.

To make sure the lamp my wife had was not defective, I borrowed a similar lamp from a neighbor to try it. I found it to perform in exactly the same manner except that the frequency of oscillation was somewhat different. There is no manufacturer or distributor name on the lamp or packing container. The lamp was made in Taiwan.

I am writing so that others who may be experiencing similar difficulties may have some idea of the probable source of interference. After I described what I discovered to a ham friend, he realized that such a unit had been causing interference to his station for more than a month.—*Cal Enix, W8EN, 209 S Kalamazoo St, White Pigeon, MI 49099*

[2]D. Yungling, "The KI6O 160-Meter Linear-Loaded Sloper," *QST*, Apr 1986, p 26.

METEOR-SCATTER CHECKSUM

☐ The meteor-scatter technique described in Nov 1986 *QST* can be used to send text as well as signal reports.[3] This is done by using a manual checksum technique similar to that used with computers.

In setting up your schedule, agree to assign a number to each letter of the alphabet. For example, the letter A can be assigned the number 1, and Z, the number 26. When you transmit a word, follow the word with the sum of the numbers assigned to the letters of the word. For instance, TEST64 OF21, and so on.

The receiving operator can recompute each checksum to see if the words were received correctly. If you repeat words in a meteor-scatter transmission, be sure to include a checksum with each word.—*Nick Leggett, N3NL, Apt 610, 1500 Massachusetts Ave NW, Washington, DC 20005*

[3]K. Willis, "Meteor Scatter—European Style," *QST*, Nov 1986, pp 35-39.

Feedback

☐ December's Feedback item (p 47) on "In Search of the Perfect Picture," *QST*, Jan 1986, transposed the device and pin numbers. The second and third lines from the bottom should read (in part): ". . . the arm of S1 and U6, pin 3."

☐ Please refer to "Electromagnetic Pulse and the Radio Amateur," Nov 1986 *QST*, p 33. The radical sign in Eq 3 should extend over the variable, SWR. In Eq 4, extend the radical over the value, 1.5. This changes the final value of V, which becomes 88.32. Also, the FCV (final clamping voltage) would then be equal to 264.96.

This error was brought to our attention by Sheldon C. Shallon, W6EL. Author Bodson, W4PWF, verified the error, which exists in the original document on pp 5-11 to 5-13.

New Products

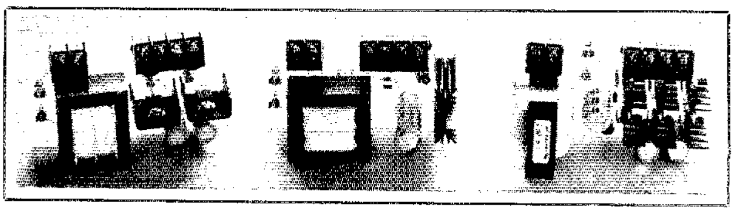
A & A ENGINEERING POWER SUPPLIES

☐ Five general-purpose power supplies are available from A & A Engineering. Created to fill the needs of hams, experimenters and electronic hobbyists, all five supplies employ three-terminal regulators with built-in overcurrent and overtemperature protection.

The power supplies are available as triple, dual and single-voltage units. The two triple-voltage supplies are rated at ± 15 V at 50 mA and + 5 V at 360 mA (model no. 135), and ± 12 V at 60 mA and + 5 V at 360 mA (model no. 133). The dual-voltage supplies have ± 12 V output at 175 mA (model no. 137), and ± 15 V at 150 mA (model no. 139). The single-voltage + 5 V supply (model no. 130) can supply 650 mA, and also has a tap at the input to the regulator.

Each supply is equipped with a board-mounted fuse holder that accepts a 20 × 5 mm fuse rated at ½ A. Ac input and dc outputs are connected through a screw-terminal barrier strip. Separate transformer secondary windings are used for the + 5 V and ± 12 and ± 15 V supplies in the triple-voltage units. Full-wave rectification is employed in all 5-V supplies, and full-wave bridge rectifiers are used in all dual-polarity supplies. All IC regulators are equipped with heat sinks.

These supplies are offered as assembled and tested units, complete kits, or as circuit boards, only. Prices for assembled and tested units are: model no. 130, $29.95; model nos. 133 and 135, $39.95; model nos. 137 and 139, $32.95. For other prices or information contact: A & A Engineering, 2521 W La Palma Ave, Unit K, Anaheim, CA 92801, tel 714-952-2114.—*Paul K. Pagel, N1FB*



Hints and Kinks

Conducted By Bob Schetgen, KU7G
Assistant Technical Editor

FINGERTIP BEAM HEADINGS

☐ I have a poor memory for beam headings. I once used the beam-heading references from the DX *Callbook*, but it took time to find the book and locate the country and heading. The DX station would usually contact someone else or change frequency before I found the heading, and I would lose him. My solution is a Desk Top Automatic Directory (model 43-105; $24.95) from Radio Shack®. This device is intended for fast location of telephone numbers. I use it to find beam headings rather than phone numbers. If I hear a TI call sign, I simply push the button lettered "T" and see that TI is Costa Rica and the beam heading is 199°. It's both speedy and efficient.

The directory is powered by two C-size batteries. It has a keyboard consisting of 15 buttons labeled from A to Z. It contains about 40 index cards, which can be selected by pressing the appropriate button. I listed the countries alphabetically according to their call-sign prefixes and have over 340 on the index cards. Call signs with numbered prefixes are listed under "MN" and "QR."—*George R. Golodich, K2OEK, West Haverstraw, New York*

☐ Here is a way to have beam headings and international prefixes instantly available. With this simple gadget, you can have your antenna pointed at that rare DX station before he finishes his CQ call.

Next time you go grocery shopping, buy a large can of tomato juice. I found a 46-ounce can that is 7 inches tall and 4½ inches in diameter, with no dents—just right!

1) Remove the label, empty and rinse the can through two small holes in one end.

2) Drill a hole in the exact center of each end to snugly fit a pencil-size rod about four inches longer than the can. (A 2-inch extension at each end serves as an axle for the rotating drum.) Apply a little solder or epoxy to the axle and can ends to hold the rod in place.

3) Remove the page of International Radio Amateur Prefixes from the *Callbook*, and write the beam heading for each country next to the prefix. Trim the page margins to fit the drum, and secure the page to the drum with tape.

4) Make a rack of wood or metal to hold the drum, and place the assembly near your rotator controller.

With the completed beam-heading drum you can have your beam set "right on" and ready to answer when that DX station signs "over."—*Mal Tindall, KA8GOB, Sarasota, Florida*

QSL HOLDERS

☐ While I am a photographer by profession, I rarely use 3- × 5-inch prints. So, when a recent mailing included a sample page of clear vinyl holders for ten 3.5- × 5.25-inch prints in a three-ring binder, I almost threw it out. But I suddenly thought, "Aha! QSLs!" Sure enough, a standard QSL fits quite nicely if you can spare about ¼ inch that must be trimmed from the length. The photo industry offers quite a range of mounts, albums, pages and the like for the 3- × 5-inch size, which is very common in amateur photo processing.

A wide variety of storage and viewing systems are also made for 4 × 5, a common size for professional negatives and 5 × 7, which would probably hold oversize QSLs quite nicely. Put some typical QSLs in your glove compartment and stop into a photo or department store. You might find just what you need to organize and display all those stacks of cards gathering dust.—*Fred Anderson, KØIHG, Nisswa, Minnesota*

PENCIL CONTROL FOR CONTESTERS

☐ In a CW contest, it is a terrible nuisance to keep track of your pencil, and you may have wished there was some simple way to eliminate that constant search. There is: *Wear* the pencil on your middle finger, cradled next to your forefinger. Attach the pencil to your middle finger with two rubber bands positioned between the knuckle and first joint, with the pencil point somewhat back of the middle finger tip. To write, curl your forefinger over the pencil and draw it down to be gripped between the forefinger and thumb on one side and the middle finger on the other side. (That's not how you were taught to hold a pencil, but penmanship is good enough for printing a log sheet.) After writing, curl your forefinger under the pencil and the rubber bands to lift it out of your way. Voilà! Pencils that are over five inches long don't seem to balance well.—*W. A. "Spud" Monahan, K6KH, Manhattan Beach, California*

TIDBITS FOR THE STATION AND SHOP

☐ Kodak® sells 35-mm photographic film in 50- and 100-ft bulk packs, which come in tin-plated steel cans suitable for small electronic projects. The 100-ft can is about 4 (diam) by 1¾ inches deep, while the 50-ft can is about 3¾ (diam) by 1-5/8 inches. The cans are easily soldered, and the 50-ft can nests inside the 100-ft can. Paint the cans to prevent rust.

• You can add a spring-open feature to pliers not so equipped by the maker. Spread the tool handle fully open, clean the insides of the handles near the pivot and place a big dab of silicone caulk there so that it contacts both handles. Once the plastic cures, it will cause the handles to spring back to the open position. If the return action is too strong, cut a "V" in the caulk and remove some of the material.

• I affixed a sponge to my Ungar® soldering-iron holder by putting a loop of no. 22 AWG wire through both the sponge and the holes in the holder legs.

• "Travel Pak" QSL labels are handy for labeling your radio gear. They are inexpensive and can easily be placed anywhere—like inside a hand-held (transceiver) battery pack or a cabinet. I use the same labels to identify camera gear and other valuables.

• I transport my Kenwood TS-130S transceiver and accessories in a discarded typewriter case. It came from a Smith Corona® of mid-1960s vintage, and seems ideal. A "tricked-up" mount lets the TS-130 lock in place just as the typewriter did. Since the case is much taller than the radio, I store logs, connecting cables, a paddle key, "homebrew" keyer and so on inside the case with the radio.—*Timothy N. Colbert, Burton, Ohio*

☐ With three battery packs for my hand-held transceiver, it has been a problem to keep track of which pack is charged or discharged at any particular time. A common solution is to use some kind of sticker to label the packs. Many stickers, however, are not easy to peel from the battery pack.

I found an answer in 3M® Post-it™ note pads. Post-it notes have a strip of weak wax-like adhesive along one edge. They are meant to be repeatedly placed and peeled away without damage. I cut several pieces small enough to fit inside the top of the battery pack. When a pack is discharged, I place the sticky strip so that the paper covers the battery terminals. After charging, I move the strip so that the terminals are exposed. The strips can be used repeatedly, and there is no damage to the battery packs.—*Bob Schetgen, KU7G, ARRL HQ*

☐ You can straighten short pieces of kinked-up wire by placing one end of the wire in a vise and the other in the chuck of a variable-speed hand drill. Then turn the drill motor slowly while holding tension on the wire. When done, polish the wire with steel wool and give it a coat of clear acrylic paint. I've used pieces of no. 8 and no. 10 AWG wire straightened by this method for VHF whips.—*Harold F. Keenan, KA1FJR, Danbury, Connecticut*

☐ Loose coil slugs can be tightened by removing the slug and trapping a short piece of rubber band between the slug and hole as the slug is screwed back into the hole.—*Boris Golovchenko, KB2TN, Delray Beach, Florida*

☐ A handy solder dispenser can be made from a container used for 35-mm photographic film. Wind a coil of solder to the appropriate size using a screwdriver handle as a form. Punch a hole in the container cap, insert the coil in the container and feed a few inches of solder out through the hole in the cap. I have a number of these containers—each contains a different size or formulation of solder.—*Hal Simmerman, KE4OR, Marietta, Georgia*

☐ Empty Solder Wick™ spools make excellent dispensers for small-diameter solder. Just pull a few feet from a large roll and wind it on the empty spool.—*David A. Brown, W6NBM, Wildomar, California*

☐ Fishing-tackle stores sell plastic float beads that are good element tips for home-built antennas. Simply heat the end of the element and push it halfway through the bead. The plastic beads can't prevent corona discharge like a metal ball, but they do prevent injuries from sharp element ends.—*Jack Demaree, WB9OTX, Versailles, Indiana*

REPLACEMENT PA TRANSISTORS

☐ With winter here, I would like to pass some practical advice along to owners of the Kenwood TS-130. On a winter day in January 1983, I had left my mobile rig out in the cold for several hours at about 0°F. When I switched the rig on, the collector current rose to a very high value, and one of the PA transistors developed an emitter/collector short. I checked with an RF engineer and found that this is common failure mode for RF power transistors that are several years old. He suggested that I avoid this problem in the future by warming the rig to about 20° before applying power.

I replaced the original Toshiba 2SC2290s[1] with a pair of matched Motorola MRF-421s, which are listed as direct replacements in the Motorola manual. The replacement procedure is very straightforward: Simply install the new transistors and adjust the bias current as described in the shop manual. The results are excellent, and the new transistors produce slightly more power than the originals on 10 and 15 meters. These transistors have been in service for about three years now, with no signs of instability or other problems.—*George Hovorka, WA1PDY, Milton, Massachusetts*

A STEADY TONE FOR MAKING MIC-GAIN ADJUSTMENTS

☐ I use a recording of a steady, long (30-seconds) CW note to adjust the microphone gain on my SSB transceiver. [A code practice oscillator, or sidetone from a keyer, should also work well.—Ed.] To make the adjustment, play back the tone at moderate volume with the tape recorder speaker about two or three inches from the radio microphone, increase the microphone gain until the radio output power stops increasing, then reduce the gain a little. The CW note makes a much steadier signal than the common voice "Haaaaa Loooo" I often hear on the air.

I make frequent checks, and reports indicate that my signal is no wider than 3 kHz even when using my amplifier. Also, do use a dummy load while making transmitter adjustments.—*A. F. "Pete" Peters, KF7R, Livingston, Montana*

MORE ON USING COAXIAL FEED LINES IN PARALLEL

☐ Coaxial cables of different impedances can be operated in parallel to obtain special impedance characteristics. Cables apparently follow the same impedance and power-distribution laws as resistors. For example, if 50-Ω and 75-Ω cables are used in parallel, the resulting impedance is 30 Ω. This 30-Ω impedance may be useful for matching mobile or vertical antennas. It could also be used as a λ/4 matching section between a 50-Ω line and a Yagi antenna. Depending on the exact impedance of the cables, a wire beam that presents an impedance of 18 to 20 Ω can be nearly matched. Fig 1 shows a test arrangement for experimenting with parallel connected cables.

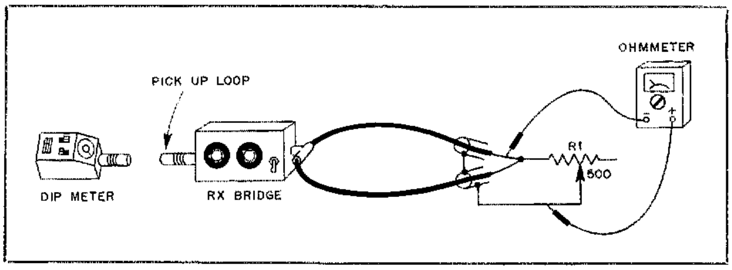


Fig 1—The test circuit for parallel-connected coaxial cables. When the potentiometer is set for 30 Ω, the RX bridge reads 30 Ω at any frequency. When the potentiometer is set for 18 Ω, the RX bridge reads 50 Ω when the frequency is such that the cables are an electrical λ/4.

When connecting coaxial cables in parallel, the electrical lengths of the lines must be equal. Different physical line lengths will result if the velocity factors of the cables differ.—*Bob Perthel, W9MWD, Elm Grove, Wisconsin*

PLATE-CAP CONNECTORS

☐ Heat-sink plate caps are nice to have, but some of us that build amplifiers don't run 3 kW. If you have gone into an electronics supply house lately and asked for a plate cap, you probably got puzzled looks and a profusion of dusty boxes flying out of a back room.

A suitable cap can be made from a block-style fuse holder. Do so by drilling out the rivet that holds the fuse clip to the plastic block, then use a hammer to form the clip completely around a metal rod having the same diameter as the plate cap. The rivet hole fits a no. 4-40 screw for connections.—*Karl Kauffman, NI6H, Morgan Hill, California*

COAX-SEAL WARNING

☐ After my experience during a hot California August weekend, I feel that potential users of Coax Seal™ should be warned that the product is temperature sensitive. Although there is no information in the directions, an inquiry to Universal Electronics, Inc resulted in a new roll of Coax Seal and a product-specification sheet. The specifications state that the material should be applied when ambient temperature is between 50°F and 90°F. I found it impossible to remove the "plastic mastic" from its container at 95°F. What a mess! [I think this problem can be avoided by refrigerating the Coax Seal for a short time before use. —Ed.]—*Don Johnson, KD6DT, Livermore, California*

ANOTHER WAY TO WEIGHT KNOBS

☐ Here is another way to weight hollow tuning knobs such as that on the TS-830S. First, purchase some lead "wool" at your local hardware or plumbing supply house. It takes two ounces (about 30 cents worth) to do one knob. Use a screwdriver with a small blade to pack the lead into the spaces on the inside of the knob. The wool can be packed very tightly with moderate hand pressure. (Lead wool packs more tightly than lead shot, so more weight can be added in less space.) If you feel the need for a sealant, cover the wool with some silicone caulk or epoxy. —*D. F. Christensen, W8WOJ, Midland, Michigan*

[1][These same PA transistors are used in many contemporary radios as well, such as the TS-430S.—Ed.]

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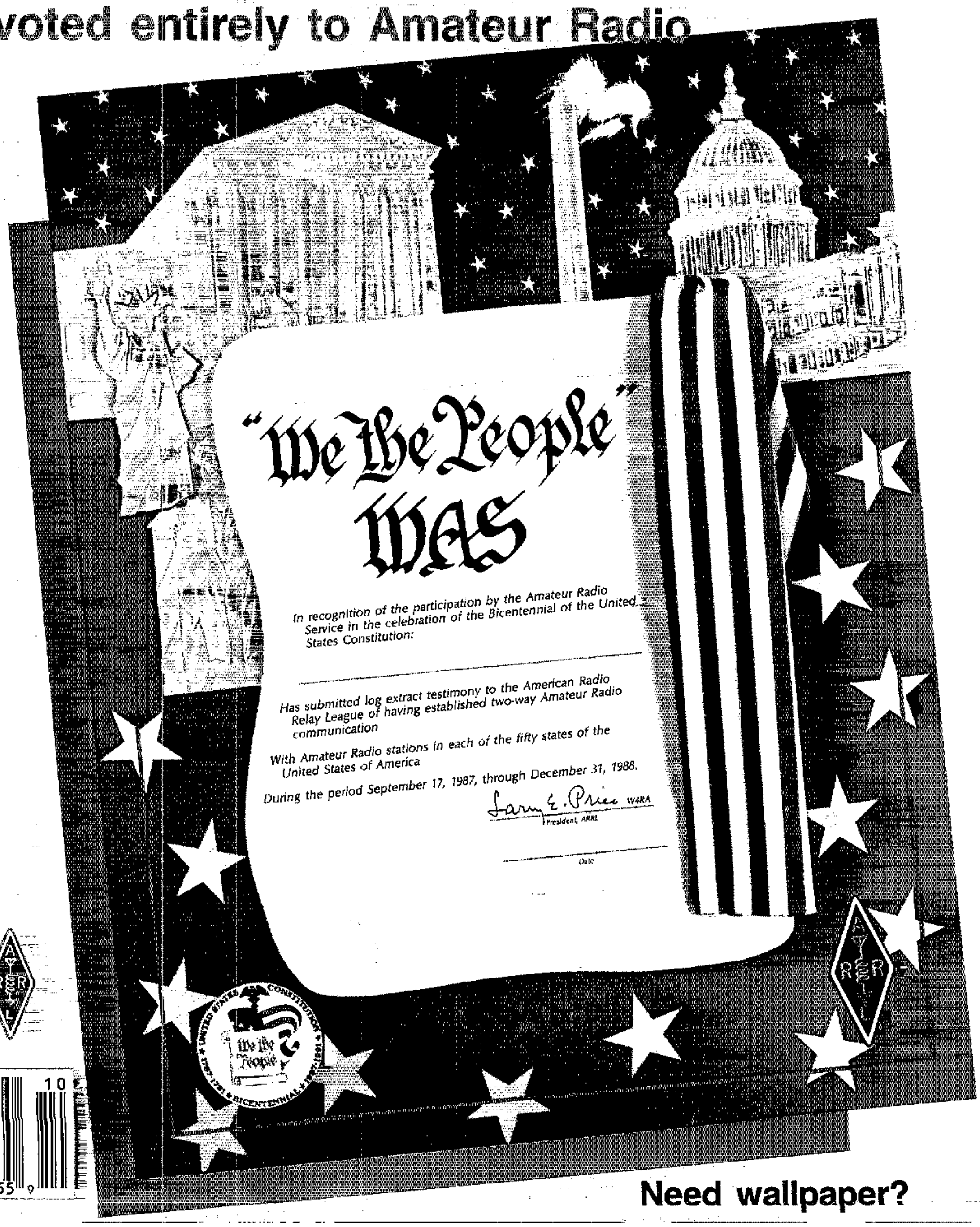

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October 1987 *Volume LXXI Number 10*

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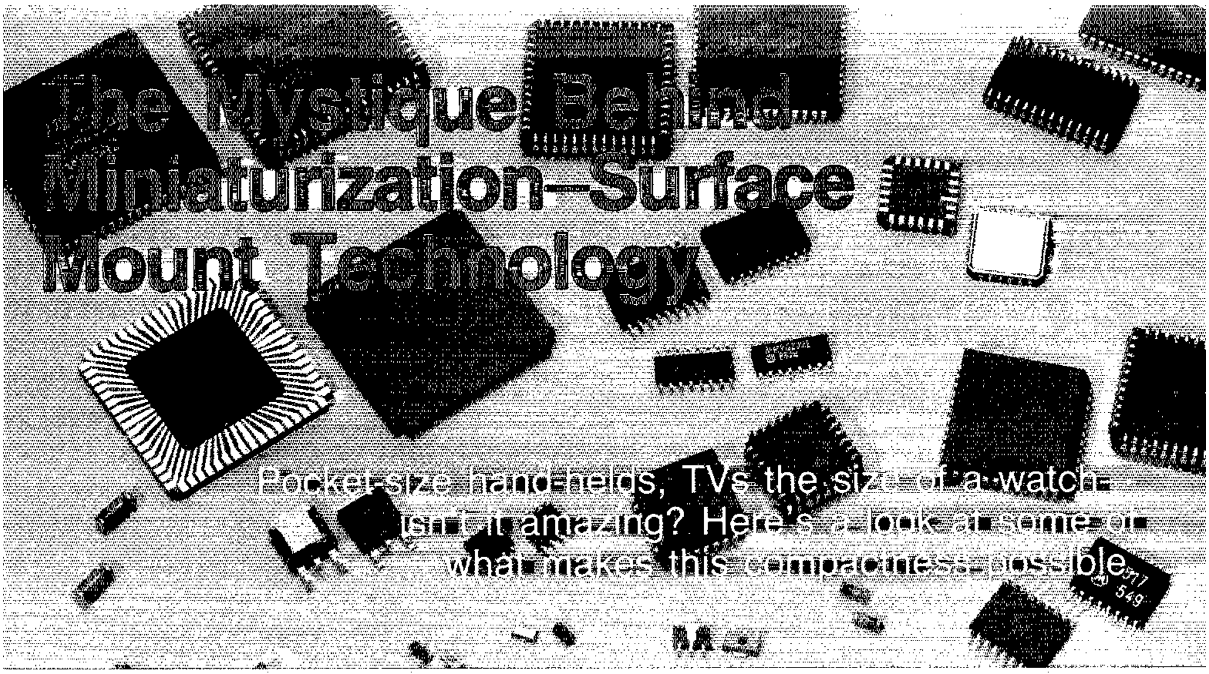

The Mystique Behind Miniaturization—Surface Mount Technology

Pocket-size hand-helds, TVs the size of a watch—isn't it amazing? Here's a look at some of what makes this compactness possible.

By David S. Hollander, N7RK
2313 E Ocotillo Rd
Phoenix, AZ 85016

The electronic packaging revolution is upon us. Electronic equipment is getting smaller and smaller, with miniaturization being the name of the game. We now have hand-held transceivers that fit into a shirt pocket. Station transceivers that would have occupied an entire desktop 20 years ago, now are essentially portable radios. How has this all come about?

One of the major contributors to miniaturization is the use of surface-mount technology (SMT). Several years ago, electronics manufacturers began to mount miniaturized components directly on the surface of PC boards—an automated technique that evolved from thick-film hybrids. (Here, "hybrid" means an assembly built on a substrate using chip capacitors, resistors and so forth.) Today, surface mounting can meet the electronics industries' insatiable demand for boards that are smaller, cheaper and more reliable.

Surface mounting is changing most aspects of the electronic industry. For example, the electronic component industry must now create whole new families of tiny active, passive and electromechanical devices to meet the demand for surface-mountable components. Some of these devices are shown in the title photo. New kinds of automatic assembly and soldering machines currently used in production lines place and attach components to boards at fantastic rates. This automated equipment is constantly being improved.

In this article, I'll introduce you to some surface-mount components available from Motorola, and acquaint you with the terminology and manufacturing processes of the surface-mount world. Then, you'll have a better understanding of just how all that electronics power at your disposal is contained in such a small package.

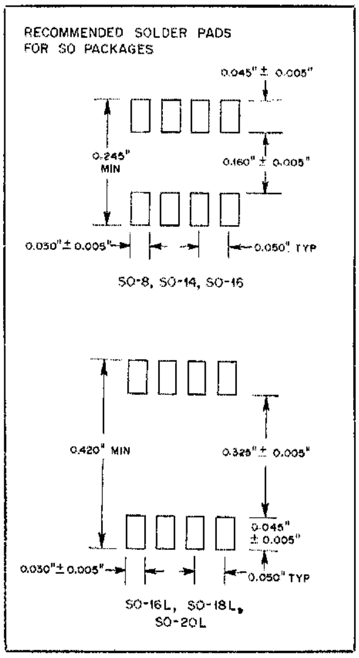

Fig 1—Typical surface-mount component footprints.

What is Surface Mounting?

Surface mounting involves soldering a component directly to a series of solder pads called a *footprint*, rather than inserting the component leads into holes on a PC board. The footprint is a series of pads that conform to the lead layout of the surface-mount device (SMD) or component (SMC); see Fig 1. Both old and new mounting techniques are shown in Fig 2.

Surface mounting has several advantages over the insertion method it is replacing. For example, the use of smaller components and the elimination of PC-board through holes can *triple* board density. The use of a smaller board with fewer layers cuts costs immediately. Additionally, circuit performance is improved. With the smaller boards, traces between components are shorter, lowering parasitic inductance and capacitance. Table 1 shows the benefits achieved by redesigning a board to use SMT. The table illustrates only the savings obtained by redesigning a *single* board. Approximately 65% of a unit's costs are related to component size. Some of the cost parameters related to component size include the number of PC boards, cabinet size, connectors and cabling, and cooling requirements.

Surface mounting allows components to be placed on *both* sides of a PC board—a major advantage. The use of chip capacitors, resistors and semiconductors can, in theory, give these boards densities equal to those of hybrids.

Table 1
Assembly Technique Comparison

	Through hole	*Surface Mount*	*% Reduction*
Board size (inches)	11 × 14	6.5 × 9.6	59
Number of layers	6	4	33
Board cost (dollars)	150	75	50

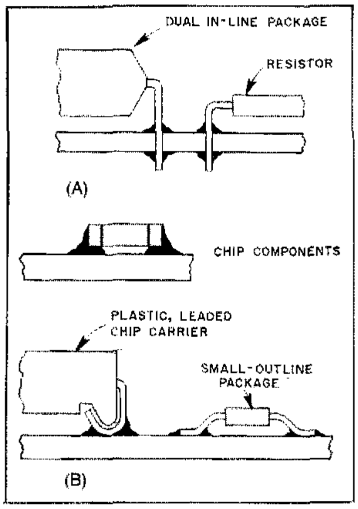

Fig 2—For years, the through-hole mounting of leaded components (A) has been common. Surface-mounting techniques (B) with leadless chip components and miniature IC packages are now being used in volume board assemblies.

The Surface Mount Assembly Process

Figs 3A and 3B show the top and bottom, respectively, of a surface-mount IC. Prior to mounting, the leads of the SMD are plated or tinned to provide a better solder joint. In addition to providing better solderability, the tinning adds a small amount of clearance between the package and the board, which permits automated cleaning of solder flux residue from the board.

Fig 3C shows the PC-board footprint to which the SMD is attached. Pretinned PC boards (provided by most PC-board manufacturers) aid SMD attachment. That's because the electrical and mechanical connections are made at the footprint pad by solder reflowing and joining the parts. Extra solder is required at this joint. Therefore, solder paste is "printed" onto the pads as shown in Fig 3D. This is normally done by a screen printer. The paste allows the required solder to form the joint fillets that are so important to electrical and mechanical connections. After the component is placed on the solder paste (Fig 3E), the operation is completed by means of a vapor phase reflow soldering process that melts the solder and bonds the SMD to the PC board as shown in Fig 3F. Then, the board is cleaned with a solvent and ready to be tested.

Component Packaging

All SMDs come packaged in one of the following forms: tape and reel, sleeves, bulk and in vials. With SMDs, it's no longer necessary to preform axial component leads. This eases the automated PC-board assembly process. Automated assembly lines for SMD boards occupy up to 50% less factory space than autoinsert lines do. Fig 4 shows how automation is used in assembly of a surface-mount board.

Surface-Mount Components

Components presently available in surface-mount packages include chip resistors, inductors, chip capacitors, ICs, switches, crystals, relays, transformers and connectors. New surface-mount components are being introduced every day.

Passive Components

A typical chip resistor and its construction are shown in Fig 5. The solder coating on the termination metallization provides a pretinned connection point suitable for reflow or other soldering techniques. The resistance element is a glass-passivated, thick-film element on a highly pure alumina substrate; the result is a reliable and precision component. Chip resistor values range from 10 Ω to 2.2 MΩ, with tolerances of 5 or 10%; power dissipation is 1/8 W.

Chip capacitors (Fig 6) are of monolithic construction and have a totally encapsulated electrode system and metallized terminations. The electrodes are deposited in the ceramic chip using an interleaved pattern, with two electrodes forming a single capacitive layer. The layers are stacked to increase capacitance. Chip capacitor values presently range from 1 pF up to 33 μF.

Discrete Low-Power Packages

There are several low-power packages in SMDs. These include the SOT-23, SOT-143, SOT-89 and SO-8; the SO prefix stands for "small outline." The SOT-23 (TO-236) shown in Fig 7A is 0.115 inch wide and 0.090 inch high. Such a package

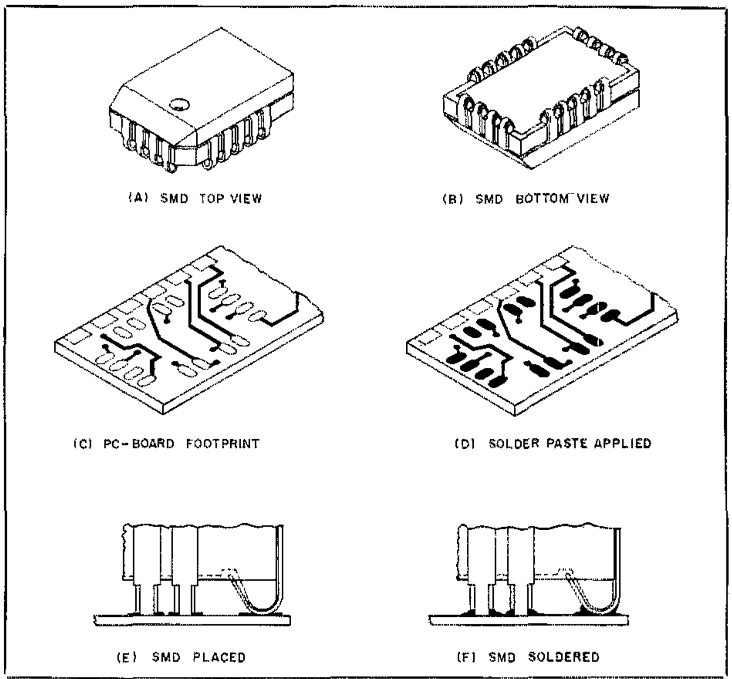

Fig 3—A pictorial description of the surface-mounting process. Close-ups of one corner of the SMD are shown at E and F. See text for more details.

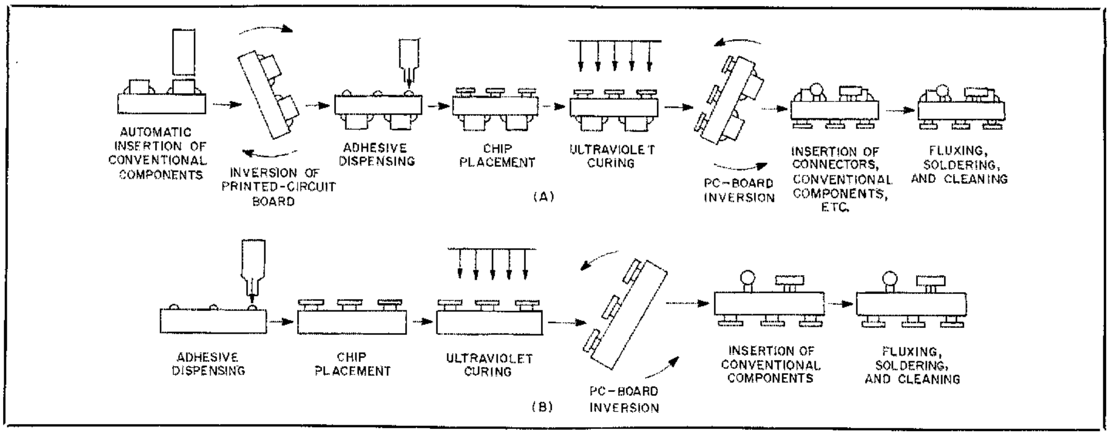

Fig 4—Surface-mount PC-board assemblies can be produced automatically (A) or semiautomatically (B). On semiautomatic assembly lines, the through hole leaded components are inserted manually.

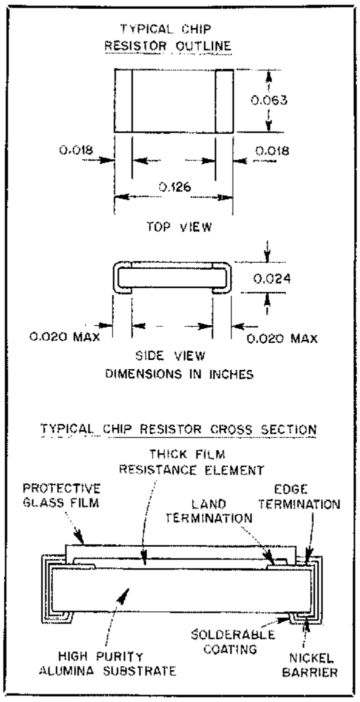

Fig 5—Typical surface-mount chip resistor construction.

can dissipate up to 200 mW in free air, or up to 350 mW when attached to a ceramic substrate. Products available in this package include small-signal transistors (bipolars and FETs), tuning, switching and Zener diodes, and SCRs. The SOT-143 is similar to the SOT-23 with the exception of having four leads. Bipolar RF transistors are available in this package.

For applications where high power dissipation is needed, there's the SOT-89 (Fig 7B). This package (only 0.178 inch across and 0.059 inch high) can dissipate 500 mW in free air and 1 W when mounted on an alumina substrate. Products in this package include bipolar, high-voltage, RF and Darlington transistors.

There are two packages available for use in RF applications: the SOT-143 and an SO-8 modified for RF use known as the SORF. The SORF package has a power dissipation of 1.5 W at 25 °C. Currently, 870-MHz bipolar transistors are being offered in this package. Where the need arises for transistor and diode arrays, Motorola offers low-voltage quad transistor arrays in the SO-16 package and diode arrays in the SO-14 package.

Leadless Diodes

A wide variety of rectifiers and Zener diodes are produced in the small cylindrical glass package referred to as MELF (metallized electrode face), MINI-MELF and MLL (Motorola leadless). Two packages are offered—the MLL34 and MLL41. A full range of ¼, ½ and 1-W Zener diodes are made using the same die as products presently offered as DO-35 and DO-41 Zener diodes. The rectifier category includes 0.5- and 1-A general-purpose and Schottky rectifiers.

Power Devices

Until recently, SMDs have been primarily available in the low-power category. For applications requiring high-power components, there are two options: the DPAK and TO-220 cases.

The DPAK is a power package developed specifically for surface-mount applications; it resembles a miniature TO-220 case. The DPAK has a power dissipation of 1¼ W at 25 °C in free air, and 1¾ W when mounted to a glass-epoxy PC board. DPAK product offerings will include bipolar power transistors, TMOS™ power MOSFETs, thyristors, rectifiers, Zener diodes and transient suppressors.

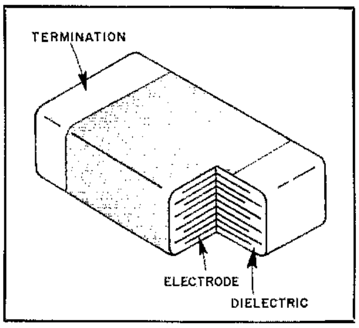

Fig 6—Chip capacitor construction.

For power devices requiring a higher power rating and larger die size than DPAK can accommodate, there's the industry-standard TO-220 package. The TO-220 has a power dissipation rating of 4 W when mounted on a glass-epoxy PC board. Any existing TO-220 product can be lead-formed for surface-mount applications. The current Motorola TO-220 family includes bipolar power transistors, TMOS power MOSFETs, thyristors, rectifiers, Zener diodes, transient suppressors and RF power transistors.

Integrated Circuit Packages

ICs are produced primarily in two packages: the SOIC (standard outline integrated circuit) and the PLCC (plastic leaded chip carriers). The packages have pin counts dependent on the device functions. PLCCs offer the flexibility of higher pin count functions in a smaller package than its

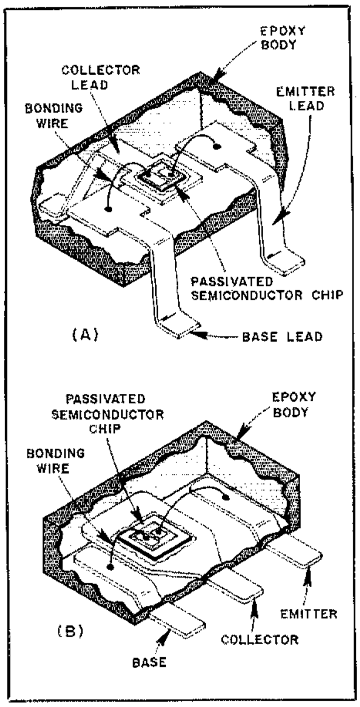

Fig 7—SOT-23 (A) and SOT-89 (B) package construction.

leaded equivalent. PLCCs take up approximately one-third the board space of their equivalent leaded device. A wide variety of digital-logic and linear ICs is produced as SMDs.

Gull-Wing and J Bends

SMDs are supplied with the two lead configurations shown in Fig 8. SOICs, SOTs and plastic flatpacks have gull-wing leads; PLCCs have the J bend. There are advantages and disadvantages to both lead types. Gull-wing leads can be probed easily by test leads and gull-winged packages are more easily handled by "pick and place" equipment. Packages with J-bend leads have smaller footprints and take up less real estate on the PC board. Their solder joints, however, are not inspected easily and test points must be provided to access the leads.

Surface-Mount Devices and You

Although surface-mount technology is benefiting Amateur Radio in commercially produced equipment, it's probably not well suited for use by the casual experimenter. Many of the components are designed to be placed on circuit boards by high-speed automated pick-and-place equipment and cannot be manipulated easily by hand. Additionally, most of the SMDs are presently not available in small quantities: One must purchase an entire reel of components, which could contain as many as 10,000 pieces! If you want to try hand

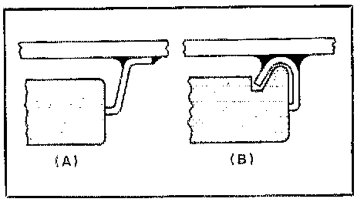

Fig 8—SMD lead variations. Gull-wing leads (A) are inspected easily; they can be accessed with test probes. The J-shaped counterparts (B) have a smaller PC-board footprint and are handled easily by automatic feeding machines.

assembly with SMDs, here are some ideas on how to go about it.

First, you'll need some sort of magnifying glass because most of the components are extremely small. The PC boards must be laid out with footprints to accommodate the devices to be used. Recommended footprints for SMDs can be found in most manufacturer's data books, data sheets or surface-mount guides.

The techniques for laying out and etching an SMD PC board are much the same as you've always used, except that no through holes are necessary for mounting SMDs. When determining component placement on the board, anchor the board so it is free from vibration. If you sneeze or bump the board before the components are glued in place, you'll not only have to start over, you may have a difficult time finding the missing components! Prior to component placement, all pads should be tinned. Glue the component into location. Although I've not done so, you might try using Super Glue™ as it can be dissolved with acetone or nail polish remover (take proper precautions when using these materials) if a component is placed incorrectly.

To handle the small components, you'll need tweezers, perhaps of different sizes. The tweezers should preferably be the type that are normally closed, as they will retain the component easier than standard tweezers. Once all the components are in place, proceed with the soldering. Use as little heat as possible on components with metallized ends (chip capacitors, diodes, and so on) as too much heat can cause the metallization to leach off, which renders the component unusable.

After soldering, clean the boards of remaining flux. Inspect the board with a magnifying glass. Look for solder bridges, cracks in traces, leads or components, cold solder joints, missed connections and so on. Remember: For SMDs, the solder joint provides the mechanical *and* electrical connection of the component lead to the board. Too little solder results in a weak joint that can cause problems later.

To remove a misplaced or defective component from the board, use solder wick and an adhesive remover. Dispense the adhesive remover using a small syringe to keep the liquid confined to the component being removed.

Summary

Surface-mount assemblies are becoming more common every day. These assemblies increase the potential of fully automated assembly lines and lead to size and cost reductions as well. How much smaller can your radio be? Only time will tell!

Dave Hollander's interest in radio dates back to 1961, when he built a crystal set. About the same time, his father, then unlicensed, gave Dave an old Hallicrafters S-41W receiver. SWLing kindled Dave's interest in Amateur Radio and DXing. Dave obtained his Novice license, WN6IWX, in 1963, and immediately began operating. The DX bug bit hard when a KM6 called Dave early one morning on the 80-m Novice band. In 1965, Dave acquired his General class license and the call WB6NRK, which he held until 1977 when he received N7RK. Dave's also held the calls ZM0AJN and VK2ERK.

Over the years, Dave's interests in Amateur Radio have included building equipment and antennas, CW operation, HF and VHF DXing, and HF mobile operation. Dave has 320 countries to his DXCC credit, but claims his biggest accomplishment in the DX realm is receiving WAZ No. 23 on 75-m phone—the sixth such certificate issued in the US, and the first one to be issued outside of California.

There are several hams in his family. Dave's wife, Jo Ann, is KA7LRG; his dad is N6UC (another DXer) and his brother-in-law is WA6SOJ.

Dave holds a BSET from Arizona State University and has worked at Motorola in the Discrete Semiconductor Group for over 13 years. That experience includes having worked five years in the RF Power Transistor group (100-MHz to 1-GHz power devices), three years in the Low Frequency Power Transistor group (he was involved in the start-up of TMOS Power MOSFETs) and the past three years in Discrete Product Marketing.

Dave's other interests include downhill skiing, camping, model railroading and antique cars—he owns a 1947 Plymouth coupe that he restored. Dave has published articles in QST *and several of the electronic trade journals, and he has published several application notes at Motorola.*

QEX: THE ARRL EXPERIMENTERS' EXCHANGE AND AMSAT SATELLITE JOURNAL

Fuji-OSCAR 12 is Japan's first Amateur Radio satellite. Its downlink signal is transmitted by phase-shift keyed (PSK) modulation, and JAMSAT designed a PSK modem to decode the satellite's packet signals. In turn, the Tucson Amateur Packet Radio Corp tested and evaluated the modem, making appropriate circuit changes for more efficient operation. TAPR "lets the cat out of the bag" this month by featuring the schematics of their modified PSK modem in the pages of *QEX*.

The September issue of *QEX* also includes articles on:

- "Thoughts on Emergency Use of Phase IIIC and Phase IV," by James Eagleson, WB6JNN
- "Circuit Designer's Interface for the IBM PC," by Larry Rockfield, W6UB

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Alternative Energy—An Overview of Options and Requirements

Part 2: Energy storage is necessary to smooth out natural variations in supply. And what about system safety once your alternative energy plant is up and running?†

By Michael Mideke, WB6EER
Box 123
San Simeon, CA 93452

Some alternative energy sources, such as wind and sunshine, are intermittent and variable in nature. Others may be constant, but of a level too low to meet intermittent peak demands. In all such cases, energy use is determined by the vagaries of nature unless some form of energy storage is employed. One way or another, a means of smoothing out the peaks and filling in the valleys of energy production must be provided.

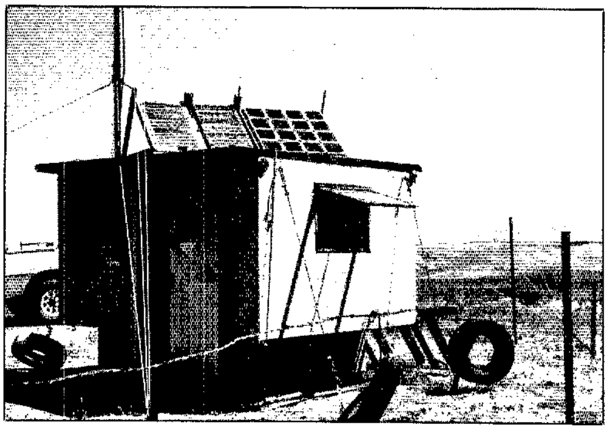
In hydroelectric systems, this storage may amount to no more than the confinement of water in a reservoir until its energy is needed. Then, opening a valve or sluice gate sets the water in motion, and the kinetic energy in the flow may be tapped by a turbine. Reservoirs work well with water, but are impractical—to say the least—when the energy source is wind or sunshine. A way must be found to store the energy from these sources after it has been converted to electricity.

Capacitive Storage

Electrical energy can be stored in capacitors. This is a useful approach when the available charging current is small in relation to a momentary high-current demand, as in photoflash systems, or if the powered system requires voltage at relatively little current, as is the case with short-term memory backup in computer circuitry. Advances in capacitor design allow us to store more and more energy in ever smaller packages, but we are still a long way from seeing capacitors that can compete with storage batteries when the application is one of sustained and regulated discharge.

Electrochemical Storage

Storage batteries provide a practical means for storing large amounts of electrical energy, though it is not really accurate to say that *electricity* is stored in such a battery in a manner akin to capacitive storage. Rather, electrochemically stored energy is invested in a chemical reaction that is reversed when the battery is discharged. The reversibility of this storage reaction is what makes the difference between primary and secondary cells: The electrochemical reaction in primary cells is not easily reversible, disallowing recharging; secondary cells may be discharged and recharged many times.



Here's solar-powered 2-meter repeater WB6RHR/R, Red Hills (near Shandon), California. Although this installation is not connected to commercial power in real time, it owes its hardware and maintenance to energy-intensive techniques—as do *all* alternative-energy systems. *(photos by WB6EER)*

A wide variety of storage batteries has been developed to meet many storage needs. Sizes and storage capacities range from tiny to enormous. Various battery chemistries are used, depending on the intended service. Which battery you use is determined by the application you have in mind. Size, weight, charge and discharge characteristics, expected lifetime in the proposed service—all of these are important considerations in choosing a storage battery. There is some advantage in using the largest batteries that size, weight, cost and acceptable float-charge load allow: Large batteries mean a large reserve capacity for emergencies or unanticipated use. For a given battery chemistry, life expectancy is generally greater for large batteries than for small ones.

Nickel-Cadmium Batteries

Highly portable low-power applications are commonly powered by nickel-cadmium (NiCd) batteries. These batteries produce a nominal 1.2 V per cell and should survive around 500 charge-discharge cycles. Some NiCd cells can safely sustain rapid recharging, providing an extra measure of flexibility in portable and emergency situations. NiCd cells are produced in the cell packages commonly associated with primary cells (AA, D, C and so on) and can be used interchangeably with primary cells to some extent. It's important to bear in mind, however, that the difference between zinc-carbon and NiCd cell voltages at full charge (0.3 V) makes for significant under-voltage when NiCd cells are series connected to take the place of an equal number of zinc-carbon cells. Perhaps one or two more NiCd cells can be added to such a battery to make up the difference. But the voltage

†Part 1 appeared in Sep 1987 *QST*, p 17-21.

match is rarely exact in such cases, and addition of more NiCd cells often means substituting too much battery voltage for too little. Since equipment may be damaged by excessive supply voltages, substituting NiCd cells for zinc-carbon units is trickier than it may seem at first—especially if you've added additional cell holders to a battery and someone unknowingly installs zinc-carbon cells!

Lead-Acid Batteries

When small battery-powered equipment is used in such a way that the battery is subject to frequent deep discharges, NiCd cells may be the preferred choice. Where deep discharges are only occasional and float-charge current is generally available, a gelled electrolyte lead-acid storage battery should prove more economical in the long run. The nominal cell voltage for lead-acid batteries is 2.0 V.

When it is necessary to power remote sites, especially if they are not vehicle-accessible, 12-V gel batteries rated at about 30 Ah are nearly ideal. Weighing 25 to 30 lbs, they can be transported nearly anywhere with relative ease. Because these are sealed batteries with rugged mechanical characteristics, there is little danger of damage regardless of the contortions that may be necessary to get them to their destination. When higher voltage or greater storage capacity is required, simply use more batteries in series or parallel and distribute the hauling job among carriers or over time. This is infinitely superior to struggling with one giant battery.

Higher power applications, such as operating HF transceivers or household lighting and appliances, require larger batteries. Where the powered site is accessible and power requirements are large, the 30 Ah gel battery is no longer a cost-effective building block. Then, the best compromise between economy and service life is the liquid-electrolyte lead-acid battery.

Automotive batteries are often pressed into this service, more because of their ready availability than suitability for the job. The automotive battery employs a lead-calcium plate chemistry that is satisfactory for brief periods of high-current discharge followed by immediate and complete recharging. Such batteries are not suited to deep-discharge applications where they will be repeatedly drained to a 50% discharged state. In fact, a dozen or so such cycles will reduce the battery's capacity to the point where it should probably not be counted on to start a car. By contrast, batteries designed for deep-cycle service should be good for a few hundred charge-discharge cycles.

This does not mean that automotive batteries are unsuitable for all alternative energy applications. Where the average load current is low and some energy is available to keep the battery float-charged to near capacity most of the time, its useful life may considerably exceed its rating for automotive service. Although the life of such a battery *will* be reduced by deep discharging, the battery will deliver something close to its rated capacity for the discharge rate in question. Prompt recharging will restore the battery almost to its initial capacity. The self-discharge rate for healthy automotive batteries is lower than that of equivalently rated deep-cycle batteries, so the float-charge current required to keep an idle battery fully charged will be lower for the automotive battery.

Where regular use of higher-power equipment (perhaps 30 W and up) or conversion of battery power to 117 V ac is contemplated, the most practical and economical battery "building block" appears to be the 6-V, 217-Ah units designed for golf carts and similar applications. These are deep-cycle batteries with a lead-antimony plate chemistry. They weigh approximately 70 lbs each and can be moved around fairly easily. For increased storage capacity, they can be connected in series and parallel. Such deep-cycle batteries should have a service life of nearly 10 years if reasonable care is taken in their application.

Large batteries no longer capable or trustworthy in their original service may still do useful work with smaller or less critical loads.

Battery manufacturers consider a battery's useful life to be over when its storage ability has dropped to 50%-80% of its capacity when new. This does not really hold true where the battery has more capacity than necessary for the job. If normal usage of a battery draws only 10% of its rated capacity, it doesn't make much difference whether the battery is 90% as good as new or only 50%. As long as the battery delivers its rated open circuit voltage (no shorted or dead cells) and maintains acceptable voltage under load through the required duty cycle, it is still usefully "alive" for that application. Of course, as a battery ages, its emergency reserve becomes questionable, and overall efficiency is reduced. Eventually, the battery *will* fail; all batteries have a finite life span. The point here is not that we should buy batteries that are much larger than we need, but that large batteries no longer capable or trustworthy in their original service may still do useful work with smaller or less critical loads. This is especially true of older batteries, which can be used to store surplus energy if it is available to trickle charge them.

More Battery Chemistries, Old and New

Earlier this century, much use was made of the nickel-iron chemistry of the Edison cell, particularly because of its lighter weight and tolerance of abuse as compared with the lead-acid batteries of the day. If you can find salvageable Edison batteries, it's quite possible that they can be made to work for you. See the sidebar, "Edison Batteries," for the story.

Looking to where the present blends into the future, research continues in the quest for increased battery life and capacity. Recently, rechargeable lithium cells have made the scene.[2] The dependability of alternative energy systems rests heavily on energy storage, so each improvement in battery and energy management technology is good news for alternative energy planners—especially as the reliability of new technology goes up and costs come down.

Safety in Alternative Energy Systems

As consumers of commercially produced power, we are protected to a considerable degree from electric shock, explosion, mutilation, poisoning and a host of other potential consequences of living in close proximity to the systems and energies that power our civilization. When we take things into our own hands and build energy systems from the ground up, we must consciously build safety in. It is necessary to evaluate hazards and take measures to minimize them.

Next, we'll survey the basic classes of hazards you may encounter in working with the sort of alternative energy techniques outlined so far. This material should not be a substitute for all warnings and instructions that may come with machinery and substances employed in alternative energy work. Nor should it be a substitute for doing personal safety *research,* in the library and face-to-face with experienced people.

The hazards inherent in the production and storage of electrical energy may be divided into three closely related categories: mechanical, chemical and electrical. Some of these hazards are no different from those encountered by any electricity user. Others are more characteristic of complete power systems. As different as they may seem from each other, mechanical, chemical and electrical hazards *are* closely related: A failure or accident in one category is likely to bring about failures in one or both of the others. Such multiple failures can be nearly instantaneous and the consequences can be catastrophic.

[2]Noulan Bowker and Christopher Dollard, "The Magic of MOLI," Jun 1987 *QST*, pp 22-25.

Edison Batteries

First marketed in the early 1900s, the nickel-iron alkaline Edison cell has accumulated a reputation for capacity and indestructibility that is only partially justified. It is *not* the perfect storage cell, but it does have some interesting qualities. Batteries of Edison cells were designed to survive rough mechanical abuse in railroad lighting and vehicle propulsion service. Largely because of the strong, lightweight construction of its steel case and its rugged internal structure, the Edison battery achieved this objective with a better power-to-weight ratio than could be attained readily by the lead-acid batteries of the time.

The construction and chemistry of the nickel-iron cell is such that it can survive abuse that would be fatal to a lead-acid cell. As long as it is not drastically overheated, the Edison cell can be overcharged to the point of vaporizing all of the electrolyte and no great harm will result. Nor will the cell be harmed by being left in a totally discharged condition. I know of used Edison cells that recovered a good percentage of their original capacity upon being filled with distilled water and run through a few charge-discharge cycles—after having been dry and totally neglected for *over 40 years*.

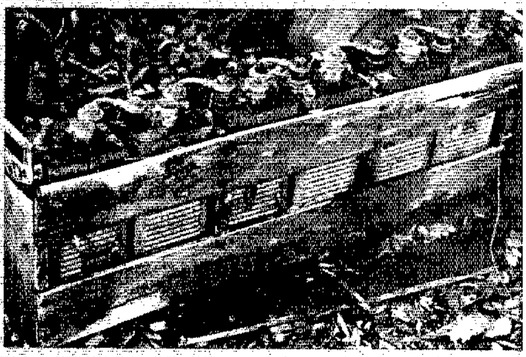
Now for the bad news. As compared to lead-acid cells, the Edison cell has a high internal resistance and a high self-discharge rate. Thus, voltage regulation during load variation is poor, and the cell shows a continuous loss of voltage throughout its discharge cycle—from nearly 1.4 V at full charge to 1.0 V at the bottom of the cycle. Hydrogen and oxygen are vented continually, though to varying degrees.

Edison cells employ a potassium hydroxide electrolyte. This is a strong base and must be handled with caution. Acids and acid-contaminated tools should *never* be used in or around Edison batteries—something to keep in mind if your battery "stable" is to include both lead-acid and Edison cells.

A hydrometer is not of much use in determining the state of an Edison cell because the specific gravity of the electrolyte changes little between the charged and discharged states. Cell voltage, charging time and charging current are the best indicators of charge for Edison batteries.

Terminal voltage in the discharged condition for a single Edison cell is considered to be 1 V. New Edison batteries had an expected lifetime of 2000 charge-discharge cycles. Most of these batteries were probably used by railroads for passenger car lighting and trackside signaling, although many saw service in domestic wind power installations. Despite their age, however, Edison batteries may still be found. Many of their cells will undoubtedly be in salvageable condition (see photo).

If you come across an odd-looking battery like that shown in the photo, don't assume that it is dead and gone. If the steel case of a given cell is intact and the poles are not internally shorted or shorted to the case, it is quite possible that the cell can be revived. Cases of adjacent cells in an Edison battery must be insulated from each other or electrolytic action will eat through them in short order. (In an Edison cell, the steel case is isolated from both poles but common to the electrolyte.) A socket wrench and a good gear puller are essential for disassembly of Edison batteries. Details on the care and feeding of Edison batteries can be found in older electrical engineering handbooks.*



A battery of six Edison cells as collected on a salvage expedition. Most of the cells are good, but the original wooden rack is in bad shape. These are A-8 cells, originally rated at around 220 Ah each.

*Greatly detailed information on Edison and other secondary cells may be found in George Wood Vinal, *Storage Batteries*, 2nd ed (New York: John Wiley and Sons, 1930).

The sidebar, "Harmless," offers an example of the kind of nasty multiple failure that can happen around an alternative energy installation. Although the chain of events depicted there may seem farfetched, it isn't. When you achieve long periods of accident-free alternative energy production, you *won't* have wasted your time anticipating and guarding against the worst!

Mechanical Hazards

Moving parts, especially gears, vee belts, pulleys, wind turbine propellers and the like, should all be made inaccessible to accidental contact. This is usually accomplished with covers and enclosures. When such moving parts must be exposed, they should be located out of reach. A wind turbine should not be able to touch anyone on the ground or working on its tower.

Towers should be designed and supported to withstand worst-case weather conditions for the area. They should receive regular inspections and maintenance as needed. When in doubt, consult a structural engineer. Towers are attractive nuisances, so they should not be climbable by children or passersby.

Persons developing any energy resource must take a certain responsibility for their safety and that of their neighbors.

Chemical Hazards

All motor fuels and their vapors are flammable and potentially explosive. They must be handled in suitable containers, lines and fittings. Most fuel vapors have distinctive odors, so use your nose! Don't ignore what your sense of smell tells you. Track down and repair leaks. Never store fuels near operating engines or sources of open flame and sparks.

Internal combustion engines produce carbon monoxide gas as an exhaust product. This is a colorless, odorless and lethal substance. Do not breathe exhaust fumes; also, do not risk operating engines in enclosed spaces unless exhaust fumes are properly vented through a gas-tight system. Even with a good exhaust system, it's good

Harmless

An industrious mouse enters the battery compartment of an alternative energy system. Shuffle, sniff. No loose scraps worth taking—just a foot-long piece of bare no. 10 wire carelessly abandoned in the framing of the compartment two years ago. Exiting the compartment, the rodent shoulders the scrap aside, causing it to fall across the terminals of a 12-V storage battery. There is an immediate electrical failure as the wire welds to the battery terminals, shorting the system. The wire reaches red heat in a matter of seconds. As it glows brighter and begins to melt, the wire slumps onto the plastic battery case. The case melts like butter under a hot knife.

At this point, the electrical failure is over: The wire melts through the battery case with a sizzling arc that causes the hydrogen and oxygen within the battery to unite with explosive force. The explosion rips the already damaged battery open, spewing sulfuric acid, acid vapors and hot metal all over the battery compartment.

With luck, the problem ends here, with no fire climbing the walls and no injuries—just a terrible mess to clean up. But don't count on it. A chance encounter with a harmless scrap of wire and a mouse has already blown up your battery. Why should chance stop there?

Such a series of events may seem highly improbable. But trusting to probability implies taking chances—in other words, playing odds. And that's exactly what *not* to do when building safety into an alternative energy system. Dangerous system failures are possible unless care is taken to make them *im*possible. You must build safety in.

insurance to keep a carbon monoxide alarm in the engine room.

Engine exhaust systems can emit burning gases and hot carbon particles, both of which can ignite dry materials in the vicinity of the exhaust outlet. When internal-combustion-engine driven generators are to be used outdoors under dry conditions, use spark arresting mufflers or spark arresters approved by the US Forest Service. Clear a ten-foot radius to bare dirt around the generator and *keep* it clear. Have a shovel and fire extinguisher nearby and in plain sight.

Whether they're acidic or alkaline, battery electrolytes are nasty substances. They can corrode metal, creating both mechanical and electrical problems. They can destroy clothing in short order, and their activity does not stop when they get to the flesh underneath. Soft tissues, such as eyes, are particularly prone to rapid damage from exposure to battery electrolytes, so wear eye protection when working around batteries. Keep some means of flushing away accidental exposures at hand; a garden hose will do. Don't wear your best clothing when working with batteries—some exposure to electrolyte is almost inevitable. The evidence may not appear until that special shirt comes out of the washer looking like cheesecloth!

Avoid panic by having emergency procedures well in mind. Your flesh won't dissolve right off your bones if you *do* get electrolyte on it, so don't go into shock. Just start flushing the affected area immediately. If garments are saturated, get out of them.

Storage batteries (except for completely sealed recombining types) emit hydrogen and oxygen gases, particularly under heavy charging and overcharging. This is a highly flammable, explosive mixture. Although hydrogen is much lighter than air and tends to dissipate rapidly, it cannot do this in confined spaces—such as the space between the electrolyte surface and the filler cap of a battery. Dangerous concentrations of hydrogen can accumulate here. Thus, checking the electrolyte level by match light or "testing" a battery by drawing sparks across its terminals are dangerous techniques and should *never* be used.

Dangerous system failures are possible unless care is taken to make them impossible. You must build safety in.

Storage batteries also tend to vent corrosive vapors that can damage delicate electronic equipment. If vented batteries are used indoors, the vents should be extended to the outdoors with plastic tubing. The best practice is to provide storage batteries with their own well-ventilated compartment or room.

Electrical Hazards

Electric shock is to be avoided at all costs. Shock danger from 12-V dc systems is minimal, but as system voltage approaches 32 V, it's possible to get "bitten" and even be electrocuted if conditions are just right (or wrong!). Both storage batteries and solar panels connected in series can add up to shock potential in short order. Remember that the output voltage from solar panels is much higher with no load than it is when a load is connected. Where sinusoidal ac energy is concerned, thinking in terms of RMS voltage can be deceptive, because ac peak voltage works to overcome your skin resistance—and *peak* voltage in a sine wave exceeds RMS by a factor of 1.414.

Current Kills—But It Also Burns

Even small storage batteries can deliver high currents sufficient to bring small conductors to red heat, creating potential for fire and burns. Larger batteries, such as those found in automobiles and alternative energy storage systems, can deliver hundreds of amperes. Such currents can heat and melt large conductors. Rings, bracelets and wristwatches should never be worn by people working with electrical systems for this reason. Electrocution may be the first danger that comes to mind when considering the wearing of metal jewelry, and it should never be ruled out, of course. But stories of fingers amputated and cauterized by a white hot ring welded across a high current source are not fables—it can happen to *you*.

Protect battery terminals from short-circuits. Exercise extreme caution if you must work around batteries with metal tools. Always keep one terminal covered to avoid the possibility of a short circuit.

Modern battery cases melt readily even at soldering temperatures (360-460° Fahrenheit for common solders). These cases also deteriorate rapidly in sunlight,

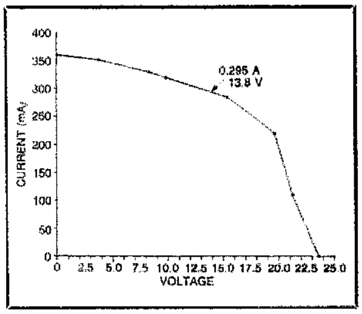


Fig 2—Voltage across the terminals of a "12-V" solar panel varies considerably with load, and this must be allowed for in the design of a solar energy system. (The graph shows voltage versus current for the 5-W Sovonics panel described in the article called out at Note 1 in Part 1 of this article.)

leading to embrittlement and cracking. Keep them out of the sun and handle them with care.

Fusing and Load Switching

Fuses are essential insurance for electrical safety. Fuses or circuit breakers rated to handle full load current should be placed as closely as possible to the battery. Great care must be taken with insulation and dress of the wiring from battery terminals to fuses. Since high currents at low voltages are involved, low-resistance connections to fuses and breakers must be provided. Further fusing of subsystems as appropriate to their individual current demands can be installed at a convenient location farther from the battery.

In switching and fusing a photovoltaic system, bear in mind that "12-V" solar panels may produce more than 20 V across an open circuit or high-resistance load (see Fig 2). This could have disastrous consequences for equipment should the line from the PV array to the battery open with equipment still connected to the PV array. If at all possible, meters should be used to monitor charging current, load current and battery voltage in an alternative energy system. Then, proper operation of the system can be confirmed at a glance.

Conclusion

If you find yourself inspired to become involved with alternative energy projects, you'll discover a wealth of literature devoted both to specific and general topics in the field. The few references I've listed in the bibliography will help get you started. It's also quite likely that you can share ideas and questions with someone in your own area who is working commercially or privately with some aspect of alternative energy. Such people may well be the most valuable untapped resource you'll find as you work to develop an operational energy system.

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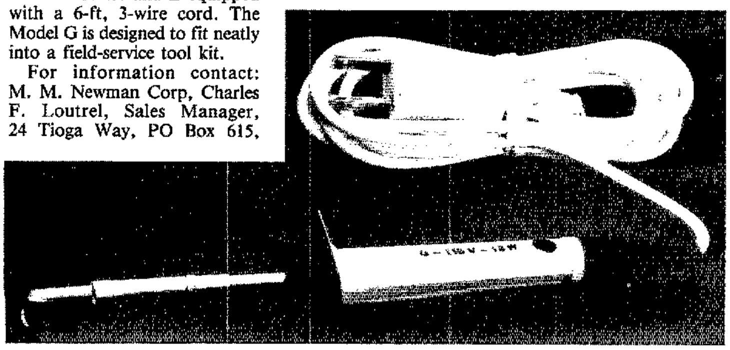
New Products

ANTEX MINIATURE SOLDERING IRON

☐ An industrial-grade miniature soldering iron that heats and cools rapidly is available from Antex. The Model G soldering iron reaches operating temperature in just 45 seconds and cools enough to be put away in less than two minutes. The soldering-iron handle always stays cool because the heating element is in the tip. Designed for continuous or intermittent operation, over 40 different slide-on tips are available, including a 0.012-inch tapered needle point.

The iron is only 6½ inches long, weighs a mere ¾ ounce and is equipped with a 6-ft, 3-wire cord. The Model G is designed to fit neatly into a field-service tool kit.

For information contact: M. M. Newman Corp, Charles F. Loutrel, Sales Manager, 24 Tioga Way, PO Box 615, Marblehead, MA 01945, tel 617-631-7100. Retail price: $15.95.

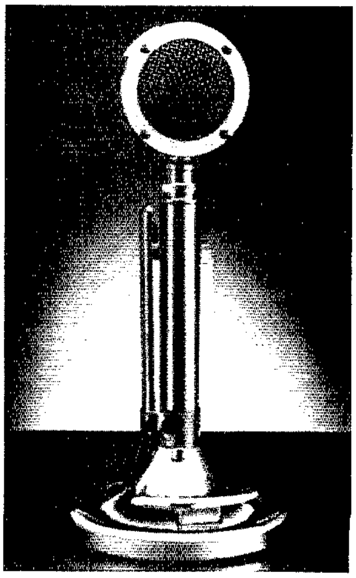


ASTATIC SILVER EAGLE PLUS MICROPHONE

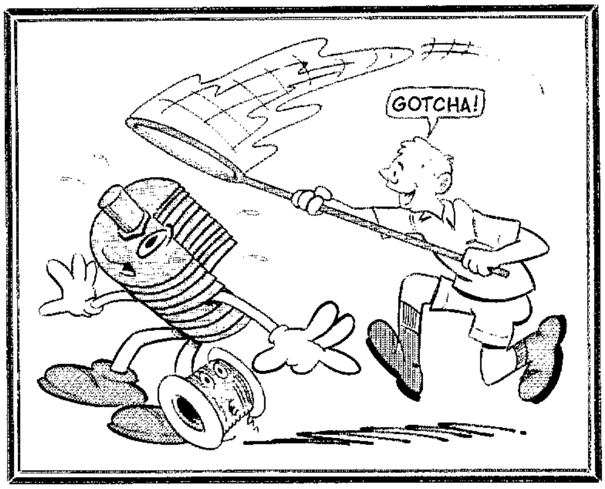
☐ Astatic Corp, manufacturer of the D104 microphone, has introduced a new version of the Silver Eagle. The ETS9-D104SE is the Silver Eagle plus a new mic amplifier, switching system and built-in end-of-transmission signal (ETS). The ETS is a switch-selectable, 1-kHz tone produced when the mic is unkeyed to indicate completion of the transmission. The tone is audible to the mic user as well as the person receiving the transmission.

Additional features include a new VOX switch, a redesigned amplifier circuit and a 20-dB pad on the audio output. The Silver Eagle can be powered by a 9-V battery or directly from the radio.

The Silver Eagle Plus is manufactured by Astatic Corp, Harbor and Jackson Sts, Conneaut, OH 44030-0120, tel 800-421-3161. Price class: $136.



Stalking Those Fugitive Components



Specialty components appear hard to find for those who aren't experienced gleaners. Let's learn where and how to obtain some of these bread-and-butter items.

By Doug DeMaw, W1FB
ARRL Contributing Editor
PO Box 250, Luther, MI 49656

What's this you're saying? You would build more ham gear if only you could obtain the necessary components? I receive dozens of letters to this effect each year. Most of them seem to be from the newer hams who have yet to learn the fine art of foraging for those seemingly elusive parts. Some correspondents are critical because my *QST* articles are not based on using parts that can be purchased at Radio Shack stores. Sure, Radio Shack stocks a lot of things that are useful for building projects, but many of the circuits we amateurs want to build require components that Radio Shack will never carry. A designer is severely restricted if he has to rely on any single supply source. At best, his output will soon be reduced to rinky-dink projects.

What, then, might you do to solve the annoying parts-procurement problem? This subject has been addressed frequently in *QST*, but only in general terms. That is, the authors did not focus on specialty items that many of us need from day to day. This article is aimed at those unique parts that we do not find at the corner parts store. All you need is some ambition and a few postage stamps to equip yourself with the means to get the parts highlighted here.

Some of the suppliers I list in this article have many parts to offer in addition to those discussed here, and numerous other suppliers exist. I concentrate in this article on those dealers from whom I purchase most of my parts and materials. I consider their prices fair and generally below the figures set by new parts distributors that aren't in the surplus business. I have experienced neither poor service nor rip-offs from any of the dealers listed, but neither the ARRL nor I endorse them. As the saying goes, "let the buyer beware."

Locating Component Sources

I watch for some of the smaller display ads in *QST* and other amateur publications, and keep tabs on the classified ads in the various magazines. That is where you'll often see information that can lead to a free catalog of bargain parts. I respond to every ad of that type. Consequently, I have stacks of catalogs. It is a practice I recommend to all of you who enjoy building amateur equipment. There is scarcely a component I can't find for my projects, if I scan the pages of these mail-order catalogs.

Writers (myself included) often recommend ham-radio flea markets as a source of parts for home use. Flea markets are, indeed, wonderful places to look for certain items. But, owing to the infrequency of flea-market events in any given region, procuring parts by that means is a long-range situation at best. I depend on flea markets mainly to stock up on items for future, unplanned projects. For example, if I see a super bargain on 2N2222s, polystyrene capacitors or 2200-μF filter capacitors, I buy them for later use. This practice also enables me to help other hams in the area, should they have a sudden need for something I have in my goodie cache.

Parts and materials never appear magically! We may daydream until doomsday, but that won't yield results. We must also innovate as the demand dictates.

Equipment Cases

Consider the low cost and simplicity, for example, of fashioning a small project case from galvanized furnace-ducting material. Most plumbing and heating shops will give you scraps or pieces from stock, or they may charge you a few cents per pound for the material. A large pair of tin shears can be used to cut the sections of metal to shape, and bending can be done by hand over any right-angle form. The cabinet walls and top can be soldered together, or fastened with no. 6 sheet-metal screws. The completed cabinet can be spray painted with sandable gray primer, sanded and then coated with your favorite color of paint for the finishing touch.

Large cabinets, such as those used for antenna-matching networks, can be fashioned from tempered Masonite®. This material can be painted any color you prefer. The front panel can be made from an aluminum cookie sheet, available at most variety stores. There is no need to contain a Transmatch in a shielded cabinet, since it does not generate TVI. The signal going into the Transmatch should already be clean!

I have mentioned many times the ease and low cost of making small boxes from sections of single- or double-sided PC board. The cost of any of these homemade enclosures is substantially less than that of a commercially made box, and the materials are available locally. These methods permit almost instant construction of an equipment case.

Magnet Wire

Many hams ask me where they can find magnet wire. I must say that the market has, for the most part, dried up with respect to magnet wire. Radio Shack sells small spools of enameled wire, but only in a few popular gauges. Jug Wire Co in New York was my primary source for magnet and bare bus wire, but a recent notice from Jug indicated that they were going out of business.

What can you do to solve this problem? First, check with your local electric-motor repair shops. The operators are often willing to reel off a reasonable number of feet of the wire you need, and at a nominal cost. Here, again, use your initiative.

When I first became a ham, it was common practice for my colleagues and me to acquire old power transformers just for the purpose of removing the magnet wire from the windings. The same was true for old dynamic speakers from junked radios. The speaker field coils contain hundreds of feet of small enameled copper wire! Still another source of magnet wire is the field coils of large, low-resistance dc relays—12- and 28-V units in particular. Generally, the larger the relay and the lower the field-coil resistance, the larger the wire gauge. Look for these relays at flea markets. They can be available for 25 cents or less.

Another excellent source of magnet wire is picture-tube yokes from discarded TV receivers. The vertical- and horizontal-deflection coils contain many feet of usable sizes of wire.

Litz Wire

Litz (short for *litzendraht,* which means "stranded wire") wire is desirable for winding small LF, MF and HF slug-tuned coils. It provides a higher Q than plain enameled wire. This is because many strands of enameled wire are used to form a cotton- or silk-covered conductor. The additional surface area afforded by multiple conductors offsets *skin effect*—the tendency for ac to flow at or near the surface of a conductor, resulting in greater ac resistance with rising frequency. I have never seen Litz wire offered in surplus equipment catalogs. I obtain my Litz wire by purchasing old RF chokes and slug-tuned coils that are wound with it. Many WW II power RF chokes contain Litz wire, and you may want to consider this method of garnering some.

Coil Forms and Insulating Material

Blank slug-tuned coil forms are currently too expensive to consider for most amateur projects. There are some surplus bargains, however, and you should watch for them. Stock up on these forms should you see them at flea markets, but be aware of the effects of improper core material on operating frequency. Low-frequency cores will spoil the Q of an HF or VHF slug-tuned coil. The same is true of improper toroid-core material. A relative test of coil Q may be made by winding a coil on an unknown form, then placing a silver-mica or variable capacitor in parallel with the coil to obtain resonance at a desired frequency. Check the tuned circuit with a dip meter. If a good dip can be had with the dipper coil a fair distance from the test coil (say, one inch), the Q is reasonably high. If, however, the dipper must be coupled tightly to the test coil to obtain a dip (usually shallow at best), the Q is probably too low to consider for your circuit. In other words, the farther the dipper coil is from the test coil, consistent with a deep dip reading, the higher the Q of the coil.

Homemade fixed-inductance coils can be wound on plastic tubing and rods at a low cost. Included are power-line RF chokes, antenna traps and antenna-loading coils. First, check the scrap department of your local plastics outlet for odd-lot bargains. Such materials as Teflon®, Delrin, polystyrene, Plexiglas™, PVC, Tenite® and Lexan® are often available in small pieces at attractive prices. You may also obtain a catalog from United States Plastic Corp in Lima, Ohio, a mail-order house that has tubing, rod and sheeting of all types (see listing at the end of this article).

Feed-line spreaders can be made inexpensively from such materials as hair curlers, plastic clothespins, sections of plastic coat hangers and even ballpoint pen bodies. Again, I stress the value of being innovative!

Special Capacitors

I've read many laments about how "impossible" it is for some *QST* readers to locate high-voltage disc-ceramic capacitors, polystyrene capacitors, NP0 capacitors and even silver-mica capacitors. These items are *widely* available from the surplus-parts vendors. I must admit, however, that large transmitting variable capacitors *are* scarce (and extremely expensive). Radiokit seems to be the main outlet for large variable capacitors. When the Cardwell Corp bought the tooling and stock of E. F. Johnson and Hammarlund several years ago, it seemed that a variable capacitor monopoly was taking shape. The James Millen Co was the only other major manufacturer of these parts and, to complicate matters more, Millen went out of business, too. It was a sad day for Amateur Radio! You may still be able to obtain Millen capacitors from Radiokit. Our best hope is to remove large variable capacitors from surplus radio gear, such as WW II command transmitters and BC-191/BC-375E transmitter tuning units. Fair Radio Sales in Lima, Ohio is worth checking for these units and other large WW II electronics equipment. Their catalog will fill many of you older hams with nostalgia!

The Joys of Stripping

Lest someone misunderstand, I refer to radio parts! When Lew McCoy, W1ICP, was the Beginner and Novice editor for *QST,* years ago, he constantly stressed the value of stripping parts from old TV and radio sets for use in ham projects. I'm sure that many of you recall his "transmitters from old TV sets." We at ARRL HQ often wondered why he never made a TV set from *an old transmitter,* but he refused the challenge when it was offered to him! Nonetheless, his advice in those days was sage. Even today we can glean countless excellent small parts from old TV and transistor-radio sets. I saw six table-model TV sets for sale last fall at the Hudsonville, Michigan, ham flea market. The owner was asking 25 cents apiece for the sets! Many PC-mount fixed and slug-tuned coils are found in TV receivers, in addition to a host of resistors and capacitors. Also, you can

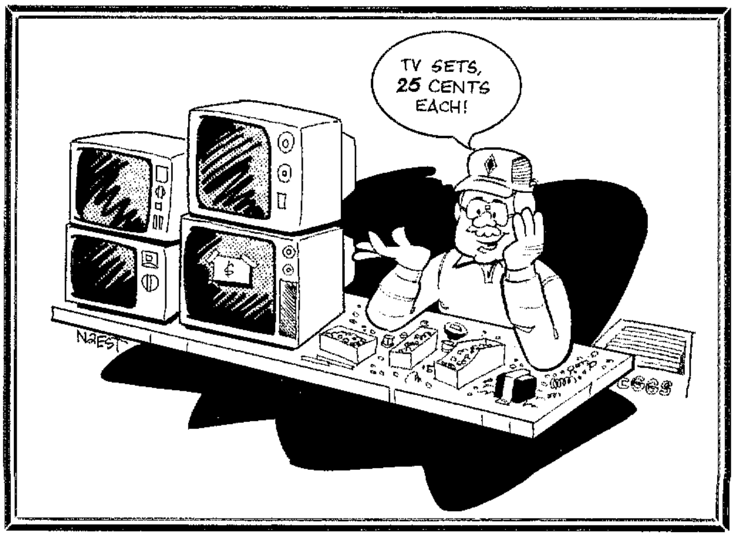


Table 1
Sources for Hard-to-find Components

Item	*Source**
Capacitors	
Feedthroughs	MPJ
High-voltage disc	ME, MPJ
Monolithic chip	AE, CS, MPJ
NPO ceramic	CS, ME
Polystyrene	AE, ME
Silver mica	AE, CS, ME, MPJ
Small air variables	BCD, FRS, MPJ, RK
Tantalum capacitors	AE, ME, MPJ, DK
Transmitting variables	FRS, RK
Trimmers	BCD, CS, FRS, ME
Chokes and Coils	
Coil forms	BE, USP
Loopsticks	CS
RF chokes (miniature)	BCD, CS, ME, DK
Slug-tuned inductors	BCD, DK
Crystals	
Specific-frequency	ICM, JAN
Microprocessor	BCD, CS, MPJ, DK
Muffin fans	AE, ME, MPJ, DK
Hardware	
Dial cord	ORA
IC headers	CS, ME, MPJ, DK
Machine screws and nuts	BCD, BE, ME, DK
Metric hardware	ORA
Metal standoff spacers	BE, ME, MPJ, DK
Telescoping antenna rods	ORA
Heat-shrink tubing	CS, MPJ, ORA, DK
Heat sinks	AE, BCD, ME, MPJ, DK
Keyboards and key pads	AD, BCD, BE, ME, MPJ, DK
PC-board materials	
Donut pads, layout tape	CS, ME
Perf board, push-in terms	BE, CS, DK
Tin-plating solution	CS
Plastic tubing, rods and sheeting	
Acrylic, Delrin, Lexan, Nylon, polyethylene, polyurethane, PVC, Teflon and Tenite. Also, plastic cements and tooling.	USP
Small relays	AE, BCD, ME, MPJ, DK
RF and audio transformers	
Audio (miniature)	CS, ME
IF (455 kHz and 10.7 MHz)	BCD, CS, ME, DK
RF transformer blanks (slug-tuned)	AA
Switches	
Microswitches	AE
Multi-deck push button	AE
Small rotary wafer	AE, BCD, ME
Toroids and other cores	
Balun (binocular) cores	AA
Ferrite beads	AA, BCD
Powdered-iron toroids	AA, PE, RK
Ferrite pot cores	AA, BCD
Ferrite RF-choke forms with leads	AA, BCD
Ferrite rods	AA
Ferrite toroids	AA, BCD
Transistors	
Small-signal bipolar	BCD, ME, DK
Japanese (large listing)	ORA
JFETs	CS, DK
RF power	BCD, CS
Unijunction	CS

***Sources**

AA	Amidon Associates, Inc, 12033 Otsego, N Hollywood, CA 91607.
AE	All Electronics Corp, PO Box 20406, Los Angeles, CA 90006.
BCD	BCD Electro, PO Box 830119, Richardson, TX 75083-0119.
BE	Bigelow Electronics, PO Box 125, Bluffton, OH 45817.
CS	Circuit Specialists Co, PO Box 3047, Scottsdale, AZ 85257.
DK	Digi-Key Corp, PO Box 677, Thief River Falls, MN 56701
ICM	International Crystal Mfg Co, 10 N Lee St, Oklahoma City, OK 73102.
JAN	JAN Crystals, 2400 Crystal Dr, PO Box 06017, Fort Myers, FL 33906-6017.
ME	Mouser Electronics, 11433 Woodside Ave, Santee, CA 92071.
MPJ	Marlin P. Jones & Assoc, PO Box 12685, Lake Park, FL 33403-0685.
ORA	ORA Electronics, 20120 Plummer St, PO Box 4029, Chatsworth, CA 91313.
PE	Palomar Engineers, Box 455, Escondido, CA 92025.
RK	Radiokit, PO Box 973, Pelham, NH 03076.
USP	United States Plastic Corp, 1390 Neubrecht Rd, Lima, OH 45801.

salvage many potentiometers and switches, as well as a variety of hardware to add to your stock of nuts and bolts.

Pocket-size transistor radios are loaded with small resistors and capacitors. How many of these little radios have you thrown away when they became defective? Consider the parts you could have salvaged for later use. Discarded AM and FM receivers also contain small variable capacitors that can be used for homemade receivers and QRP transmitters. The IF transformers can be used as is, or can be rewound for other frequencies. Not only can you increase the bulk of your parts larder by stripping TV sets and transistor radios, you will have a nice pastime for those rainy or snowy evenings in winter. Solder wick or solder suckers are invaluable for this job.

Source Listing

Table 1 lists a number of hard-to-find components keyed to the suppliers that stock them. The dealer identification is given at the bottom of the table. I have identified specific components that are offered by these suppliers, but they carry many additional items. Their catalogs are worth adding to your reference library. Remember that quantities and specific values may be limited, depending on the supplier.

Some Final Comments

Although this month we haven't covered theory, applications or a practical project, I feel that parts procurement is an important part of construction. I have addressed those parts that readers seem to have the greatest difficulty locating. Perhaps this article will reduce the number of inquiries I receive!

Unfortunately for us amateurs, some of the suppliers listed specify a minimum order. In such instances, it is sometimes convenient to pool your order with those of other hams in your area. This may require some salesmanship on your part, but it can be done. Good luck in stalking those fugitive components!

Strays

I would like to get in touch with...

☐ anyone with a schematic for a Vista XXR power supply. T. W. Jentges, W6ALO, 706 East Adams Ave, Orange, CA 92667; Vernard Rush, W9LDS, 5234 SR 45 S, Lafayette, IN 47905.

☐ anyone with operating instructions for an Electronic Measurements Corp Model 801 resistance capacitance bridge. Raynald Gilbert, 2604 Mont-Joli St, Sainte-Foy, PQ G1V 1C3.

Amateur Radio and the Blind

Part 1: What difficulties does a blind person encounter with Amateur Radio? What advantages and opportunities does Amateur Radio offer the blind? In this series, we'll discuss subjects you may have thought of only occasionally, but you're certain to find interesting and informative.

By Butch Bussen, WAØVJR
Box 142,
Wallace, KS 67761

I've been an active Amateur Radio operator for the past 18 years. Like most of you, I marvel at what technology has brought us. I've watched my ham shack fill with radio and computer equipment as I try RTTY, AMTOR and packet radio.

Think back a few years: Who would have dreamed so many of the technical miracles we enjoy today would be possible so soon? Now, close your eyes for a moment and ask yourself: "How could I make use of all of this marvelous technology if I couldn't see?" That's what this article series is about.

Certainly there are other, possibly better, solutions to the problems I'll be discussing. This article isn't the end, only the beginning; it's the tip of the iceberg. It's written to encourage those handicapped hams who have wanted to try these communications modes and for those hams without handicaps who want to get some idea of how they can help us. I'm writing about some of my experiences and the solutions I found to some of the difficulties I encountered.

Although I'm addressing visually handicapped hams here, let's not forget those who are deaf or have impaired motor skills. And, there are those who have combinations of two or more of these handicaps. Yet, we *can* and *do* enjoy Amateur Radio!

Some Background

I've been totally blind since birth, yet I can now enjoy many facets of our hobby that a few short years ago would have been unreachable. I've always loved technical things, especially electronics. This is probably because I always depended on electronics for entertainment. I love the old radio mysteries and used to listen to them for hours; and I enjoy "watching" TV. Most of the books and magazines I read are either on record or tape, so it was only natural that I looked toward Amateur Radio for more knowledge and entertainment.

Some Hills to Climb

Many of the problems I faced as a new ham parallel those faced by visually handicapped people all through life. It's hard to explain, but it's the *little* things that really drive you crazy! For instance, it's not knowing when the cup of coffee you ordered has been placed in front of you, or not knowing someone is holding out their new hand-held transceiver for you to see. Some people are thoughtful and understand a blind person's situation without being told. Then there are those who come up to you and say, "Guess who this is!" or, "Do you know who I am?" That kind of thing really can put you on the spot! If you're not sure you will be recognized, just *say* who you are. If I don't recognize the voice right away, at least that way I'll know for sure who I'm talking to. As I said, it's the little things.

I think reading is the thing I miss most.

Two of the big obstacles blind people face are not being able to drive a car and not being able to read printed material. Amateur Radio has helped overcome these hurdles. I can visit anywhere in the world through my radio. Many times I have had another ham—hundreds of miles away—locate a transistor substitute or an address I need.

I think reading is the thing I miss most. Henry Kuhn, W2IRU, of Buffalo, New York, offers a magazine on audio tape. It's called *The Radio Digest.* Henry has been producing this monthly magazine for over 25 years. How do you thank someone for that kind of dedication? Henry reads selections from the various computer, electronics, and Amateur Radio magazines. *The Radio Digest* is available from the Associated Services for the Blind.[1] *QST* is also available on floppy disk from the Library of Congress.[2]

It's impossible for me to separate Amateur Radio, computers and general electronics from my daily life. They're all tied together and I depend on them so much. Amateur Radio is not just one of my hobbies, it's a *necessity.*

My Introduction to Amateur Radio

I attended the School for the Blind in Kansas City, Kansas, for 11 years. In my senior year, I attended our local high school. When I was in the seventh grade, a Kansas City ham volunteered to teach a Novice license class. His name is Elmer Rose. Elmer showed up without fail each week that year until we all had passed our tests. Jerry Foster, my sixth-grade teacher's husband, was also involved in helping us. Jerry's was the first ham station I saw. I don't remember Jerry's or Elmer's call sign, but I will always remember them. I hope somehow they know their efforts were not in vain. At least one of us out of that class finally upgraded and continued on in Amateur Radio. Jerry and Elmer, wherever you are, thank you!

I never understood the logic of it, but after we got our Novice tickets, we were not allowed to assemble a station at school! The school let us hold the Novice instruction classes, but antennas and radios were "too ugly," so, no ham station. I came home with my license and had no idea where to turn! I ran an ad on a local radio station and was contacted by a couple of hams from Colby, Kansas. One of them

[1]Notes appear on page 31.

Hammarlund HQ-110 receiver he wanted to sell; I finally convinced my Dad that I just *had* to have it! I barely figured out how to run the receiver. I had no idea how to put up and tune an antenna, or how to tune and operate a CW transmitter. No one else in my family knew anything about electronics, and they weren't interested in it, so I was on my own. I listened a lot, but never got on the air. I never made one contact. My license expired, I sold the receiver, bought my first stereo and joined a record club. Novice tickets weren't renewable in those days.

The Ham Bug Keeps Biting

In 1966, I graduated from high school and enrolled at a local vocational technical school to study electronics. I'd tried enrolling in a couple other schools in Kansas, but they refused me, saying: "There is no future in a blind person studying electronics," and "We have no idea how to teach you, anyway." One of the first things our vocational school class did was tour the KLOE TV and radio stations in Goodland, Kansas. That is where I met John (Darel) Graves, WAØGBN. I told him I was interested in Amateur Radio, and he said he would be glad to help. The ham bug just would not go away!

Darel loaned me an old paper-tape code-practice machine and read the sample questions and answers to me on tape so I could study the theory. He had to learn how to read and describe schematic diagrams to me. To a blind person, everything is point-to-point wiring. It is done like this: "The base of transistor Q1 goes through R2, a 47-kΩ resistor, to ground. The base also goes through a 0.001-μF capacitor to the hot side of J1, the audio-input jack." Explained that way, the diagram can be written in Braille, or put on tape for review later. We blind people learn to read descriptions like that and put the picture together in our heads.

A Shocking Experience

At that time, I didn't have a receiver to copy CW, but some people I met in Goodland gave me a Hallicrafters S-38C. I spent a lot of hours listening to that receiver (and I still have it). I strung a wire out the window for an antenna and tied it to the clothesline. It was steel wire and really worked fine. One damp and rainy day, Mom wanted to know why she got shocked when she touched the clothesline. It didn't take me long to figure that one out: The S-38 receiver is a 5-tube ac/dc set!

My First Real Rig

One Sunday afternoon I was listening to my receiver (no longer hooked to the clothesline), and I heard a strong signal. It belonged to Ray Penington, WAØCTP, who lived in Oakley. That's a town about 40 miles east of me; Ray ran a drugstore there. The next time I was in Oakley, I walked in, asked for Ray, and introduced myself. He acted as if he had known me forever, and promised me this time I *would* get on the air! It took less than 10 minutes for him to get my name and phone number and to offer the loan of a rig, a Heath HW-12.

Because of my handicap and the distance I lived from an FCC field office, I was eligible to take the Conditional-class license test. Roy Sanderson (Sandy), WØEKL, gave me my test. He said he was sure I had passed, but I wasn't convinced. In a couple weeks I got a letter from the FCC. I knew it had to be bad news—you don't get a license that quickly! Sure enough, no license; I had forgotten to sign something. Well, at least they didn't say I had failed. Finally, the license came!

The next day, it was back to Oakley to get the HW-12, an ac-operated power supply and portable dipole from Ray. I went home, ate dinner in record time and put up the antenna. Ray had sent everything, including the transmission line. All I had to do was climb my tower, affix the

Where to go for Help

Lloyd Rasmussen, National Library Service for Blind, 1291 Taylor St, NW, Washington, DC 20011, tel 202-287-9324. Check here for the location of your regional library. Many books, magazines and journals, such as *QST*, are available free of charge.

National Braille Press, 88 St Stephens St, Boston, MA 02115, tel 617-266-6160. Source for some Braille information. Publications include *The Second Beginner's Guide to Personal Computers for the Blind and Visually Impaired* and *Add-Ons: The Ultimate Guide to Peripherals for the Blind Computer User.* Copies are available in Braille, audio cassette and printed form.

Stanley Doran, Newsreel Club, 176 Braille Ave, Columbus, OH 43223, tel 614-279-0780. An audio tape newsletter.

Ed Potter, *Playback,* 1308 Evergreen Ave, Goldsboro, NC 27530, tel 919-734-9173. This is an audio tape newsletter of general interest that reviews various types of electronic equipment and includes many addresses and toll-free telephone numbers.

American Printing House for the Blind, 1839 Frankfort Ave, Louisville, KY 40206 tel 502-895-2405. Sells tape recorders, appliances and books recorded on audio tape and in Braille.

Bill Gary, Smith-Kettlewell Visual Sciences, 2232 Webster St, San Francisco, CA 94115, tel 415-567-0667. Produces a quarterly electronics magazine in Braille called the *Smith-Kettlewell Technical File.*

Educational Tape Recording, 10234 S Kedzie Ave, Evergreen Park, IL 60642-3795, tel 312-499-3666. Offers books on audio tape; several computer manuals are also available.

Recorded Periodicals, 919 Walnut St, 8th Floor, Philadelphia, PA 19107, tel 215-627-4230. Several technical magazines are available on audio tape. You may rent these at a cost of $20 a year. (I highly recommend *The Radio Digest.*)

Recordings for the Blind, 215 East 58th St, New York, NY 10022, tel 212-751-0860. Several books (including computer manuals) are available on tape.

IRTI, 26699 Snell La, Los Altos Hills, CA 94022, tel 415-948-8588. Sells audio tape and other products of interest.

Trian Corp, 302, 177 Telegraph Rd, Bellingham, WA 98226, tel 800-628-2828. Sells a talking clock for $30 and talking watch for $50.

Sense-sations, 919 Walnut St, Philadelphia, PA 19107, tel 215-627-0600. A source for appliances and other aids for the blind.

Street Electronics Inc, 1140 Mark Ave, Carpinteria, CA 93103, tel 805-684-4593. Comments: Manufactures the Echo GP, Echo PC and Echo Plus speech synthesizers.

Stone Mountain Engineering Co, PO Box 1573, Stone Mountain, GA 30086, tel 404-879-0241; in Canada, Atlantic Ham Radio Ltd, 416-636-3636. Comments: Offers the QSYer, a DTMF keypad that plugs into the Yaesu FT-757GX and IC-735 transceivers to permit direct entry of frequency. Price: $89.50 plus $2.50 shipping and handling. (See also S. Reyer, "The DIGI-CAT," Apr 1987 *QST*, pp 40-43.)

Franklin Research Center, 20th and Race St, Philadelphia, PA 19103, tel 215-448-1416. Offers a talking digital multimeter ($450).

American Foundation for the Blind, Consumer Products Department, 15 West 16th St, New York, NY 10011, tel 212-620-2000. They sell many products especially adapted for the visually handicapped—games, tools, kitchen appliances and more.

Talking Computer Products, Ronald (Butch) Bussen, Box 142, Wallace, KS 67761, tel 913-891-3532. A source for computer aids for the blind including speech synthesizers, the Laser 128 (an Apple compatible computer), talking software and items produced by Computer Aids of Fort Wayne, Indiana. Talking Computer Products items, such as The Talking Checkbook program, are also available.

Computer Aids, 124 West Washington, Lower Arcade, Fort Wayne, IN 46802, tel 219-422-2424.

center insulator, tie the ends of the dipole to tent stakes driven in the ground and that was it. I connected everything together—and I was on the air! Ray was my second contact that afternoon. Over the years, we spent hundreds of joyful hours on the air. Ray is now a Silent Key, but I will never forget him.

The HW-12 didn't really need any tuning. I had no idea what the antenna system SWR was. I wasn't even sure that it mattered, and I didn't have an SWR meter anyway. I had no way to tell what frequency I was on, but that didn't matter either, as the rig covers 3.8 to 4.0 MHz, so I was "legal" anywhere the rig would go. But, you know hams—we always want more. There were all those other bands. . . and I needed *my own* radio.

. . . how do I tune the radio?

Finally, I bought a National NCX-300. This is a 5-band version of the NCX-3 tri-band transceiver. But now, I had real problems. How could I tell what frequency I was on? This transceiver can cover entire amateur bands! The rig has tuning and loading controls! How do I tune the radio? I had to get someone to read the manual to me so I would know what to do with all those "extra" knobs.[3]

Receiver/Transceiver Tuning

Until the days of microprocessor-controlled radios, determining my operating frequency was a problem I never solved. The best solution I ever came up with was to use a crystal calibrator, find the beat notes and count the turns of the VFO knob. If I lost count, I went clear to the top or bottom of the band and started counting all over. At least I had an idea where I was—sort of. Once I called an SSB CQ on 3.770, before this was part of the US phone band. When I finally discovered where I was, I dreaded getting the mail for a month fearing someone had heard me!

Transmitter Tuning

Tuning a tube-type transmitter is critical, and I've tried several approaches. I found I could take a standard broadcast radio, key the transmitter and find a heterodyne. By listening to this, I could adjust the drive, plate and load controls. Then, I got a little E. F. Johnson monitor from Ray. In the AM position, I could hear and peak the audio hum from my transmitter to get maximum output.

Then I *really* came up in the world! A ham in California sent me a transistor device that hooked across my plate-current meter and gave me an audible indication of what was going on. As the current rose, so did the tone pitch; if the current fell, so did the pitch. I know several articles have been published describing such devices (see the bibliography), but this one is the best I've found so far. It's the most sensitive and stable. I use this same device plugged into my SWR meter, and by listening to the pitch of the tones on forward and reflected power, I can get an idea of the SWR.

Radios and What to Look For

I've spent a small fortune trying to keep pace with technology, and have owned quite a few different radios. After the NCX-5, I bought a Yaesu FT-101. This is a nice radio, but I still had to use a crystal calibrator to determine my operating frequency, and I used an audio device tied across the plate-current meter for tuning. I could get the drive adjustment close just by peaking the receiver noise.

When the all-solid-state radios appeared on the market, I knew I *had* to have one! It's so neat to change bands at the flip of a switch, and no transmitter tuning is required! If you remember the old rigs, try and imagine the fun I had trying to tune my old E. F. Johnson Viking One on 160 meters!

The solid-state transceivers still left me with the problem of getting to a specific frequency or telling me where I was. I had a Ten-Tec transceiver equipped with the optional speech synthesizer. The synthesizer helped a lot, but it was difficult to find an exact frequency as I had to turn the dial a bit, listen to the readout, and then turn the knob again. What a sighted person can see at a glance, I have to listen to. My next rig, an IC-701, was equipped with the optional RM-2, which allows direct keyboard entry of the operating frequency. I still could not read the display, but I could at least key in my operating frequency. The keys on the RM-2 are laid out like those of a Touch Tone® telephone, so it's easy to use.

Gary McDuffie, AGØN, recorded the '701 manual on audio tape and did a lot of work on the radio for me, including some modifications. I used the '701 for quite a while and traded it in for a Yaesu FT-980. I liked this rig a lot, but I missed the IC-701's keypad layout; the '980 keypad is unlike a Touch Tone pad or calculator key pad. Also, the FT-980 has no provision for a speech synthesizer. I really think the keypad and synthesizer are helpful. If I had to pick one or the other, I would choose the keypad, but a synthesizer makes it easy to tell exactly where you are. It just goes to show you: There is no end to a wish list! Enter Kenwood's TS-940S and '440 (I now own a '440). They have keyboard entry, an optional speech synthesizer and CW announcement of the mode you've selected.

Keyboard frequency entry, a speech synthesizer, or both, make it so easy to get on or find a particular frequency. Much Amateur Radio operation these days is channelized, and it's essential to be on the proper frequency. VFO stability is very important; I want to be—and stay—where the readout, keyboard or speech synthesizer say I am. Stability is important because of the narrow bandwidth of these digital modes and also because I cannot read the modem tuning lights or an oscilloscope display. If my radio drifts, it's very difficult to chase the station I'm talking to up and down the band. Things like that can drive you nuts if you are trying to figure out what is wrong and there is no sighted ham around to give you a clue!

For AMTOR, TR (transmit/receive) switching time is another factor to consider. Though this is important to a sighted person, I feel it is even more so for me as I have enough things to keep track of.

VHF and Up

For operation on 6 meters and above, we must be more selective. A lot of this equipment, though digital, has just up and down frequency control keys. Not many such rigs have provision for keyboard entry of the operating frequency. Blind hams should try and spend some time with a particular radio at the store or at a friend's house before deciding on what they're going to buy. For instance, I bought an IC-551 6-meter transceiver a few years ago. I kept it only about six months because it was so difficult for me to operate. There is no provision for a frequency entry keyboard or speech synthesizer. Every time you power it up, it comes on tuned to the bottom of the band. The problem is that its VFO "tunes forever." There is no mechanical stop for reference, and if I got lost, I had to power down and start over. All I could do was count the turns of the knob. If I got down to 50.000 MHz and moved slightly below, the rig went to 53.999 MHz.

. . . the keypad and synthesizer are helpful.

I've owned radios with thumbwheel switches. There is usually no way to mark such switches; they just keep going round and round. So, if you forget what frequency you're on, you'll need sighted help.

If a radio has frequency-controlling keys, be sure you can enter the operating frequency directly. There was a 10-meter FM radio I wanted, but the frequency controlling keys were just up/down keys. I could not enter the *exact* operating frequency I wanted. Some hand-held transceivers are also set up this way. The presence of a speech synthesizer doesn't solve all the problems. Be sure it will tell you *all* you want to know. Does it announce the offset, memory number and the frequency stored? If the radio has an

Fig 1—Here's how the Dymo label is used to identify a floppy disk. *(photos by Gary McDuffie, AG0N)*

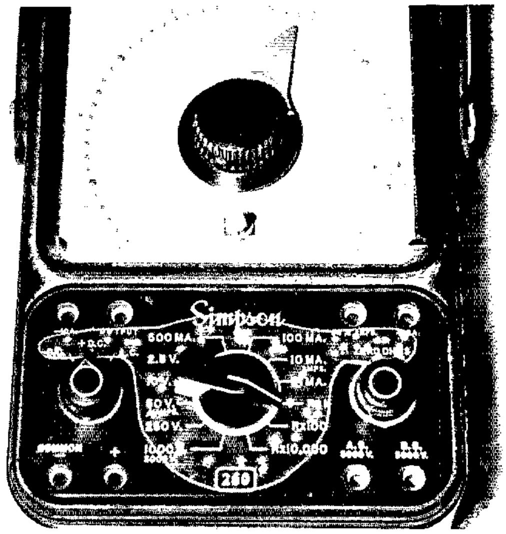


Fig. 2—A Simpson 260 VOM outfitted with a Braille dial and a tone generator. The pointer-equipped knob is turned until the tone is nulled out; then you read the Braille scale. Since this is a linear scale, a Braille conversion table must be used for reading resistance.

optional subaudible tone, does the synthesizer voice the tone settings as well? Can you tell if you are transmiting on VFO A or B? Can you tell if you are operating "split" between the two? The synthesizer should also be able to speak when the radio is in the transmit mode so you can be sure where you are transmitting.

I have an IC-02AT. I don't have much trouble operating it, except for the keyboard lock. To lock or unlock the keyboard, you hold down the FUNCTION key and press the LOCK/UNLOCK key. The problem is that there is no way to tell whether the keyboard is locked or unlocked unless you have a local repeater you can bring up as a reference. What's really needed is a hand-held with a built-in speech synthesizer.

...spend some time with a particular radio at the store or at a friend's house before deciding what to buy.

I find the Kenwood '7800 and '7900 series radios easy to use on 2 meters. The '7900 series has a feature that really comes in handy. The radio emits an audible beep each time you select the first memory. I've also used the KDK-2016. The frequency switches on this radio have stops on them, so it's easy to dial up what you want.

Something else to look for in a rig is the control layout and presence of knobs with pointers or notches that are easy to feel. Such knobs are especially important on microphone gain and transmitter drive controls that are difficult to set without reading a meter. Once I know where to point the knob, I can get pretty close. If I have no way to read the meter, I have a sighted friend check me once in a while to be sure things are as they should be. If I can get someone to read the instruction manual to me, and go over the location of the various front- and rear-panel controls, switches and jacks of the radio with me, I put this information on audio tape for later reference. Such a recording is handy until I get things memorized; and the recording is nice to have around for later reference.

There are different methods you can use to identify things around the shack. One method I use is to put Braille characters on half-inch-wide Dymo® tape to label switches, disks, audio and video tapes and other items (see Fig 1).

Antenna Work

I don't have much trouble doing my own antenna work. I can climb towers well enough, but sometimes need help to tell which way the antenna is pointed, or to make sure I don't have any wires crossed. I use a noise bridge or an audio device plugged into the SWR meter for making antenna adjustments. A speech synthesizer connected to the meter would be a welcome addition; it could tell me at which frequency the SWR dip occurred. Fortunately, my TS-440 has a built-in automatic antenna tuner, so tuning for minimum SWR is one less thing I have to worry about. Aiming a rotatable antenna can be a problem. Telex manufactured a Braille rotator control box, but it is no longer in production. The only rotator I know of that can be equipped with a speech synthesizer that tells you which way your antenna is pointed is the controller from Prosearch.[4] I saw one at Dayton a year or two ago, and put it on my wish list. It's a very smart box with memory, direct degree entry from a keyboard, and it talks! It costs about $500 with the synthesizer, but some day I hope to have one.

Test Equipment

When I began studying electronics, I had a need for various types of test equipment. One of the first things I got was an aural signal tracer. Because I cannot read a scope, this was the best way to trace a signal path through a piece of equipment. I now have a new Heath solid-state unit with a built-in audible continuity checker. It is completely portable and very handy.

Science Products (formerly Science for the Blind) offers an audible VOM, among many other items.[5] The meter is a modified Simpson 260 with a Braille dial (see Fig 2). A pointer-equipped knob is turned until the tone is nulled, then you read the Braille dial. (This company also makes a device that can be connected across an existing voltmeter.) I have never found this meter practical for tuning a circuit as it is much too slow to follow circuit action with the pointer. Listening to a changing tone is much easier and faster, so I usually use this type of device for adjusting transmitters, aligning tape heads and the like.

I also have a talking digital voltmeter. This one speaks the reading every six seconds or so, or you can use a foot switch to make it speak when you want. The meter works fine for monitoring power-supply voltages and is quite accurate, but it's also not practical for tuning purposes. This is true of most digital measuring equipment, whether or not it talks.

Some Hints

Before anyone gets really excited about all this great talking technology, I must warn you that all of it is not cheap! I'm lucky to be able to afford what I have over the years. The talking digital meter costs around $500. My first talking calculator cost $395. Now, Sharp and other companies have talking calculators for around $50.

A lot of features and equipment that are novelties for most people are necessities for the blind. Be careful when purchasing equipment. Remember, most of this stuff talks because modern electronics has made synthesized voice cheap and cute, not because it's designed for use by the blind. Radio Shack's talking watch (RS 63-5040) and talking clocks (RS 63-903 and 63-906) are great buys. The Radio Shack talking clocks are easy to set and use. I've not tried setting their talking watch. The talking watch I have (a Setoki) speaks the time when you press the button, but nothing talks when you set it, so you can get into some real problems trying to set the time. My watch has a calendar, alarm, elapsed time and all that, but only the time is announced.

I mention my watch to stress a point. If at all possible, *try before you buy!* As you will find when I discuss talking computers and software, there are very few sighted people who *really* understand or appreciate what we need. Something that may talk well enough for them, may not talk enough for us—or it may talk *too much.* What may be fast and convenient for a sighted person to use may be impossible for us to use independently.

If you are assisting a handicapped person, try to be patient. Give that person time to become familiar with the controls and features of the equipment. On the other side of the coin, a handicapped person who goes shopping should take someone along who is willing to take the time to explain things and read controls and specifications from the instruction manual.

Enter the Computer

About three years ago, I got an Apple® computer and equipped it with a speech synthesizer. I use software especially written to allow the computer to talk, and I cannot begin to tell you the changes the computer has made in my life! As far as Amateur Radio is concerned, the computer has opened the door to digital communication for me. I put my talking computer

. . . most of this stuff talks because modern electronics has made synthesized voice cheap and cute, not because it's designed for use by the blind.

together with some of the modern modems and I have access to RTTY, AMTOR and packet. The problems and solutions associated with interfacing a computer and Amateur Radio equipment are subjects for future discussion. In upcoming installments, I'll cover computers, voice synthesizers, software, modems, RTTY/AMTOR and packet-radio operation. Computers are a dream come true for many of the handicapped.

Notes

[1]Associated Services for the Blind, Recorded Periodicals Division, 919 Walnut St, Philadelphia, PA 19107, tel 215-627-0600.

[2]Library of Congress, Division for the Blind and Physically Handicapped, 1291 Taylor St, NW, Washington, DC 20542, tel 202-287-5100.

[3]Kantronics and AEA make equipment manuals available as ASCII text files on disk for handicapped hams. Some of the older Kantronics manual files are available on Apple formatted disks; newer manual files are on MS-DOS formatted disks. Contact Kantronics at 1202 East 23rd St, Lawrence, KS 66044, tel 913-842-7745.

AEA manuals for the PK-87 and PK-232 can be obtained from Norm Sternberg, W2JUP, PO Box 125, Farmingville, NY 11738 (telephone no. unpublished), or by contacting AEA at 2006 196th St, Lynnwood, WA 98036, tel 206-775-7373. (Requests sent to AEA are routed to Norm.) Requests should indicate the disk format preferred: IBM PC or AT, Apple, C64 and so on. Almost any disk format (with the present exception of Atari) can be supplied. AEA and Kantronics do not charge for these services: Stamped mailers and formatted disks are not required.

[4]Prosearch Electronics, 1350 Baur Blvd, St Louis, MO 63132, tel 800-325-4016; in Missouri, 314-994-7872.

[5]Science Products, Box A, Southeastern, PA 19399, tel 215-296-2111.

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[If Butch's byline seems familiar to you, it's probably because he authored "The Squawker," which appeared in July 1987 *QST*. You can find his biography there.—Ed.]

Strays

I would like to get in touch with . . .

☐ anyone with information on a Swan linear amp. Russ Smith, W6ONK/7, PO Box 141, Brownsville, OR 97327.

☐ anyone with a manual for a General Radio Type 650-A impedance bridge. Robert Weir, HH2WR, MFI Box 15665-WT, West Palm Beach, FL 3406.

☐ anyone with a manual/schematic for a Central Electronics monitor scope, Model MM-2. Burt Engel, W3KFZ, 17425 N 96th Dr, Glendale, AZ 85508.

☐ anyone with a schematic for a W-S Engineering Portapeater board. Duane Kilbourn, W8NZ, 453 W Territorial, Battle Creek, MI 49105.

☐ anyone with information on using a Xerox 400-1 FAX machine for amateur FAX. Hal Wilson, WB9FNN, 11727 Lamey's La, Evansville, IN 47711.

CHECK YOUR LABEL

☐ Are you a League member and FCC-licensed, but your call sign doesn't appear on your *QST* mailing label, and your membership certificate says "Associate Member"? Then you're missing out on the chance to vote for League Directors, Vice Directors and Section Managers. Help us correct your membership records by sending your name, address and call sign (and, if possible, the seven-digit number that appears on your mailing label) to ARRL Circulation Dept, Dept C, 225 Main St, Newington, CT 06111.

Conducted By Mark J. Wilson, AA2Z
Senior Assistant Technical Editor

ICOM IC-275A 2-Meter Multimode Transceiver

The ICOM IC-275A is the 2-meter offering in ICOM's latest line of VHF/UHF transceivers. The new rigs are noticeably smaller than the last generation, yet they pack a number of added features. If you didn't know that this was a VHF transceiver, you would think it was an HF rig at first glance.

Like the previous generation of ICOM 2-m multimode transceivers, there are two versions of the IC-275 available in the US marketplace. The IC-275A features SSB, CW and FM operation from 140.1 to 150 MHz, 25-W-plus output and a GaAsFET front end. In addition, there are 99 memories, a versatile scanning system, passband tuning and notch filter, subaudible tones and full-break-in CW operation!

A switching power supply is built in, but there is a jack on the rear panel if you want to use an external 13.8-V source (at 6 A). The IC-275H offers the same features as the IC-275A, except that power output is 100 W.

It would take many pages to describe *all* of the features of the IC-275A. I'll highlight some of the significant and not-so-obvious features.

Frequency Control

The IC-275A features ICOM's direct-digital synthesizer. This allows the transceiver PLL to lock up in just 5 ms. Fast lock-up time is important for modes (such as AMTOR) that require fast TR turn-around time. We measured turnaround times of 7 ms using the DATA (quick TR) feature in the USB or LSB mode (typically used for RTTY or AMTOR). See Fig 1.

The IC-275A shares many of the elaborate frequency-control features found on other ICOM HF and VHF rigs. There are provisions for VFO A/B selection, a scanning mode that allows scanning of selected portions of the band or preset memory channels, RIT and complete flexibility in selecting standard repeater offsets or programming oddball ones.

With such a large frequency range to cover, the main tuning knob does yeoman duty. For large frequency excursions, punch in the MHZ button to the right of the main tuning knob, and each revolution of the knob moves you 10 MHz. Once you're in the right MHz range (for example, 144 MHz for SSB and CW or 146 MHz for repeater operation), you can tune around at several rates. On SSB or CW, normal tuning is in 10-Hz steps at 10 kHz per knob revolution. Normal tuning for FM is 5-kHz steps and 500 kHz per revolution. Pressing the TS switch in any mode changes the tuning rate to 1-kHz steps at about 100 kHz per revolution. For SSB and CW, the TS feature is handy for large frequency excursions, while for FM it is useful for tuning odd splits.

The IC-275A has VFO A/B capability that may be used for split-frequency operation, one for receive and the other for transmit, or they may be used independently. The VFOs need not be set to the same part of the band or even for the same mode.

Repeater offsets are controlled by the DUP button. Press the DUP button once and the transmit frequency automatically shifts *down* 600 kHz from the displayed receive frequency. Press it again, and the transmit frequency shifts *up* 600 kHz from the receive frequency. Press it again and you're in the simplex mode. You press the CHK button to listen on the repeater input frequency (your transmit frequency).

If you want to use a split other than the standard ±600 kHz, you have two choices. You can use the SET switch in conjunction with the main tuning knob to set the offset to anything up to 9.999 MHz, or you can use the SPLIT switch and set one VFO to the input frequency and the other to the output. With this much flexibility, you can work *any* repeater.

The display tells you at a glance whether your offset is DUP+ or DUP−, and always shows the operating frequency (transmit or receive). The display also shows when you're in the SPLIT mode.

Memory and Scanning

When the MEMO switch is pressed, the MEMO DN/UP knob below the RIT control allows you to switch through the IC-275A's 99 memories. Each memory stores not only the frequency, but also the mode of operation and any information on repeater splits or subaudible tones. For example, memory 1 might store 144.200 USB; memory 2 could store 145.010 FM, DATA mode (simplex); memory 3 could store 146.780 FM (duplex, standard −600-kHz offset); and memory 4 could store 146.100 FM (duplex, +850-kHz offset). The possibilities are endless.

Memory information is written from the VFO dial with the MW switch, and memory information is cleared with a touch of the M-CL switch. If you want, you can turn frequency control over to the VFO at the memory channel selected by pressing the M>VFO switch.

This transceiver can scan! There are four powerful, yet easy-to-use scanning modes, each of which is designed for a distinctly different purpose.

1) If you press the MEMO and then SCAN buttons, the IC-275A automatically scans through all programmed memory channels, skipping the ones with no information programmed into them.

2) You can select any two frequencies (memories P1 and P2) and scan continuously between them. For example, you can let the transceiver scan 144.080 to 144.250 MHz, if you anticipate a band opening, but don't want to sit in front of the rig turning the knob all evening. The TS switch will speed up or slow down the scanning rate.

3) Using the MODE-S switch, you can scan only those memories that are programmed with a specific mode (for example, FM).

4) By using the SKIP switch, you can lock out any memory channels that you don't want to scan. For example, you can program the scanning function to check only memories 1 through 9, 67 and 85.

The receiver scanning speed is adjustable by a switch inside the top cover. In any of the four scanning modes, the scan will stop when a signal breaks the squelch. You can use the main tuning knob or press the SCAN switch to remain on that channel. If you don't press the switch, scanning resumes after 3 or 10 seconds (user selectable).

Receiver

The IC-275A has several useful receiver features. The squelch works in all modes. I found the noise blanker to be very effective against automobile ignition noise, but it often didn't do much for power-line noise. Unfortunately, with the noise blanker in operation, the receiver's dynamic range is reduced and strong local signals create noise and spurious signals that mask weaker signals. If interference is a problem, you can try the passband tuning (PBT) feature or the notch filter. Both are reasonably effective in combating nearby interference on CW and SSB. The AGC switch affords two choices—fast or slow.

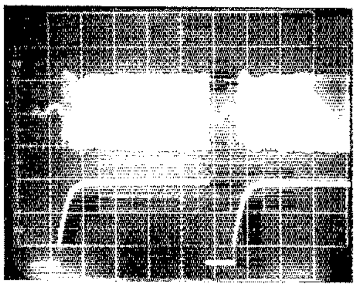
Transmitter

Like most current multimode VHF radios, the IC-275A offers 25 W (and more) output on all modes. This power level is convenient for local "barefoot" operation, and will drive a number of popular solid-state and tube-type power amplifiers.

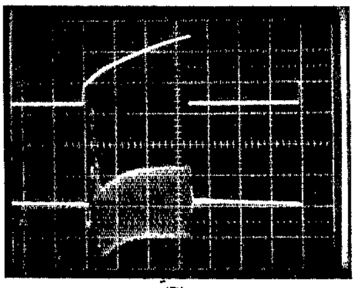
The COMP button switches in a speech compressor. You can adjust the compression level with a rear-panel COMP LEVEL control. Another interesting rear-panel control is the MIC TONE adjustment. By using a combination of the tone and compression-level controls, I was able to get a clean-sounding signal with a little added punch. This is a step forward for VHF transceivers. (Of course, I was also able to adjust these two controls for a truly awful sounding signal! It's important that you or a friend monitor your transmitted signal

ICOM IC-275A 2-Meter Multimode Transceiver, Serial No. 01182

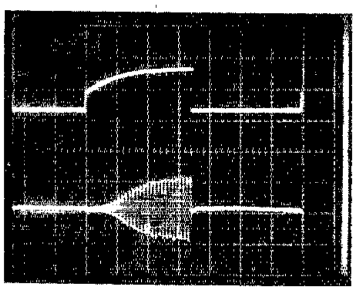
Manufacturer's Claimed Specifications	***Measured in ARRL Lab***
Frequency coverage: Transmitter, 140.10 to 150.00 MHz; receiver, 138 to 174 MHz.	As specified.
Modes of operation: FM, USB, LSB, CW, digital.	As specified.
Frequency display: 7-digit LEDs, black on a yellow background, 3/8-in-high digits.	As specified.
Frequency resolution: 100 Hz.	As specified.
Frequency stability: ±5 ppm (0° to 50°C).	Less than 100-Hz drift after 30 min.
S-meter sensitivity (µV for S-9 reading): Not specified.	6.1 (USB mode). Note: S meter was not accurate; 10-dB increase in signal results in approximately 20-dB increase on meter.
Transmitter	*Transmitter Dynamic Testing*
Power output: 2.5 to 25 W, adjustable.	2.7 to 34.8 W.
Spurious signal and harmonic suppression: Greater than 60 dB below peak power output.	−66 dB (see Fig 4).
Third-order intermodulation distortion products: Not specified.	See Fig 5.
Keying waveform: Not specified.	See Fig 2.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: SSB and CW, less than 0.1 µV for 10 dB S/N; FM, less than 0.18 µV for 12-dB SINAD; less than 0.25 µV for 20-dB quieting.	Minimum discernible signal (Noise floor), (dBm): −139
Receiver dynamic range: Not specified.	Blocking dynamic range (dB): 111 Note: Measurement may be in error because AGC could not be defeated. Two-tone, 3rd-order intermodulation distortion dynamic range (dB): 89 Note: Measured at 40-kHz spacing. The measurement was noise-limited at the normal 20-kHz spacing. Third-order input intercept (dB): −5.5 Receiver quieting (µV for 12-dB signal + noise + distortion/signal + distortion): 0.165
Receiver recovery time: Not specified.	See Fig 1.
Squelch sensitivity: SSB/CW, less than 0.56 µV; FM, less than 0.1 µV.	Min 0.07 µV, max 0.28 µV.
Receiver audio output at 10% total harmonic distortion: More than 2 W.	2 W
Color: Black.	
Size (height, width, depth): 4.25 × 9.6 × 11.6 in.	
Weight: 13.6 lb	



(A)



(B)



(C)

Fig 1—Receiver recovery (turnaround) time waveforms for the IC-275A. Shown at A is the turnaround time in USB mode using the DATA feature. This combination might be used for AMTOR operation. Each horizontal division is 100 ms. The lower trace shows the PTT release. The upper trace is receiver audio output. The receiver is tuned to an S1 signal. Upon key opening, the delay from opening to 90% audio output is measured. The turnaround time is 7 ms. A similar measurement is shown at B, but in the FM mode using the DATA feature. This combination might be used for packet radio operation. Each horizontal division is 10 ms. The upper trace shows PTT release, while the lower trace shows receiver audio output. There is some audio at 3 ms after PTT release, but it is lost in a spike. At 5 ms, there is usable audio. The turnaround delay is about 13 ms until audio is at the 90% level. For comparison, the photo at C shows turnaround time in the FM mode, but without using the DATA feature. Note the absence of the audio spike. Turnaround time here is 24 ms.

to get the right settings.)

The IC-275A has new features for the CW operator. Although full-break-in (QSK) CW operation is standard on most of the newer HF transceivers, I'm not aware of any 2-m transceivers other than the IC-275A that offer this feature. A three-position rear-panel switch allows you to choose between SEMI and FULL break-in, and also allows you to turn the break-in feature OFF. After careful listening tests, it quickly became obvious that the QSK mode really works! You can hear signals in the receiver between characters, and there is only the slightest shortening of transmitted characters. Of course, you'll have a tough time finding a power amplifier and mast-mounted preamplifier that can support QSK on this band.

The CW signal sounds good in either full or semi-break-in, and I couldn't hear any clicks while listening to a second receiver located in the shack. See Fig 2. If you're serious about CW operation, you'll want the optional 500-Hz filter. An 800-Hz sidetone-monitor level control is located on the rear panel, but there is no pitch control.

Packet operation with the IC-275A is a snap. There is no need to disconnect your microphone when you want to operate packet—there are connections for audio IN and OUT for your TNC on the rear panel. The DATA switch mutes the microphone input. Using the DATA feature and FM mode, we measured receiver recovery (turnaround) times of 13 ms—quick enough for efficient packet operation. Fig 3 shows that the carrier has a remarkably quick fall time (45 µs) in the FM mode using the DATA feature. This quick fall time as the PTT is released causes a click that could cause interference to nearby stations.

ICOM has included a subaudible tone encoder with a choice of 32 frequencies. To dial up the tone frequency, press the TONE and SET buttons, then turn the main tuning

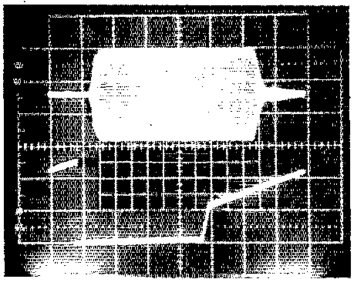


Fig 2—CW keying waveform for the IC-275A. The upper trace is the RF output; the lower trace is the actual key closure. Each horizontal division is 5 ms.

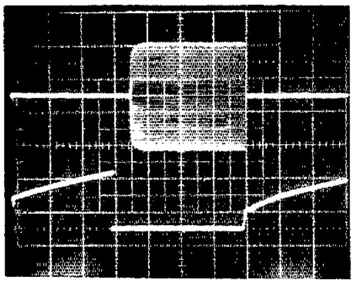


Fig 3—Photograph of the transmitted waveform of the IC-275A in the FM mode using the DATA feature. The upper trace is the RF output; the lower trace is the PTT line closure. Each horizontal division is 5 ms. The rise time is about 300 μs, and the fall time is about 45 μs.

knob until the correct tone frequency appears on the display.

The Manual

The IC-275A manual does an excellent job of explaining the rig's many features, and uses a unique method of combining text with graphics to describe the controls and operation. In the "Control Functions" section, miniature outline drawings of the front or rear panels are shown for each control, with an arrow locating the control and a brief description of its function. A "Beep" beside the drawing designates those controls that produce an audible tone when the control is used. In many cases the control's use is explained in detail later in the "General Operation" or "Function Operation" sections, so appropriate reference to the page is given.

This same approach is followed in detailed descriptions of operations, and illustrations are included to show which controls are exercised and the method of doing so. This manual is probably the most understandable I have ever seen.

Operation

I used the IC-275A during late winter and early spring. The rig holds its own at the weak-signal end of the band. The receiver is sensitive enough to hear plenty of signals around New England, in Canada and south as far as Virginia.

FM operation is convenient, thanks to the memory features. After the initial setup, there is little to do except recall your most-used channels. Most of the time I used the rig by itself, or with an RF Concepts Model 2-317 solid-state power amplifier. The 30 W or so from the IC-275A is plenty for local QSOs, but the amplifier helped on the longer-distance contacts.

The acid test for the IC-275A came during the 2-m ARRL Spring Sprint. John Lindholm, W1XX, and I traveled to a Rhode Island hilltop, mainly to try out his new hilltopping van and generator. The transceiver proved to be well suited for such portable operation. Space is at a premium in the van, so the IC-275A's compact size and built-in power supply really helped out. The receiver held up reasonably well under strong-signal conditions. Although the IC-275A has a sensitive receiver, the preamplifier in the RF Concepts amplifier made a noticeable improvement on some weaker signals. All in all, though, the IC-275A held up well on a crowded band during the Sprint.

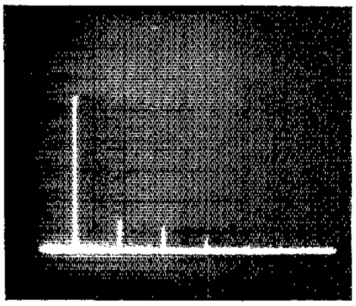


Fig 4—Spectral display of the IC-275A operating at full output. Horizontal divisions are each 100 MHz; vertical divisions are each 10 dB. The output power is approximately 35 W at 147 MHz. The fundamental has been reduced in amplitude approximately 25 dB by means of notch cavities to prevent spectrum analyzer overload. All harmonics and spurious emissions are at least 66 dB below peak fundamental output. The IC-275A complies with current FCC specifications for spectral purity.

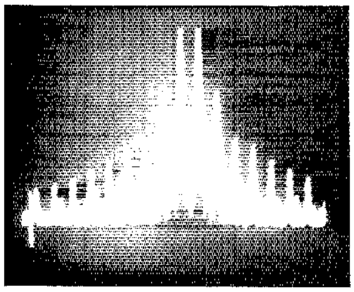


Fig 5—Spectral display of the IC-275A during two-tone intermodulation distortion (IMD) testing. Third-order products are approximately 25 dB below PEP output, and fifth-order products are approximately 40 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 2 kHz. The transceiver was being operated at approximately 35-W PEP output on 144 MHz.

ICOM has made some improvements over the last generation (the IC-271A) that really make this transceiver easier to use. There is provision for a CW filter. I prefer a narrow CW filter for weak-signal work. Also, there is now provision for keying an external power amplifier. The ACC jack on the rear panel provides a ground on transmit for this purpose. In addition, I had no trouble keying this rig with either of my keyers. I still would like to see a ¼-in KEY jack rather than the present 1/8-in jack, though.

One feature that I had not experienced in a 2-m transceiver before is the ability to monitor public service frequencies outside the amateur band (the receiver covers 138 to 174 MHz). It is interesting to use the IC-275A to hear police and fire calls, as well as listen to NOAA weather broadcasts. Such a broad receiving range gives you something to put in all those memories! The IC-275A can be the basis for a comprehensive 2-m station.

Manufacturer: ICOM America Inc, 2380-116th Ave NE, Bellevue, WA 98004, tel 206-454-7619. Price class: IC-275A, $1200; FL-83A CW filter, $35; AG-25 preamplifier, $95; UT-36 voice synthesizer, $34; UT-34 tone squelch unit, $50.—*Mark J. Wilson, AA2Z*

RF CONCEPTS RFC 2-317 2-METER AMPLIFIER

What's new in VHF and UHF equipment? For one thing, a new line of RF power amplifiers from a new company—RF Concepts of Gilroy, California. Always anxious to try out a new piece of VHF gear, I wanted to test the RF Concepts RFC 2-317 as a companion to the IC-275A reviewed in this month's column. This "brick" amplifier features 170 W output for about 25 W drive, which is just about right for most of the current crop of 2-m multimode transceivers. If your rig operates at a different output-power level, check out similar RF Concepts amplifiers with different drive requirements. They have a complete line of amplifiers with different drive/output specifications.

Circuit Highlights

The power amplifier is a single-stage design using a pair of SRF3897 power transistors in parallel. There is room on the board for another amplifier stage; this space is probably used in other models requiring less drive power. The receive preamplifier is a two-stage design using a CF300 dual-gate GaAsFET driving a U309 FET. The result is 20-dB gain with a noise figure of about 1 dB—not bad for a "free" preamp!

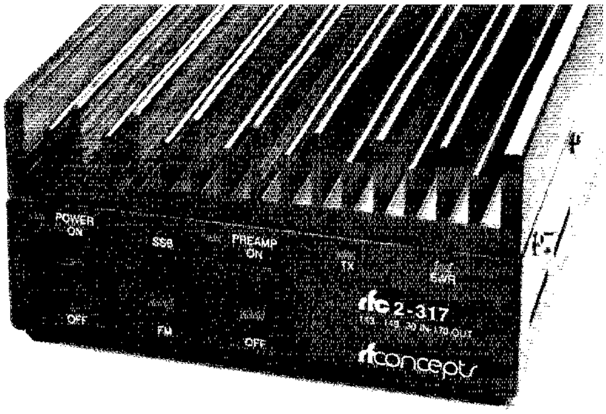
The RFC 2-317 is always biased for linear operation, even when the front-panel mode-select switch is set for FM. The only difference between the SSB and FM mode settings is the TR relay dropout time delay. The relay drops out instantly in FM, but dropout time delay may be increased so that the relays do not "chatter" during SSB operation. It's easy to vary the dropout time by adjusting a potentiometer that is accessible through the side panel.

RF-sensed switching is standard in the RFC 2-317, but there are several ways to key this amplifier. Whenever the POWER switch is ON and RF drive is applied to the RADIO (input) jack on the rear panel, the amplifier automatically switches into the transmit mode. In this mode, the power amplifier is switched into the line and the preamplifier (if the PREAMP switch is ON) is switched out of the circuit. A phono jack is provided on the rear panel for "hard wiring" the antenna relay to control it from the transceiver. You have a choice of two hard-wired keying options: Ground the center pin to transmit or apply a positive voltage to transmit. The choice depends on the requirements of your transceiver. As it comes from the factory, the RFC 2-317 requires a positive voltage to transmit.

RF-sensed switching is convenient, and in this amplifier it works very well. The manual suggests taking advantage of the manual keying feature if you plan a lot of SSB operation. If you hard wire the relay, you won't have to worry about it dropping out during pauses in your transmission.

RF Concepts has made it very difficult for you to hurt this amplifier. Protective circuitry includes:

- A built-in thermostat to shut off the amplifier if the heat-sink temperature reaches 175°F; it will not come back on until the heat-sink temperature drops to a safe level.
- SWR protection. If the SWR exceeds 3:1, the amplifier automatically shuts off. You must toggle the POWER ON/OFF switch to turn it back on.
- A 35-A fuse in the dc power line in case of a catastrophic failure.
- Reverse-polarity protection.
- A pair of diodes to protect the preamplifier from strong signals.



All components are mounted on a single high-quality glass-epoxy circuit board. The chassis, PC board and power transistors bolt to a low-profile heat sink that is surprisingly heavy for its size. There is evidence of high-quality contruction throughout. For example, plated through-holes are used on the board; the RF interconnections are made with miniature Teflon® coaxial cable; book-mica fixed capacitors and ceramic trimmers are used in the matching circuits; and liberal use of RF chokes and decoupling capacitors are in evidence.

There are three switches and four LEDs on the front panel. The POWER ON/OFF switch controls the power amplifier. As described earlier, the SSB/FM switch changes the time delay. The PREAMP ON/OFF switch controls the preamplifier. The power amplifier and preamplifier may be used separately or simultaneously, as operating conditions dictate. The four LEDs tell you when the power is ON, when the preamp is ON, when the amplifier is in the transmit mode and when the SWR protective circuitry has come on.

The rear panel is equally straightforward. There are two SO-239 connectors for input (RADIO) and output (ANTENNA), a phono jack for TR control, a five-pin DIN remote-control jack, a four-pin Jones receptacle for dc power, and the fuse holder.

RF Concepts RFC 2-317 2-Meter Amplifier, Serial No. 1114

Manufacturer's Claimed Specifications	*Measured in ARRL Lab*
Frequency coverage: 143 to 149 MHz.	Tested only from 144 to 148 MHz
Modes of operation: FM, CW, SSB.	As specified. Also works packet radio.
Power output: 170 W with 30-W drive. Input power: 0.2 to 30 W.	175-W output with 30-W drive; 130-W output for 10-W drive; 90-W out for 5-W drive.
Spurious signal and harmonic suppression:	See Fig 6.
Receive preamplifier: 20-dB gain with 1-dB noise figure.	22.93-dB gain, 1.02-dB NF at 146 MHz.
Power requirement: 13.8 V dc at 22 A.	13.8 V at 21.5 A for full output.
Size (height, width, depth): 3 × 6 × 11.5 in.	
Weight: 5 lb.	

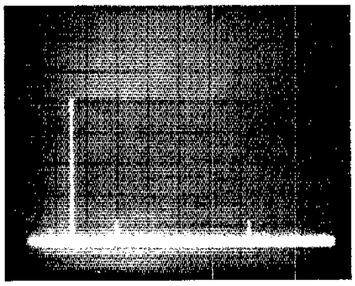


Fig 6—Worst case spectral display of the RFC 2-317 operating on the 2-m band. Vertical divisions are each 10 dB; horizontal divisions are each 100 MHz. Output power is approximately 175 W at a frequency of 146 MHz. The fundamental amplitude has been reduced approximately 28 dB by means of notch cavities to prevent spectrum analyzer overload. All spurious emissions are at least 68 dB below peak fundamental output. The RFC 2-317 complies with current FCC specifications for spectral purity.

If you wish, you can mount this amplifier in a remote location—say in the trunk of your car—and control it from your operating position. The five-pin DIN jack on the rear panel allows you to remotely turn the POWER and PREAMP switches ON and OFF, as well as switch between SSB and FM modes. Although RF Concepts does not provide a remote-control head, all that's required is a few switches and a 10-μF capacitor.

Hookup and Operation

The RFC 2-317 requires approximately 22 A at 13.8 V dc, so the manual recommends using no. 8 or 10 wire between the power source and the amplifier. If possible, the wires coming out of the back of the brick should be connected directly to the battery or ac-operated supply.

There really isn't much to hooking up the amplifier. Connect a short piece of coaxial cable between the amplifier and transceiver, connect a power supply and antenna, and you're on the air! Because the RF-sensed keying scheme suits my needs, I didn't bother to wire up a hard-keying cable.

I used the '2-317 with an ICOM IC-275A 25-W multimode transceiver. Although I made a few test QSOs on FM, I didn't have much call to use the amplifier during normal operation from my home. The ICOM is a 25-W radio to begin with, and because I live in a fair VHF location, I can work most of the local repeaters barefoot.

I do enjoy 2-m SSB and CW operation, though, so the RFC 2-317 got quite a workout on that part of the band. Near the end of the review period, I took the IC-275A/RFC 2-317 combination on a couple of portable operations at Buck Hill, Rhode Island, in grid square FN41. Using this pair makes for a compact, yet powerful and easy-to-assemble portable station. The first operation, during the ARRL 2-meter Spring Sprint, netted more that 100 QSOs in an hour and a half of operation. During this period of constant operation, the amplifier got *mildly* warm to the touch. It just sat there quietly and worked, requiring no attention whatsoever. During this contest, I had no problem working stations from northern Maine to Virginia, and out west to Ontario. During the second operation, the 902-MHz Spring Sprint, the same setup served as a liaison radio for setting up contacts on 902 MHz. Again, the amplifier performed flawlessly in the field.

I am impressed by the preamplifier in the RFC 2-317. In the past, I've found that although preamplifiers in solid-state bricks help on some contacts, for the most part they increase noise and just make the S-meter readings higher. This preamplifier, however, made a noticeable difference in readability for many QSOs, and is well worth using.

The RFC 2-317 is a well-built piece of gear that deserves consideration if you want to add some punch to your 2-meter signal. With nearly 200-W output, it's within a few decibels of 4CX250-class power amplifiers, and it takes up a lot less space. If you like to work DX, this power level is enough for aurora and meteor-scatter QSOs—and for moonbounce too, if you want to work W5UN!

RF Concepts offers a 5-year warranty on the RFC 2-317 (except for power transistors, which are warranted for 6 months). Price class: $264. Manufacturer: RF Concepts, 2140 Jeanie La, Gilroy, CA 95020, tel 408-847-7373.—*Mark J. Wilson, AA2Z*

REDUCING AM DETECTION IN DIRECT-CONVERSION RECEIVERS

☐ While building equipment for the 40- and 30-meter bands, I discovered that AM detection is a common problem in D-C receivers. I used a singly balanced, four-diode detector followed by 85 dB of audio gain and a conventional RC active filter with additional gain. When the receivers were completed, both would detect any AM signals above about 200 μV in level. This is a problem because there are many such signals in the neighborhood of our 30- and 40-meter bands.

I went to some lengths to decouple and shield each receiver's LO, and to provide RF decoupling between the detector and the audio amplifier. Neither of these changes made any improvement.

Oscilloscope display of the detected AM signal showed an interesting peculiarity: At the receiver input, most signals exhibited symmetrical noise—but the *detected* AM signals showed only *negative-going* noise. This led me to suspect that the detection was actually taking place in the audio amplifier. Further, working with a receiver with no front-end selectivity, I found that sensitivity to AM detection decreased with increasing separation between LO and AM signal frequencies. This strengthened my hunch.

I solved the problem by installing a passive L-network filter, with a bandwidth of several hundred hertz, between the detector and the audio amplifier. I used a design similar to that shown in Fig 12 on p 77 of *Solid State Design for the Radio Amateur* with good results. With the filter installed, the modulation on AM signals of several thousand μV is inaudible with a 10-kHz LO/signal spacing. —*Denton Bramwell, K7OWJ, St Joseph, Michigan*

PL-259 INSTALLATION HINTS

☐ When installing a PL-259 connector on RG-8 cable, many amateurs find it impossible to tin the braid and solder it to the connector without melting the cable dielectric. Here's an alternate method of joining RG-8 cable to a PL-259 connector. This method has all the integrity of a soldered connection, but none of the usual headaches. The possibility of heat damage to the cable dielectric is minimized because the only soldering involved is at the tip of the PL-259 center pin.

Refer to Fig 1. First, remove 15/16 inch of the jacket using a sharp knife. (Do not cut or nick the braid.) Next, cut through both braid and dielectric 5/8 inch from the end of the cable and remove the cut braid and dielectric. Slip the connector outer shell onto the cable. Unravel the remaining 5/16 inch of braid and fold it back over the cable jacket. Forcibly thread the body of the PL-259 onto the cable by hand. Lightly clamp the knurled portion of the PL-259 body with pliers, and screw the body tightly onto the outer jacket until the end of the inner conductor shows at the end of the connector tip. Use pliers to grip the cable while screwing it into the connector, but be careful not to damage the cable.[1] Lastly, solder the tip of the center pin to the inner conductor and make the usual checks for continuity and short circuits.—*Bruce M. Haldeman, KG6QY, Sun City, California*

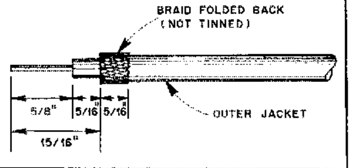


Fig 1—Cable prepared for connector mounting per KG6QY's suggestion.

MAKE A SNUG FIT FOR TELESCOPING TUBING

☐ In many antenna projects, it is desirable to have two pieces of metal tubing with a snug telescoping fit. Quite often, I find that the tubing "just right" for such a job *isn't* just right because the slip joint is too loose. Here is a solution I developed while constructing a two-section, push-up antenna mast from 1½- and 1¼-inch thin-wall electrical conduit.

First, remove the cutting blade from a pipe cutter that is large enough to cut the tube you wish to form. Purchase or fabricate a new steel roller (Fig 2). The new blade rolls a groove (Fig 3) in the pipe or tubing instead of cutting it. Install the new roller in the pipe cutter.

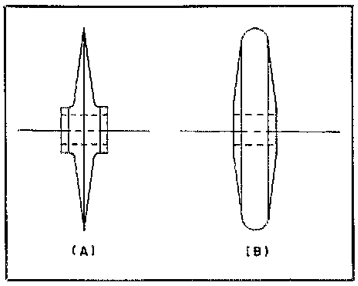


Fig 2—The original cutting roller (A) and a new forming roller (B) used to work tubing for a snug fit. (The exact shape of the new roller is not important. It should be ground from solid steel and have the same hub width and outer diameter as the cutting roller it replaces.)

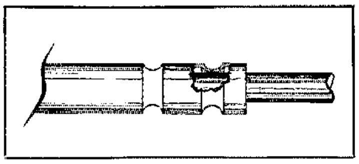


Fig 3—Use the new roller to groove the larger tube of a slip joint. This reduces the tube's inner diameter slightly to provide a snug fit with a smaller tube.

Use your new forming tool to tighten loose slip joints in this way: Place one tube inside the other and use the modified pipe cutter to roll two or more grooves in the larger tube. Continuously turn and slide the smaller tube to test the fit. Stop when there is a noticeable increase in the friction between the two tubes. (If you roll the groove too deeply, the two tubes will be permanently bonded together! This method is useful, however, for locking two pieces of tubing together.)

Application of this method is not limited to large tubes or thin-wall tubes. A similarly modified small tube cutter works with diameters as small as ¼ inch. I have used the larger tool to groove standard 1½-inch water pipe. No doubt it would work just as well with heavier (schedule 80) pipe. My only problem I encountered using this method has been an occasional split seam while I was experimenting to see how deeply I could groove welded tubing.—*J. M. Simms, N7BBC, Tucson, Arizona*

AN EMERGENCY REPLACEMENT FOR NUTS WITH ODD-SIZED THREADS

☐ I recently required the use of an old milliammeter, which had the mounting screws permanently embedded in the case flange. The nuts for the no. 2 mounting screws were missing, and there were no replacements in any of my accumulated hardware. By using the plastic sleeve that insulates hook-up wire as a replacement nut, I quickly secured the meter on the new panel (see Fig 4).

Find a short piece of insulated wire with a conductor diameter slightly smaller than the threads you wish to fit. Slide enough insula-

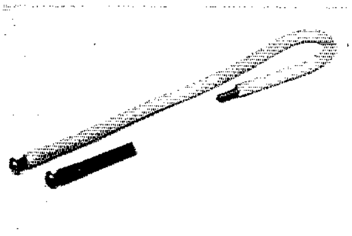


Fig 4—Samples of W1HHF's nut-from-insulation technique.

[1] I tried Bruce's suggestion with a PL-259 and RG-213 in the ARRL lab. Pliers were needed to screw the connector onto the cable, and some distortion of the cable jacket resulted. This unwanted effect should be reduced by trimming some of the braid flush with the end of the cable jacket or by trimming the shield to about 3/16 inch after folding.—*Bob Schetgen, KU7G, ARRL HQ*

increase noise and just make the S-meter

tion off one end of the wire to cover the exposed screw threads. Form a handle at the other end of the wire by making a bend. Expand the empty insulation with some needle-nose pliers, and apply a small amount of lubricant to the screw. Turn the screw into the open end of the insulation. Once the joint is tight, cut off the excess wire and insulation.—*Antonio G. O. Gelineau, W1HHF, Burlington, Vermont*

SCHOTTKY DIODES *DO* IMPROVE PRODUCT-DETECTOR PERFORMANCE—BUT WHAT ABOUT AM DETECTION?

☐ In November 1984 Hints and Kinks, the Rev Doug Millar, K6JEY, described how he replaced the 1N60 point-contact diodes in a TS-830S product detector with Schottky mesh diodes.[2] I recently made this modification to my Kenwood TS-820 transceiver and want to add my enthusiastic endorsement.

Rebalancing the product detector is simple. Connect an oscilloscope to the '820's rear-panel IF OUT connector. Set the scope sensitivity to 50 mV/div. With the '820's RF GAIN control at minimum, adjust trimmer potentiometer VR3 and trimmer capacitor TC5 (both near the product-detector diodes on the IF board) for minimum deflection on the scope.—*Dick A. Mack, W6PGL, Santa Cruz, California*

Editor's Note: Many hams use their general-coverage transceivers for shortwave broadcast reception and listening to WWV and CHU, and this often means using an AM envelope (signal rectification) detector. What about replacing a radio's *AM* detector diode with a Schottky diode of some type? The Rev Millar's 1984 H & K item sparked controversy on this question in shortwave listening circles to such a degree that a number of shortwave equipment dealers now offer a Schottky-diode AM detector modification for some receivers.

In the February 1986 Canadian International DX Club *Messenger*, Technical Talks editor Don Moman, VE6BOD, wrote of modifying his ICOM IC-R71A receiver for A/B comparison between passivated Schottky and point-contact rectification detectors: "Yes, background noise did drop roughly 3 dB, but so did the [recovered] audio level of weak signals. Using a Hewlett-Packard HP-606 generator cranked down to under 0.1 μV, I could never create a situation where there was any difference. On the HF bands, with weak or strong signals, again there was no advantage to the HCD [hot-carrier diode]. . . I don't have equipment to measure audio distortion, so I can't say much [about that] here. I couldn't note any improvement."

Have any H & K readers had quantifiable success using Schottky diodes as rectification detectors?

WHEN FUSES SHATTER

☐ In the course of performing their function, tubular glass fuses may shatter if subjected to a severe overload. This causes two problems: (1) glass shards in the holder and (2) the detached fuse end cup inside the holder base. These remnants can usually be ejected by inserting a small rod through the back end of the holder *if* that end of the holder is accessible.

These problems can be minimized by wrapping the glass body of the fuse with vinyl tape. One or two turns are enough; ¼-in-wide tape is a perfect fit on standard size fuses

[2]D. Millar, "Diode-Ring Product Detectors," *QST*, Nov 1984, pp 55-56.

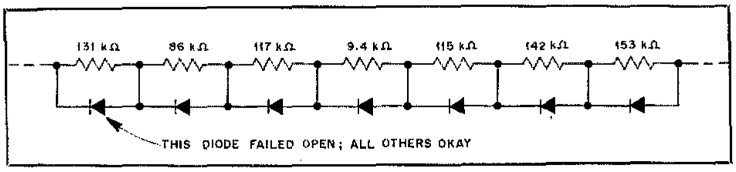


Fig 6—Equalizing resistors of unequal resistance caused breakdown in K2OZ's voltage doubler circuit. All of the resistors were originally 150-kΩ ± tolerance; overvoltage shifted their values unequally.

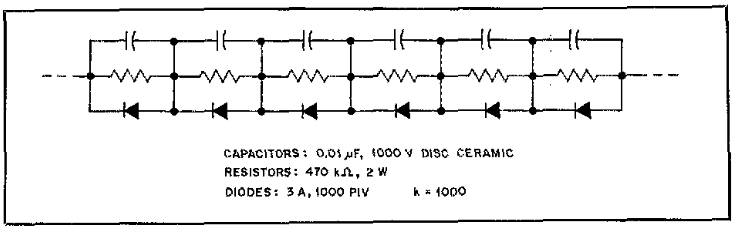


Fig 7—Equalizing resistors *and* transient-suppression capacitors keep series-connected diodes working within their ratings. The voltage rating of the capacitors and resistors should equal or exceed that of the diodes.

(3AG, and so on). Use transparent tape to allow visual inspection of the fuse element.

If the back cup of a disintegrated fuse can't be pushed or pulled from the holder by other means, here's an adhesive solution: Put a dab of mixed five-minute epoxy glue on the passive end of a wooden match. Carefully insert the matchstick into the fuse holder, glued end first. When it bottoms, twist it gently, but firmly, to seat it in the fuse end cup. Allow the epoxy cement to cure for 10-15 minutes and pull out the matchstick. If you recover only glass fragments, repeat the procedure until the errant cup is extracted. —*Marty, W6BDN, and Dan, N6BZA, Levin, Menlo Park, California*

UNEQUAL EQUALIZING RESISTORS SPELL DIODE DOOM

☐ Over the past 20 years or so, I have found the most failure-prone system in various high-power amplifiers to be the power supply—especially power supplies using voltage doubling circuitry.

My latest power supply failure occurred in a commercial amplifier less than two years old. The power supply in this amplifier uses seven 3-A, 600-PIV diodes in each of two voltage doubler legs. Each diode was shunted by a 150-kΩ, ½-W equalizing resistor; there were no protective capacitors.

As I inspected the rectifier stack for damage, I saw that one diode in one leg had cracked completely in half. But why? Measurement of the resistances of the equalizing resistors provided the answer: The resistors differed greatly in value! (See Fig 6.) (I used a digital multimeter to make this measurement, taking care to keep the positive probe on the cathode of the diode across the resistor under test. This ensured that diode conduction would not interfere with the resistance measurement.) Before the failure, the only hint of the problem had been the odor of burning resistors. Until the fireworks occurred, the amplifier worked well and the output of the power supply was normal.

In my opinion, the only way to avoid replacing components again and again in such circuits is to use a configuration similar to that in Fig 7. I use 2-W resistors because they can take a 500-V drop without breaking down. The use of equalizing resistors *and* spike suppression capacitors is a tried and true method. I have used a solid-state voltage doubler based on the circuit in Fig 7 for over 20 years without component failure.—*Paul T. Atkins, K2OZ, Park Ridge, New Jersey*

Editor's Note: As K2OZ reminds us, resistors have voltage as well as power ratings—and resistance shift caused by overvoltage was the impetus behind the high voltage metering fix presented by Steve Powlishen as part of "Improving the K1FO 8874 432-MHz Amplifier," *QST*, Jul 1987, pp 20-23. "Diodes in Series," p 6-6 of the 1987 *ARRL Handbook*, covers the how and why of RC protection for rectifier diodes, including a discussion on the voltage ratings of resistors from ¼ to 2 W.

REDUCTION-DRIVE TUNING CAPACITORS FROM UHF TV TUNERS

☐ Surplus UHF TV tuners, and those in discarded TV sets, may serve as a source of reduction-drive tuning capacitors. The geared reduction drives on these variable capacitors have practically no backlash. After you have located such a tuner, carefully open it. You should see a tiny three-section variable capacitor with an integral reduction drive. Depending on when the tuner was manufactured, it may have a detent system for channel selection. If such a system is present, remove or otherwise disable it.

Now, let your creativity be your guide. In one project, I disconnected the capacitor stators from the tuner circuitry, wired them together and brought a lead from the parallelled stators out through a hole in the tuner box. I kept the tuner knobs and used them to adjust the capacitor.—*James Smith, KD4YD, Ellenton, Florida*

Technical Correspondence

Conducted By Paul K. Pagel, N1FB
Senior Assistant Technical Editor

THE MOON AND IONS

☐ I listen almost nightly to BBC on 5.975 MHz. Around the full-moon period, when the moon is on a high azimuth track, I note the audio identification from the Republic of South Africa's Johannesburg transmitter beneath the BBC signal.

In the '40s, '50s and '60s (I was in Newfoundland and Labrador in the early '60s), I was active on 75 and 80 meter SSB and CW. I definitely recall that a number of contacts with South Africa were made when the moon was full, or nearly full. From Newfoundland, I recall a 75-m "S9 + 40" SSB contact with Venezuela—again, the moon was full.

At the moment, I do not have HF gear, otherwise I would recruit a South African station and arrange for tests on 20 and 80 meters. Has anyone else noticed extraordinary skip conditions on the lower frequencies when the moon is full?—*Phil Loosen, VE1CF, 201 Willow Ave, Fredericton, NB E3A 2E3, Canada*

THE MAGNIFICENT SEVEN

☐ In Warren Dion's article, on p 29, beneath the heading "The Seven-Cell Battery," Warren states: "There's no such thing, but maybe there should be. . . ."[1] Well, there is! A complete line of such batteries is available from the Globe Battery Division, Johnson Controls, 5757 North Green Bay Ave, Milwaukee, WI 53201, tel 414-228-2393. I purchased my 7-cell battery for the same purpose given in Dion's article—flying glider airplanes. I've had my battery for about four years.—*Kjeld Hyatum, KR1Q, PO Box 267, MIT Branch, Cambridge, MA 02139*

PROGRAM UPDATE

☐ I enjoyed Warren Dion's article, "A New Chip for Charging Gelled-Electrolyte Batteries."[2] The program he presented can be converted easily for use on the Radio Shack computer Models I-III and Model 100. The changes required involve program lines 1ØØ, 14Ø and 21Ø:

```
1ØØ R2=2ØØØØ/(VL*(1-2.3/VL))
•
14Ø R2=23ØØØØ/(VL*(1-2.3/VL))
•
21Ø A$=INKEY$:IFA$=""THEN21Ø
```

—*Ronald W. Brown, WA6WIY, 14155 Brandan Rd, Pine Grove, CA 95665*

EMP REVISITED

☐ The *QST* series by Dennis Bodson, W4PWF, contains excellent information for the radio amateur and is one I expect to use often as a source of reference information.[3] Although the title contains the words "electromagnetic pulse," readers should not lose sight of the fact that much of the information applies to protecting amateur equipment from nearby lightning strikes.

There is an error in Eq 3 as published on p 33 of the November 1986 issue. The radical line should be continued over the letters SWR. When corrected in this manner, the equation correctly gives the RMS value of the RF voltage between the two conductors of a transmission line, if the line Z_0, the SWR and the power level are known.

There is another error in this section of the November installment that is somewhat more subtle, related to the definition of peak envelope power (PEP). Rather than being peak instantaneous power, as many amateurs have been led to believe, a PEP value is the *average power* present at the *peak* of the RF envelope. Using Bodson's values for his Eq 4 as an example and the corrected version of Eq 3,

$$V = \sqrt{100 \times 52 \times 1.5} = 88.3 \text{ volts}$$

This means the RF voltage between the conductors of the 52-Ω line will be 88.3 V RMS at the peak of the envelope of a 100-W PEP signal. But for determining the clamping voltage for protection, we need to determine the instantaneous *peak voltage* value. This value is 88.3 × $\sqrt{2}$ or 124.9 V. Rather than converting RMS to peak voltage as a separate operation, it is more straightforward to incorporate a 2 under the radical sign of Eq 3. Thus, the corrected and complete version of Eq 3 is

$$V = \sqrt{2 \times P \times Z \times SWR} \qquad \text{(Eq 3)}$$

—*Gerald (Jerry) Hall, K1TD, Editor,* The ARRL Antenna Book

WEATHER RADAR ACCESS

☐ The Peacock Amateur Television Club is now operating a remote transmitter connected to a computer graphics system. The computer continuously accesses weather information from the National Weather Service and displays an updated radar display of rainfall.

This system normally monitors the Marseilles, Illinois, data, which is converted to a video signal at the club's facility at WMAQ-TV in Chicago. The amateur TV transmitter, located at a mid-rise downtown building, operates with an ERP of 40 W at 426.25 MHz. (The transmitter may be moved to a higher location in the near future.) The signal is horizontally polarized, and standard fast-scan vestigial-sideband TV transmission is employed. Station identification is made with a sequenced video display and an audio cartridge machine.

Hams from various Chicago TV stations support this system. Others involved or interested in weather forecasting or weather-related public-service work (such as SKYWARN) are invited to join PATC. For more information, contact Henry Ruh, KB9FO, c/o WMAQ-TV, Merchandise Mart Plaza, Chicago, IL 60654.—*Henry Ruh, KB9FO*

LINEARIZING CLASS-C VHF TRANSISTORS

☐ Because medium-power class-C VHF transistors are much cheaper than their linear counterparts, it's tempting (as well as feasible) to use them even for linear applications. If simple diode biasing alone is used, however, the transistors (such as the MRF227) go into thermal runaway. Two solutions to this thermal runaway problem were devised in the ARRL Lab, both of which preserve the advantages of a dc grounded case: the use of current limiting and an active bias network.

The current-limiting technique should work with any device, but is not recommended where current drain is an important consideration. The approach is simply to use a current-regulated power supply and forward bias the transistor. An LM317 current-regulated circuit is shown in Fig 1A. The transistor operates class B; forward bias is chosen by proper selection of resistance values for R_{B1} and R_{B2}.

The active biasing circuit of Fig 1B is not new, but is not commonly applied in amateur circuits. Basically, the current drawn by the transistor is monitored using a small-value sensing resistor. The voltage developed across R_S controls the biasing circuit. When properly implemented, an increase in the current drawn by the transistor reduces the forward bias, and a decrease in transistor current increases the forward bias.

Experimentation may be required to determine the correct amount of feedback required. (Use a current-limited supply to avoid destroying transistors.) These circuits are offered as starting points for further experimentation, and the ARRL Lab cannot supply complete designs for various applications.

Using $4 transistors instead of $15 transistors certainly reflects the amateur spirit! The money-saving aspect alone should create a desire for experimentation on your part!—*Zack Lau, KH6CP, ARRL Lab Engineer*

ASCII TEXT FILE MANUALS

☐ Kantronics and AEA make equipment manuals available as ASCII text files on disk for handicapped hams. Some of the older Kantronics manual files are available on Apple formatted disks; newer manual files are on MS-DOS formatted disks. Contact Kantronics at 1202 East 23rd St, Lawrence, KS 66044, tel 913-842-7745. AEA manuals for the PK-87 and PK-232 can be obtained from Norm Sternberg, W2JUP, PO Box 125, Farmingville, NY 11738 (telephone number unpublished), or by contacting AEA at 2006 196th St, Lynnwood, WA 98036, tel 206-775-7373. (Requests sent to AEA are

[1]W. Dion, "A New Chip For Charging Gelled-Electrolyte Batteries," Jun 1987 *QST*, pp 26-29.
[2]See Note 1.
[3]D. Bodson, "Electromagnetic Pulse and the Radio Amateur," in 4 parts, *QST*, Aug, Sep, Oct and Nov 1986.

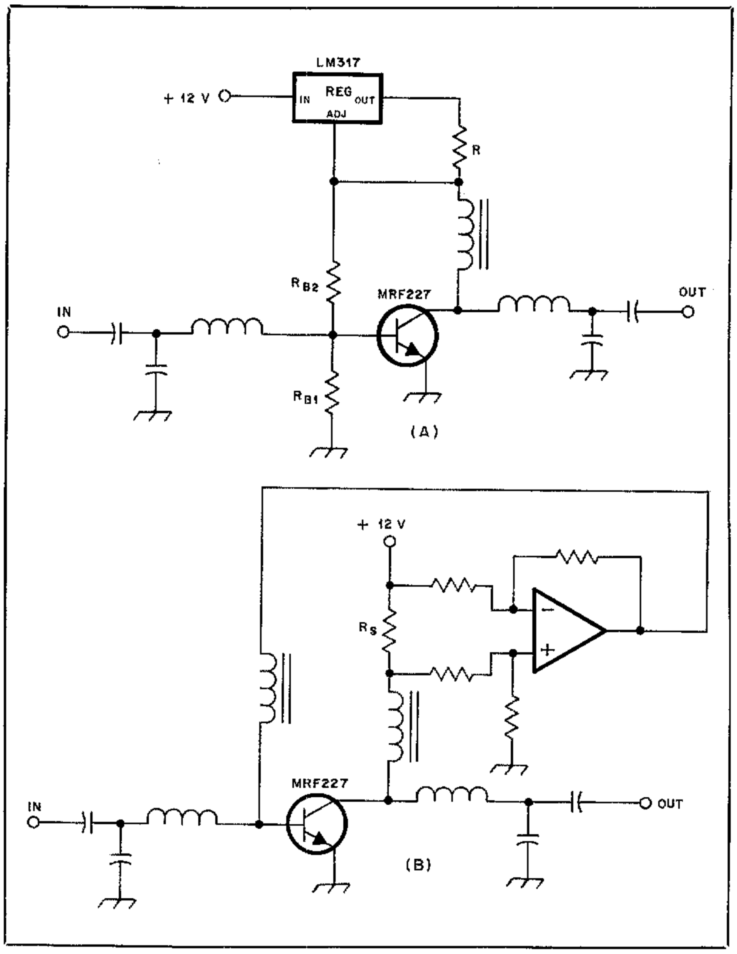


Fig 1—Two methods of using transistors designed for medium-power class-C applications in linear applications. See text for details.

routed to Norm.) Requests should indicate the disk format preferred: IBM PC or AT, Apple, C64 and so on. Almost any disk format (with the present exception of Atari) can be supplied. AEA and Kantronics do not charge for these services; stamped mailers and formatted disks are not required.—*Ed.*

TVI—ANOTHER APPROACH (COMMENT)

☐ A footnote in the July 1987 Technical Correspondence mentions Viewsonics as a source of a 10-dB amplifier. Bob Wanderer, KT2D, acting on correspondence received from Bob Koffron, WA8LPQ, learned from John Ferrarese of Viewsonics that they do not sell the amplifiers in small quantities. But Viewsonics is not the only source of 10-dB TV-channel amplifiers. You can find them at most electronic components dealers, mail-order electronic suppliers, TV repair shops and Radio Shack stores. I've seen them at some discount stores, too.—*Ed.*

Note: All correspondence addressed to this column should bear the name, call sign and complete address of the sender. Please include a daytime telephone number at which you may be reached if necessary.

Feedback

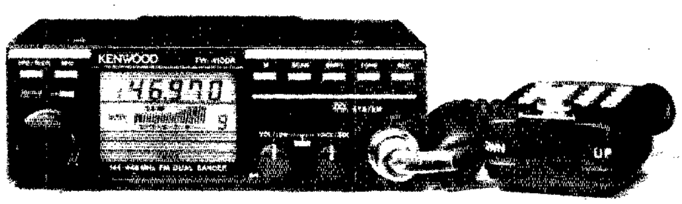
☐ Please refer to "Some Reflections on Vertical Antennas," Jul 1987 *QST*. On p 18, beginning at line 15 of the left-hand column, the sentence should read: "For example, at 14 MHz, substantial RF currents flow down. . . ." The reference to 14 MHz was inadvertently omitted in the published article.

In the Appendix on p 19, the definition of term p has the radical sign extending too far to the right. The correct definition is:

$$p = \left[\frac{X \times B}{2} \times \left(\sqrt{1 + \frac{G^2 \times 10^{-4}}{B^2}} - 1\right)\right]^{1/2}$$

New Products

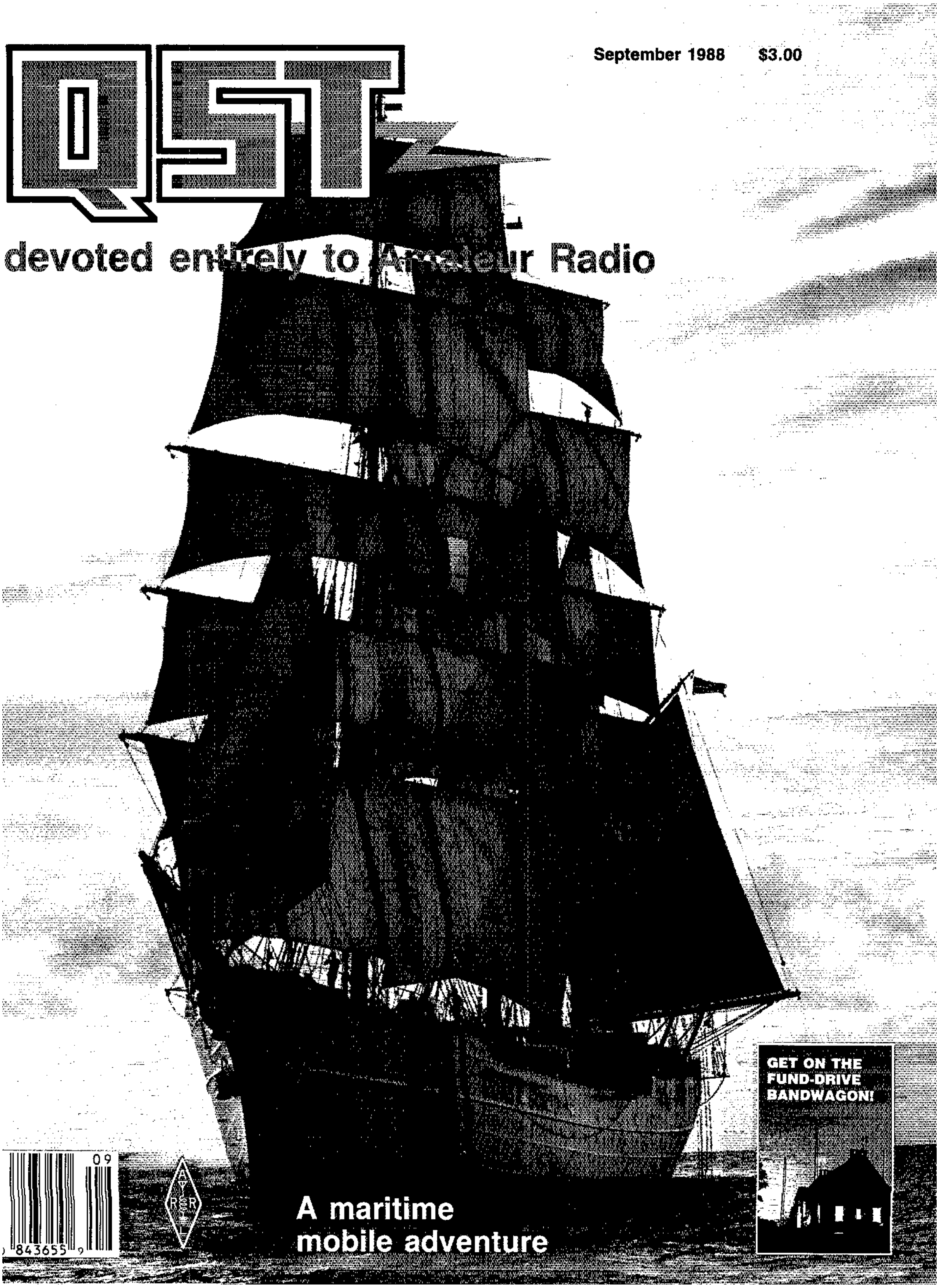
KENWOOD TW-4100A 2-m/70 cm FM DUAL-BAND TRANSCEIVER



☐ Kenwood's second-generation Dual Bander delivers 45 W output on 2 meters and 35 W on 70 cm. Low power on either band is 5 W (adjustable). Features include:

- Selectable full-duplex, cross-band operation. Cross-band repeater operation possible (a control operator is needed for repeater operation).
- Frequency coverage: 142-149 MHz, 440-449.995 MHz.
- GaAsFET front-end receiver.
- Programmable band scan and memory scan with memory-channel lockout.
- Ten memory channels with lithium-battery backup. Two channels store transmit and receive frequencies independently for odd splits or cross-band operation.
- Non-volatile operating system. Even if memory back-up cell dies, all operating features remain intact.
- Separate antenna ports for VHF and UHF.
- Front-panel-selectable CTCSS tone (with optional TU-7).
- Digital Channel Link (DCL) option.
- Multifunction voice synthesizer (VS-2) option.

Manufacturer: Kenwood USA Corp, 2201 E Dominguez St, Long Beach, CA 90810, tel 213-639-9000. Price class $650.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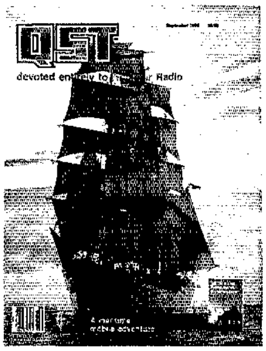


OUR COVER

Become a passenger aboard the US Coast Guard tall ship *Eagle* for an exciting maritime mobile operation. The adventure begins on page 54. (*Photo by Tom Hopkins; W1AW photo by W2ABE*)

CONTENTS

September 1988
Volume LXXII Number 9

TECHNICAL

NEWS AND FEATURES

OPERATING

DEPARTMENTS

Table 1
HF Band-Pass Filter Specifications

Band (MHz)	C1/C3 (pF)	C2 (pF)	L1/L3 (µH)	L2 (µH)	T-68-6 core L1/L3 (no. turns)	T-68-6 core L2	T-80-6 core L1/L3 (no. turns)	T-80-6 core L2	F_r (MHz)
1.8	4000	400	2.2	22	22	69	23	70	1.75
3.5	2000	200	1.1	11	16	48	16	50	3.38
7	1000	100	0.55	5.5	11	35	11	35	6.78
14	500	50	0.28	2.8	8	25	8	25	13.56
21	330	33	0.18	1.8	7	20	7	20	20.65
28	250	25	0.14	1.4	6	17	6	18	27.39

Toroidal Inductors

The inductors used in Lew's filters can be wound on a number of different toroidal cores, or they can be made from air-wound inductor stock. Toroidal inductors are preferred to air-core coils because the magnetic field of a toroidal inductor is contained almost entirely in the core, so toroidal inductors usually need not be shielded from other circuit components. This property allows filters with toroidal inductors to be built more easily, and into smaller enclosures, than those with air-wound coils.

The choice of toroidal cores for the inductors in Lew's filters depends mostly on exciter power level. For 100-W transmitters, cores as small as ½-inch OD (T-50-XX cores) can be used for the coils if there is little perceptible heating of the inductors when power is applied to the filters. If the core material saturates—which occurs when the flux density in the core rises beyond the safe region as a result of excessive applied power—the core can be destroyed. This is less likely to occur in the 0.68- and 0.80-inch OD cores (T-68-XX and T-80-XX, respectively).

Mix-6 powdered-iron material is used for the inductors in this article because its frequency response and Q characteristics are suitable, and because, for the inductances needed in these filters, relatively few turns are required on mix-6 cores. Which core to use is related to a compromise between the number of turns on the toroids and the ease of tuning the filters. Inductors made using T-80-6 or T-68-6 cores require about the same number of turns for a given inductance, but the turns will be spread over a larger area on the larger core, leaving more room for turn-spacing adjustments. If smaller (T-68) cores are used, the turns come closer to filling the core, making tuning easier.

Similarly, if you wind the inductors on T-50-6 cores (½-inch OD), the inductor turns will cover the cores more completely. Also, an inductor wound on a T-50-6 core requires more turns for a given inductance than one wound on a T-68-6 or T-80-6 core. Tuning these smaller inductors is easier, because removing one turn from a coil with 20 turns of wire is easier than removing ½ turn from a coil with 10 turns! Also, the placement of the remaining turns is less critical to inductor value on a coil with more turns. Using smaller cores is fine as long as the core material doesn't saturate when power is applied to the filter.

Choosing toroidal cores is easy to do. Using a scientific calculator, the inductance values given in Table 1 and published values for the number of turns necessary for a given inductance on a certain core, you can determine the coil-winding information for that core. Each toroidal core has an A_L value, which simply represents the number of microhenrys that 100 turns of wire will produce on that core. The A_L values for common cores are given in manufacturer's literature, *The ARRL Handbook* and other sources.† To calculate the number of turns necessary for a given inductance on a toroidal core, use

$$N = 100 \times \sqrt{L/A_L} \quad \text{(Eq 1)}$$

where

N = number of turns
L = required inductance in µH
A_L = no. of µH per 100 turns

For a 5.5-µH inductor (the value of L2 in the 40-meter filter) on a T-68-6 core (A_L = 47),

$$N = 100 \times \sqrt{5.5/47} = 34 \text{ turns.} \quad \text{(Eq 2)}$$

Wound on a T-50-6 core (A_L = 40), the same inductor would require

$$N = 100 \times \sqrt{5.5/40} = 37 \text{ turns.} \quad \text{(Eq 3)}$$

The smaller size of the T-50 core and the few extra windings makes tuning a bit easier, and reduces the chance of changing the inductor value by accidentally rearranging the winding during handling. After building filters using smaller inductors, make sure the cores don't heat perceptibly during operation, or they may be damaged.—*Rus Healy, NJ2L*

†A_L values and other winding information for powdered-iron toroids is given in M. Wilson, ed., *The 1988 ARRL Handbook* (Newington: ARRL, 1987), p 2-34.

(see Fig 2). This layout is simple enough that the boards can be prepared using an X-acto® knife, although if construction of many boards is anticipated (or if "ugly" construction offends you), etched PC boards might be desirable. Each filter is mounted in an aluminum enclosure. Install SO-239, BNC, or phono connectors at each end of the enclosures for input and output connections. The filter pictured in the title photograph is built in a Hammond 1590N enclosure.

A parts-placement diagram for the filter components is shown in Fig 3. All inductors can be wound on Amidon or Palomar T-68-6 toroids, although larger T-80-6 toroids may be used, if desired.[3] In an early design using T-50-2 toroids, the windings became warm with 100 W output, so I decided to use larger T-68-6 cores. (See the sidebar, "Toroidal Inductors.") All inductors are wound with no. 20 enameled wire, with the exception of L2 on the 3.5- and 7-MHz filters, which must be wound with no. 24 or smaller wire if T-68-6 cores are used. If you use T-80-6 cores, you can use larger wire for these inductors. In winding the inductors, start with the number of turns specified in Table 1, and space the turns evenly over about 75% of the core. Leave three or four inches of extra wire on each inductor for adjustments.

I used silver-mica capacitors in all the filters, but polystyrene capacitors can be substituted, and they're cheaper. The capacitors you use should be rated at 500 V or more. If you have access to an impedance bridge or capacitance meter, you could use 20%-tolerance disc-ceramic capacitors with adequate voltage ratings, after finding those close enough in value to do the job.

Tuning the Filters

Final adjustment of the inductors requires a dip meter. (If you have access to a network analyzer or impedance bridge, so much the better, but a dip meter will work fine for this job.) Solder each capacitor across its corresponding inductor to make a parallel LC circuit. Leave sufficient space between the leads to couple the dip meter into the circuit. The values for F_r in Table 1 are the resonant frequencies for C1/L1, C2/L2 and C3/L3 for each filter. Adjust the dip-meter frequency and watch for a dip. Be sure to couple the dip meter very lightly to the circuit being measured, and look for the frequency that produces a barely observable dip. Because my dip meter is 25 years old, I use a general coverage receiver to verify the meter's frequency readings. Of course, this is a good practice any time you use a dip meter.

Fine adjustment of the resonant frequencies specified in Table 1 can usually be done by spreading or compressing the coil turns on the cores. If necessary, add or remove one turn at a time from each coil until resonance occurs near the specified F_r. When the resonances correspond to the F_r

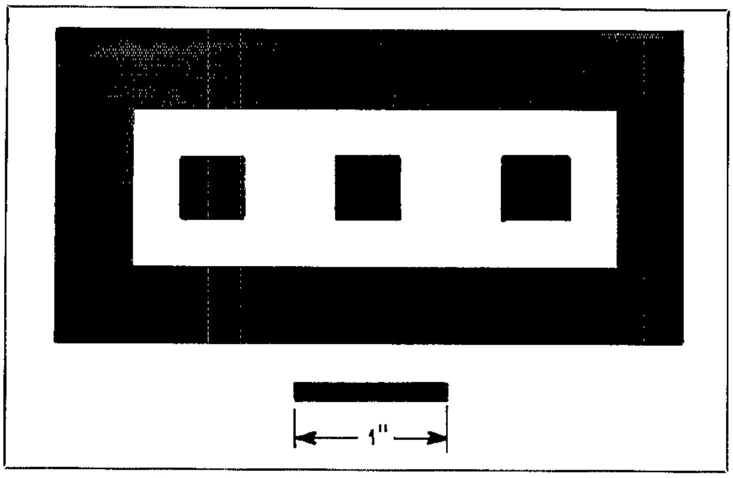


Fig 2—Full-size, foil-side PC board pattern for the three-pole band-pass filters. Shaded areas represent unetched copper foil. Components are soldered on the foil side.

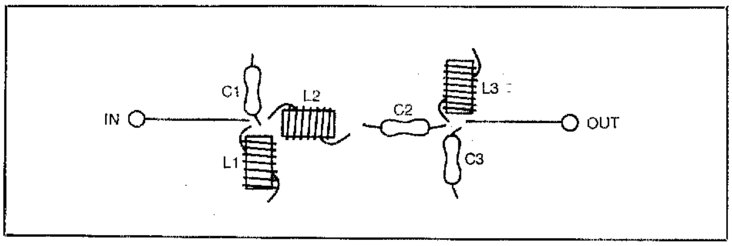


Fig 3—Parts-placement diagram for the three-pole band-pass filters. Input and output connections can be made with small coaxial cable or short lengths of hookup wire. Be sure to make a good connection from the ground foil of the PC board to the enclosure and connector grounds. See the title photograph.

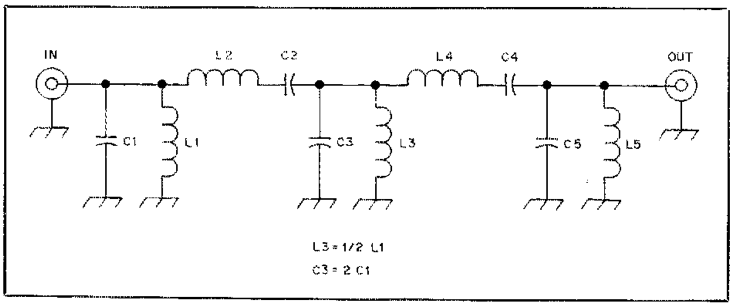


Fig 4—Schematic of a five-pole Butterworth band-pass filter. The same construction techniques as used for the three-pole filters should be used when building five-pole versions.

Table 2

Filter Loss v Frequency*

Band (MHz)	*Loss (dB) at freq (MHz)* 3.5	7	14	21	28
3.5	<0.5	29	50	>65	>65
7	30	<0.5	32	41	49
14	56	32	<0.5	16	40
21	63	44	8	<0.5	15

*Not measured at 1.8 or 28 MHz.

values in Table 1, unsolder the capacitors. Then, without disturbing the placement of the turns on the core, coat the inductors with Q Dope® or spray paint, and trim the leads to about ¾ inch. When the inductors have dried, solder them to the designated spots on the PC board. Solder in the capacitors and mount the filters in the enclosures.

If you have access to a network analyzer, you can use it to help optimize the overall filter performance. Using a borrowed HP-8656B signal generator and a 50-Ω terminated RF voltmeter, I measured the filter characteristics shown in Table 2.[4]

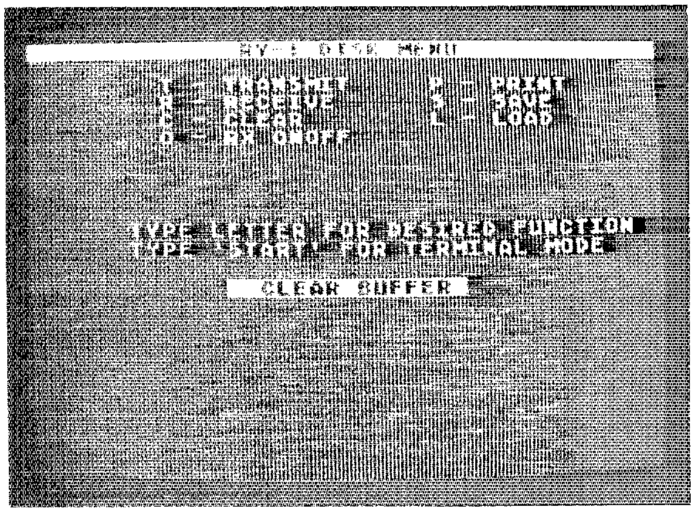
The insertion loss of these filters is less than 0.5 dB across the bands for which they are built, so obtaining adequate amplifier drive when transmitting through the filters should not be a problem. The major advantage of these filters is the near-total elimination of the phase-noise interference they provide when transmitters and receivers are operated on adjacent bands in close proximity to each other. Although the isolation they provide between the 14- and 21-MHz bands, and between the 21- and 28-MHz bands, is less than the isolation possible between bands that differ in frequency by a 2:1 or greater ratio, the filters are good enough to practically eliminate phase noise and effectively reduce intermodulation problems at my station. On 28 MHz, I can barely detect the noise from the 21-MHz transmitter, where the filter attenuation is only 15 dB (I don't use a filter on the 28-MHz rig). The relatively low attenuation of the 21-MHz filter at 28 MHz may be a result of the fact that the 21-MHz filter I use was constructed using air-wound no. 14 wire in self-supporting coils (instead of toroidal inductors) for L1 and L3 in that filter. The close proximity of these air-wound coils allows mutual coupling, which deteriorates filter performance. If you build these filters using air-wound inductors, use shields between the inductors to reduce coupling. Toroidal forms should be used, if possible.

If problems with phase-noise interference persist after installation of these filters, five-pole Butterworth filters may solve the problem. (A five-pole filter is essentially two cascaded three-pole filters.) The center section of the filter combines the output section of one three-pole filter with the input section of the other, and should have twice the capacitance and half the inductance of the end sections of the corresponding three-pole filters to maintain 50-Ω impedance (see Fig 4). Rejection should be considerably more than the values shown in Table 2. F_r is the same for the center section as for the others. Insertion loss for the five-pole filters will be slightly greater than the three-pole versions, but this is a small price to pay for interference-free operation. If a five-pole filter doesn't do the job, you may want to seriously consider replacing the troublesome transceiver!

In the past, vast improvements in selectivity, sensitivity and dynamic range that we enjoy today in Amateur Radio equipment have come about as direct results of amateurs making their feelings about equipment performance known to manufacturers. Manufacturers should seriously consider incorporating additional bidirectional filtering in their transceiver designs—users

(continued on page 23)

Baudot and ASCII RTTY Programs for Atari Computers



You can put Baudot and ASCII RTTY at your fingertips conveniently—and at low cost! Why wait to join in on the fun?

By Steven Stuntz, NØBF
1656 South California St
Loveland, CO 80537

Here are two more plug-and-play programs to add to the existing library of CW, RTTY and packet-radio software published in *QST* for Atari computers.[1-6] Now there are five programs—covering four modes—that you can easily run on these low-cost computers. If you haven't already bought one of the inexpensive 8-bit Ataris (or dug one out of your closet or attic), do it! Some Atari 400 and 800 computers can be found at yard sales for nearly nothing, and the Atari 65XE and 800XL computers can be purchased from mail-order houses for $100 or less. For such a small cash outlay, using one of these compact computers as a dedicated communications terminal is not only a temptation that's hard to resist, but a good idea, too! If you already have another computer, you can free it up for other, perhaps less enjoyable, uses—such as work...

General Description

I'll describe two programs: one for Baudot RTTY, the other for ASCII RTTY. There are some fundamental differences between the two programs. The Baudot code uses five bits per character; the ASCII code uses seven bits per character. Baudot RTTY allows the use of a maximum of 63 characters, and all alphabetic characters are uppercase only. On the other hand, ASCII RTTY permits the use of 128 characters, including upper- and lowercase alphabetic characters. Another difference is speed. The Baudot RTTY program runs at a maximum of 100 WPM; the ASCII RTTY program hits 300 bit/s.

Both the programs I've written run on the Atari 400, 600XL, 800, 800XL, 1200XL, 65XE and 135XE computers. Each program offers the following features:

- A split-screen, scrolling display.
- A 255-character type-ahead buffer.
- Three 255-character volatile (temporary) message buffers.
- Disk storage and retrieval of messages.
- Printer output.
- Word-wrapping for received and

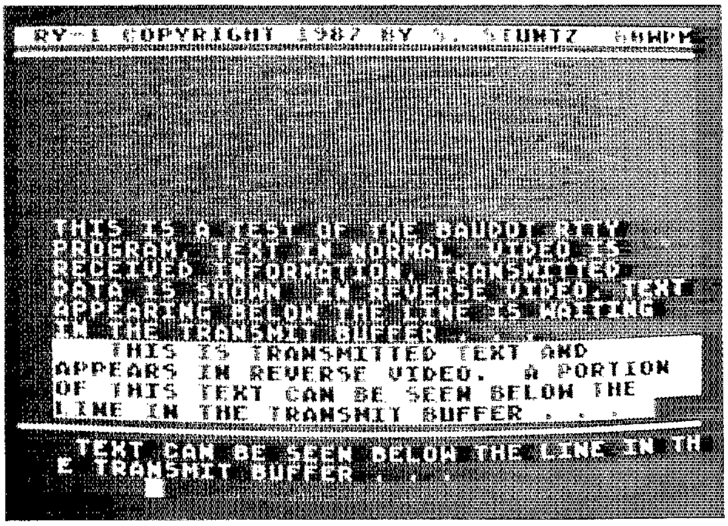


Fig 1—A sample of how the terminal-mode display screen appears during Baudot RTTY operation. A portion of the transmitted text previously stored in the transmit buffer can be seen below the lower screen-dividing line. Note the RY-1 (Baudot RTTY program) identifier in the upper-left corner of the screen. The current speed of operation is displayed in the upper-right corner of the screen.

[1]Notes appear on page 23.

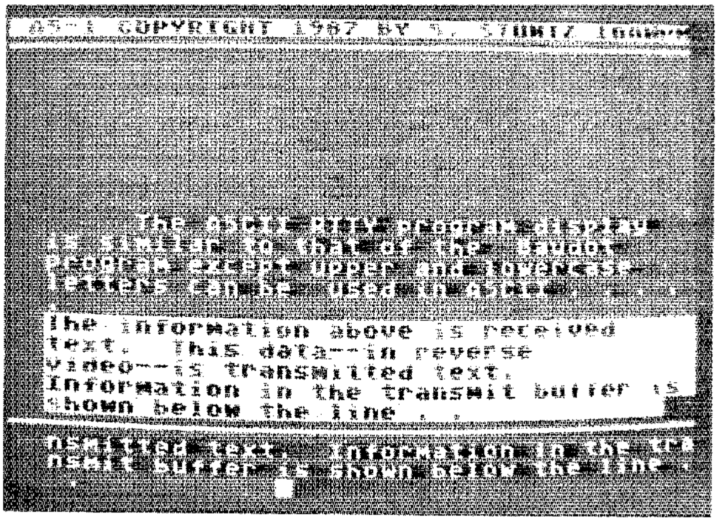


Fig 2—Here's what the ASCII RTTY terminal-mode screen looks like. At the upper-left, AS-1 identifies the program; data-transfer speed is shown in the upper-right screen corner. Here you can see the use of lowercase letters (not available in Baudot RTTY).

transmitted messages.

- Baudot RTTY speeds of 60, 67, 75 and 100 WPM.
- ASCII RTTY speeds of 75, 100, 150 and 300 bit/s.

With the two-window, split-screen format I devised, the upper window displays received messages in normal video. Transmitted information is shown in reverse video. The lower window displays the type-ahead buffer contents. (See Figs 1 and 2.)

Word-wrapping is used in the upper window. This feature prevents words from being split between two lines. Any word of 14 characters or less that extends beyond the 38th screen column is moved to the next line. Carriage returns are converted to spaces to make maximum use of the 40-character-wide display.

The word-wrapping technique used for outgoing information prevents data from being lost by mechanical teleprinters (because of type-over) when long sentences are sent. Both programs automatically generate a carriage return when a space appears after 57 characters have been sent without the operator having issued a carriage return. Also, a carriage return is automatically generated after 72 characters have been sent without an intervening space.

Of course, you need a modem or communications processor. (See "A Cheap n' Easy Modem" and "A Simple Tuning Indicator," described in the June and July issues of *QST*.[7,8]) The modem or communications processor (CP) converts the received tones to TTL levels for the computer, and turns the TTL-level output of the computer into tones for the transmitter. If your CP requires RS-232-C levels, there's a simple and inexpensive way to provide them.[9]

Program Design

I wrote the Baudot and ASCII RTTY programs in assembly language. Because I wanted the programs to run on any 8-bit Atari computer with a minimum of 16 kbytes of RAM, the programs couldn't be combined. Therefore, each program is contained in a separate 2732 EPROM.

A keyboard-and-screen loop and an interrupt loop similar to those described in my November *QST* article (see note 6) are at the heart of each program. The keyboard-and-screen loop polls the keyboard for a keypress and stores a bit representation of the character in the transmit buffer. For the Baudot program, this character representation requires 8 bits: one start bit, five bits for the Baudot character and two stop bits. In the ASCII program, 10 or 11 bits are used: one start bit, seven bits for the character, one parity bit (not used) and two stop bits—one stop bit for speeds other than 100 WPM. A more detailed description of these formats can be found in Chapter 19 in recent editions of *The ARRL Handbook.*

The keyboard-and-screen loop also checks the receive buffer for data. In both programs, this loop converts the incoming character to an Atari screen code before writing it to the screen.

Received and transmitted data is transferred between the computer and CP by the interrupt loop. For each bit sent or

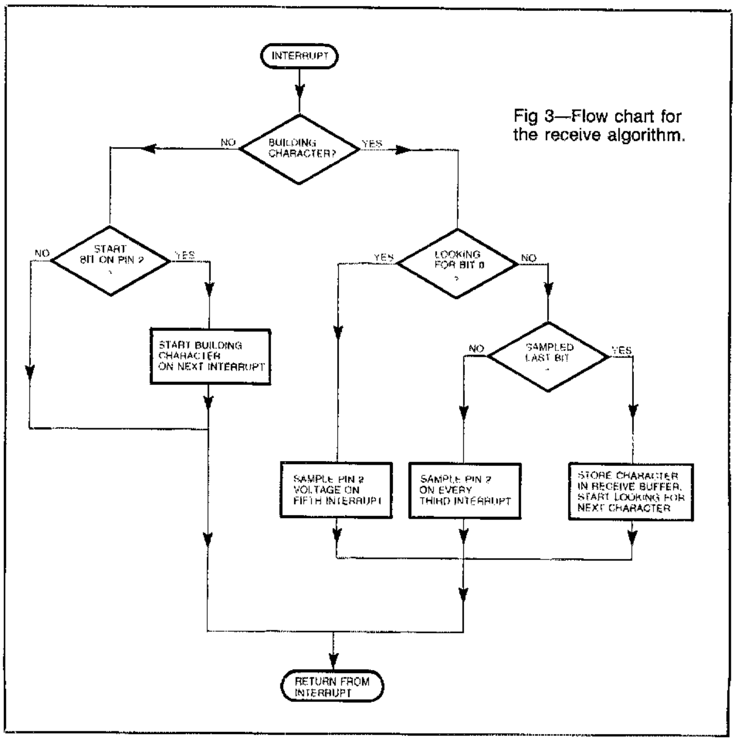


Fig 3—Flow chart for the receive algorithm.

received, this loop is executed three times. The interrupt timer is a divide-by-N counter running at 1.79 MHz. The length of time between interrupts is determined by the number (N) stored in the audio-frequency registers AUDF1 (low byte) and AUDF2 (high byte) where:

$$N = \frac{1{,}790{,}000 \times 0.996}{3 \times \text{data rate}} \quad \text{(Eq 1)}$$

A multiplier of 0.996 is used to reduce N by 0.4% to compensate for the time required to process each interrupt. For example, N equals 13,075 when the Baudot program is set to 60 WPM (45.45 bauds), and N equals 5403 when the ASCII program is set to 100 WPM (110 bauds).

Receiving Algorithm

A flow chart of the receiving algorithm is shown in Fig 3; it's the same one used in my packet program (see note 6). Fig 4 shows the waveforms that are present on pin 2 of CONTROLLER jack 1 when receiving the letter Y. The routine begins by sampling the voltage on pin 2, looking for a start bit (a transition from +5 V to 0 V) to tell it to build a character. Once a start bit is detected, the routine waits for four interrupt intervals, then samples the voltage on pin 2 during the fifth interrupt. The value of this voltage sample is stored as bit 0 of the character. Bit 0 is a 1 if the voltage on pin 2 is 0 V, and a 0 if +5 V is present.

Next, the routine determines bit 1 by waiting for three interrupt intervals and sampling the voltage on pin 2 during the eighth interrupt. The remaining bits that make up the character are determined by sampling the voltage present on pin 2 during every third interrupt until the entire character has been read. The routine finally stores the character in the receive buffer and repeats the entire process for the next character. As shown in Fig 4, the bit pattern for the letter Y stored in the receive buffer is 10101 for the Baudot program and 1011001 for the ASCII program.

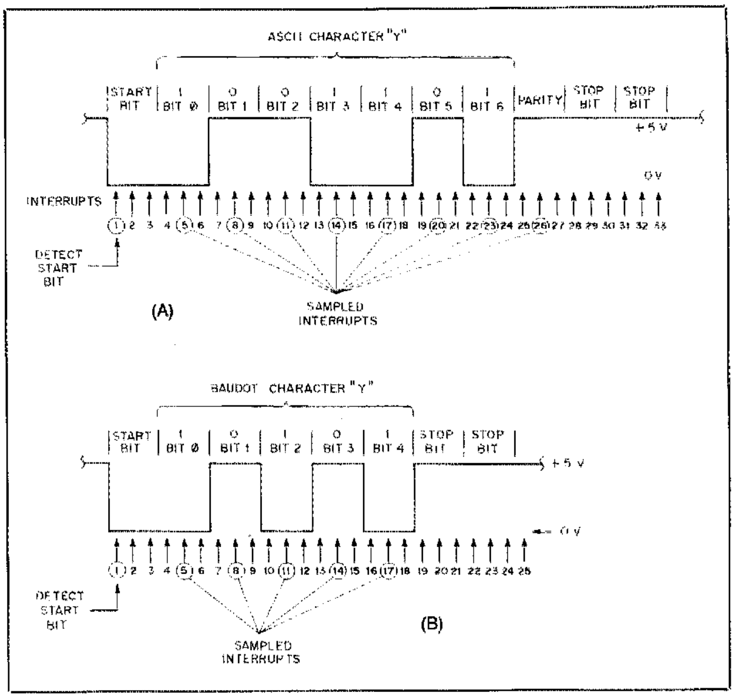


Fig 4—ASCII (A) and Baudot (B) waveforms present on pin 2 of the Atari CONTROLLER jack 1 when receiving the character Y.

Program Operation

Fig 5 shows the connections required between the computer's CONTROLLER jack 1 and the CP. No pin numbers are shown on the CP connector as they vary from one unit to another. Two display screens—a disk menu and a terminal mode—are used in the Baudot and ASCII programs.

Terminal Mode

When the computer is turned on, both programs come up displaying the terminal screen, ready to receive. On the terminal screen, received and transmitted messages are displayed (see Figs 1 and 2) above the screen dividing line. The transmit buffer is shown below the line. Table 1 lists the commands used to switch back and forth between receive and transmit status, edit user buffers and change the data rate.

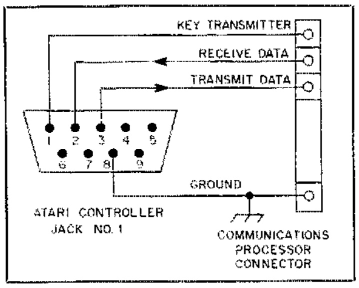


Fig 5—Pin connections for CONTROLLER jack 1 of the Atari computer. This is an outside view of the jack.

To transmit, press CONTROL T and begin typing. Outgoing messages up to 255 characters long may be entered into the type-ahead buffer while receiving data. This buffer will hold the outgoing message until CONTROL T is pressed.

Messages can also be stored in three user buffers. The information is first entered into the type-ahead buffer, then moved to the chosen user buffer by pressing the TAB key followed by the chosen user buffer number: 1, 2 or 3. A message in a user buffer may be moved to the type-ahead buffer by pressing the ESC key, followed by the user buffer number. As mentioned earlier, all buffers are volatile so, when you turn off the computer, the information is lost.

Disk Menu

Press the SELECT key to bring up the disk menu shown in the title photo. From this menu, you can store and retrieve messages to and from disk, and send information to the printer. The commands to perform these functions are shown in Table 1. Pressing the START key returns both programs to the terminal screen.

Using a Printer

The following steps describe how to send information to a printer.

1) Press the SELECT key to bring up the disk screen menu.
2) Press the R key.
3) Press the START key.
4) Perform the terminal work to be printed.
5) Press the SELECT key.
6) Press the P key to print the message.
7) Press the START key.

Storing a Message on Disk

Information can be stored in a disk file

Table 1
Command Functions

Terminal Menu Commands	Function
CONTROL T	Toggle transmit mode on
CONTROL R	Toggle receive mode on
CONTROL S	Change data rate
CONTROL CLEAR	Clear type-ahead buffer
BACK S	Backspace in type-ahead buffer
TAB (1, 2 or 3)	Move type-ahead buffer data into user buffer 1, 2 or 3
ESC (1, 2 or 3)	Move user buffer into type-ahead
Disk Menu Commands	*Function*
T	Transmit message from disk buffer to the CP
R	Store received data in disk buffer
C	Clear the disk buffer
O	Toggle receive mode on or off
S	Save the message in the disk buffer to a file on disk
L	Load a message from a disk file into the disk buffer
P	Print a message from the disk buffer

by replacing step 6 with the following procedure:

6a) Press the S key.

6b) Enter the file name (D:RY1.LIS, for example).

6c) Press the RETURN key.

Transmitting a Disk File

1) Press the SELECT key.

2) Press the L key.

3) Enter the file name (D:RY1.LIS, for example).

4) Press the RETURN key.

5) Press the T key.

The information stored in the file named D:RY1.LIS will be transmitted after the T key is pressed. Both programs are returned to the terminal screen before the disk message is sent.

Obtaining The Programs

Plug-in cartridge versions of both programs are available from me for $35 each. Disk, cassette and EPROM-only versions are $15 each. (The ARRL and *QST* in no way warrant this offer.) The assembler source-code listings for each program are available from the ARRL for $5 each to cover photocopying and handling costs.

You can purchase the EPROM only and build your own cartridge[10] by following the instructions given in the August 1986 article (see note 3). The cartridges are by far the easiest to use. This is particularly true if you change operating modes often.

Summary

I've enjoyed operating Baudot and ASCII RTTY with these programs. They're similar in structure and, with a little practice, are easy to use. The disk-storage and user-buffer features greatly enhance performance. Disk files can be used to store all sorts of information about your QTH, equipment, other hobbies and pictures or calendars!

Most any modem or CP will work with the Baudot RTTY program, but some modems, designed to accommodate Baudot RTTY only, may require modification to operate properly on ASCII. That's because the ASCII RTTY data rate is higher than that used with Baudot RTTY. Check your modem specifications; the maximum data rate should be at least 110 bauds in order to run ASCII RTTY at 100 WPM. If necessary, contact the modem manufacturer and see if they can supply you with any required modification information.

You can test both programs by copying ARRL bulletins transmitted by W1AW. The bulletins are first transmitted in Baudot at 60 WPM, then in ASCII at 100 WPM. Check *QST* for the current W1AW operating schedule.

Notes

[1]S. Stuntz, "A CW Keyboard Program for Atari Computers," *QST*, Feb 1985, pp 32-33.

[2]S. Stuntz, "A CW Receive Program for Atari Computers," *QST*, Nov 1985, pp 51-53; Feedback, *QST*, Feb 1986, p 53.

[3]S. Stuntz, "A CW Program Cartridge for the Atari Computer," *QST*, Aug 1986, pp 34-36; Feedback, *QST*, Apr 1987, p 59.

[4]R. Frohne, "Replacement Detector," Technical Correspondence, *QST*, Jul 1987, p 41.

[5]R. Lewis, "Split-Screen RTTY for Atari Computers," *QST*, May 1987, pp 16-20.

[6]S. Stuntz, "A Packet Terminal for Atari Computers," *QST*, Nov 1987, pp 15-17; Feedback, *QST*, Jan 1988, p 49.

[7]T. Miller, "A Cheap n' Easy Modem," *QST*, Jun 1988, pp 15-21.

[8]T. Miller and E. Hare, "A Simple Tuning Indicator," *QST*, Jul 1988, pp 28-31. See Feedback, this issue, p 48.

[9]S. Stuntz, "Easy RS-232-C," Technical Correspondence, *QST*, Apr 1988, p 46.

[10]Cartridge cases and PC boards are available from Best Electronics, 2021 The Alameda, Suite 290, San Jose, CA 95126, tel 408-243-6950. Cartridge cases, $1.50 each; PC boards, $1 each (minimum order, $5). The ARRL and *QST* in no way warrant this offer.

Steve Stuntz has a BSEE degree and is a licensed professional engineer in the state of Colorado. He is the Director of the System Planning and Analysis Division of the Western Area Power Administration. Steve's responsible for planning improvements to the high-voltage transmission system in Colorado and Wyoming to accommodate future energy requirements. Steve has been a ham for 28 years; he received his Novice ticket when he was 13 years old. As an amateur, Steve enjoys QRP CW work and designing computer applications for Amateur Radio. Steve's other interests include biking, skiing and hiking.

Band-Pass Filters for HF Transceivers

(continued from page 19)

not be forced to add these devices. We cannot control the received spectrum before it reaches our gear, but we *can* control the transmitted spectrum. I think that a few less memories, fewer confusing front-panel buttons, and a little more attention by some manufacturers to a clean output spectrum would be appreciated by everyone.

If your local radio club plans a serious multiple-transmitter effort for Field Day, you may want to consider making it a club project to construct these filters. Many of the components are probably available among your membership from junk boxes or "retired" projects. These filters could keep your club's Field Day effort, or your next multitransmitter contest effort, from turning into a disaster!

Notes

[1]For more information on phase noise, see J. Grebenkemper, "Phase Noise and its Effects on Amateur Communications," *QST*, Mar 1988, pp 14-20, and Apr 1988, pp 22-25. Also see Feedback, *QST*, May 1988, p 44.

[2]L. Gordon, "Bandpass Filters for Transmitters," *National Contest Journal*, Mar/Apr 1987, pp 19-20.

[3]Amidon toroidal cores are available from Amidon Associates, 12033 Otsego St, N Hollywood, CA 91607. Palomar toroids can be obtained from Palomar Engineers, PO Box 455, 1924-F W Mission Rd, Escondido, CA 92025, tel 619-747-3343.

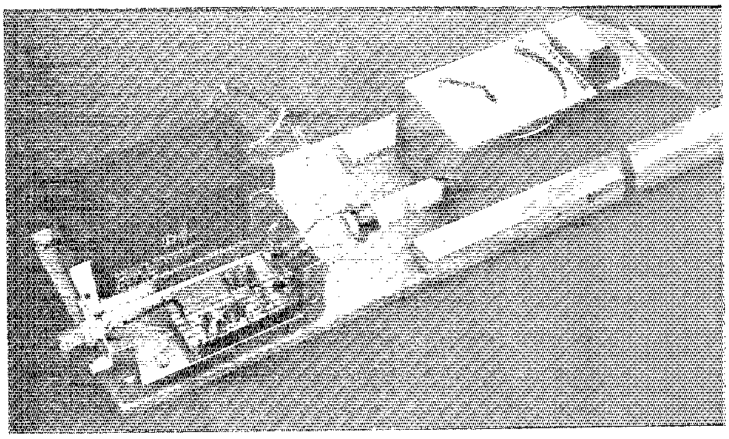
[4]Rejection values for 1.8, 24.9 and 28-MHz filters were not measured. Because of its close proximity to the 21- and 28-MHz bands, no filter component values for the 24.9-MHz band are given in Table 1.

Lew Gordon has been a licensed ham since he was 17 years old in 1947, and earned his Extra Class ticket in 1952. He has held K4VX since 1973. Lew earned a BS degree in physics from Purdue University and did graduate-level work at Georgetown University. Presently, Lew is a semiretired systems engineering consultant for government and private agencies. Lew's wife holds NS0Z, and his daughter is licensed as N0HVY.

An active member of the Society of Midwest Contesters, Lew's main love in Amateur Radio is antenna-system design and construction. His antenna farm is currently composed of eight towers ranging in height from 50 to 170 feet, and includes rotatable antennas for 40 through 10 meters. All his antennas are homemade, except for one 2-element 40-meter beam. His other radio interests include using computers to optimize antenna designs and to perform contest-log duping.

A Dipper Amplifier for Impedance Bridges

Planning to work with antennas? This dip-oscillator amplifier is inexpensive, compact and can be constructed with readily available parts in one afternoon.



By Andrew S. Griffith, W4ULD
203 Lord Granville Dr, Rte 2
Morehead City, NC 28557

If you experiment with antennas, an impedance bridge is a useful tool. Many bridges are designed to be driven by a dip oscillator. Solid-state battery-powered dip oscillators, however, sometimes do not have enough output to drive an impedance bridge. This simple amplifier solves that problem.

My impedance bridge is patterned after one in The *1988 ARRL Handbook.*[1] The battery-powered amplifier shown in Fig 1 operates class A and draws about 32 mA from a 12 V dc source. The amplifier drives the bridge to at least half-scale meter readings from 3 to 60 MHz when used with my Heath® solid-state dip meter. The combination provides useful readings up to 100 MHz.

Building the Amplifier

Construction of the dip-oscillator amplifier is simple and parts are readily available. The circuit board is made from a 1-3/8- × 2-1/4-inch piece of double-sided, glass-epoxy board; no etching is required. Following the pattern in Fig 2, cuts in the foil on the top, or component side of the board, are made with a hacksaw.[2] One way to do this is to first drill the mounting holes, then screw the board to a small block of wood to keep it flat. Place the block of wood (with the board attached) into a vise such that the block is below the top of the vise jaws and the sides of the jaws are aligned with the cut to be made. The sides of the vise jaws act as a guide for the hacksaw blade. Keep the saw blade parallel to the vertical edge of the circuit board and cut through the copper foil only. Components are mounted to the side of the board (see Fig 3) where the saw cuts are made. Ground leads are passed through countersunk holes and soldered to the bottom foil. Other leads are soldered directly to the pads formed by the saw cuts.

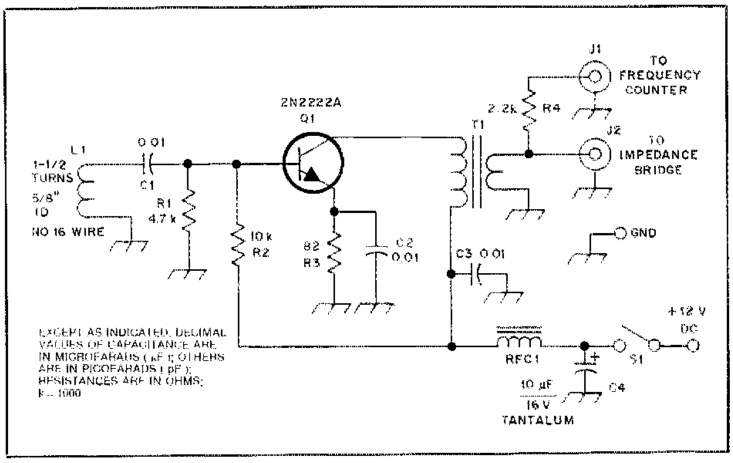


Fig 1—Schematic of the battery-powered dipper amplifier. All resistors are ¼-W units. Capacitors are disc ceramic unless otherwise noted.

J1—Phono jack.
J2—SO-239.
L1—1½ turns no. 16 enam wire, 5/8-inch ID.
Q1—2N2222A or Radio Shack® 276-2009 NPN transistor.
RFC1—3 turns no. 26 enam wire through an Amidon FB-43-101 bead (about 4.6 µH).
T1—Primary: 17 turns no. 26 enam wire covering entire circumference of an Amidon FT-23-43 core; secondary: 6 turns no. 26 enam wire over primary. (For use on 1.8 MHz, use 25 turns on the primary and 9 turns on the secondary; see text).

[1]Notes appear on page 76.

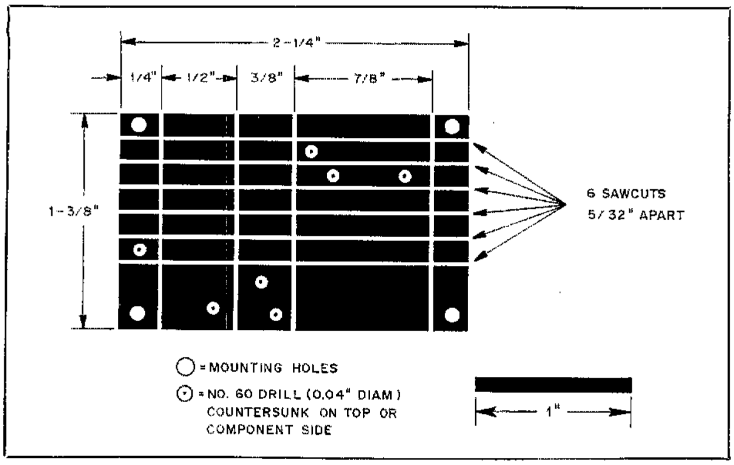


Fig 2—Circuit-board cutting pattern for the dipper amplifier (see text).

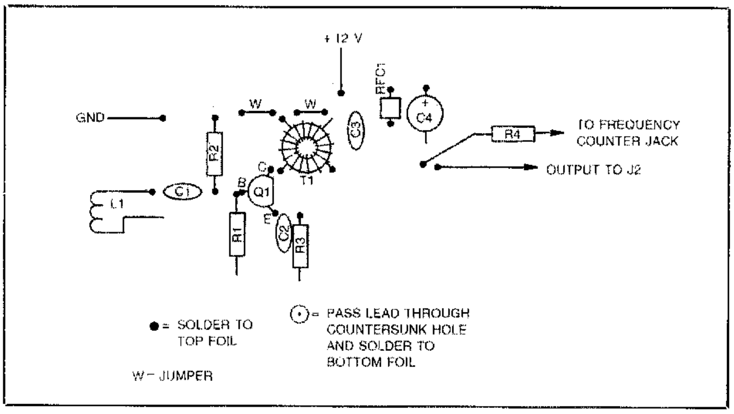


Fig 3—Parts-placement guide for the dipper amplifier. Parts are placed on the saw-cut side of the board.

The pick-up coil, L1, is made of no. 16 wire and is self-supporting. It has a 5/8-inch inside diameter to allow the coils of the Heath dipper to fit inside the loop. I mounted my amplifier in a 4 × 2 × 1-5/8-inch aluminum box. L1 projects beyond the end of the box by 1¼ inches. The coaxial output connector is mounted in the opposite end of the box.

The assembly shown in Fig 4 is mounted on a 14 × 4¼-inch piece of ¼-inch-thick plywood. The amplifier box is screwed to the plywood platform, and the dipper sits on the platform between two wooden rails. These rails keep the dipper coil aligned with L1 and permit the dipper to be moved back and forth to make coupling adjustments between the dipper and the amplifier. Two heavy rubber bands hold the dipper in place on the platform.

Using the Dipper Amplifier

Connect the amplifier to a 12 V dc battery. I use a 1.2-Ah gelled-electrolyte battery. When the amplifier is turned on, check that the current drawn is about 32 mA. If the current drain differs significantly from this figure, recheck your wiring. Since the amplifier draws only 32 mA, a battery made of eight AA cells should last quite a while.

To use the amplifier, connect the impedance bridge to the amplifier. Adjust the position of the dipper so that one-third of the dipper coil is inside L1. Turn on the amplifier and the dipper, and advance the dipper level control until the bridge meter deflects. If no reading is observed, change the position of the impedance dial on the bridge. Slide the dipper back and forth, near and into L1, until a maximum reading is obtained on the bridge meter. Adjust the

(continued on page 76)

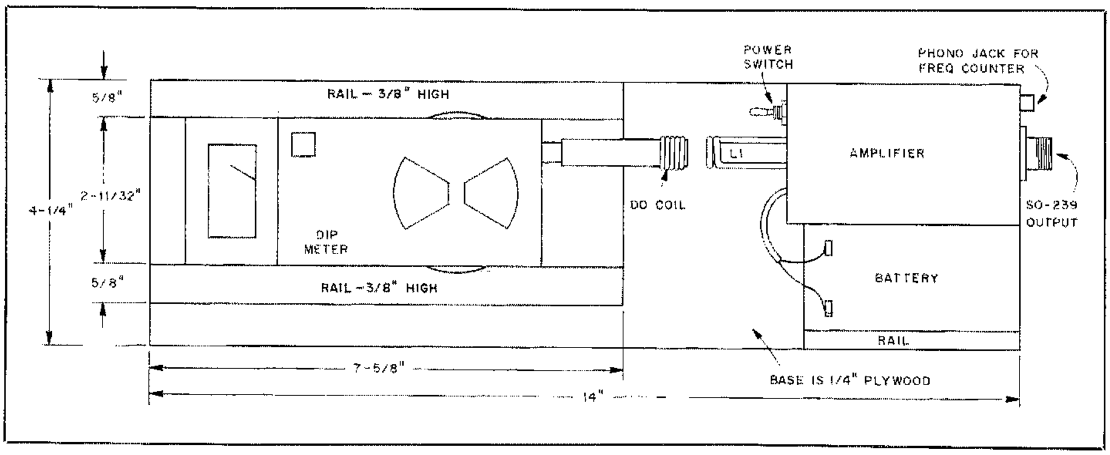


Fig 4—Top view of the amplifier box/dip-meter assembly. See text for an explanation of how the unit works.

A Simple Resonant ATU

Eliminate roller inductors and tapped coils with this simple HF-band Transmatch. This circuit is suitable for QRP or QRO.

By Doug DeMaw, W1FB
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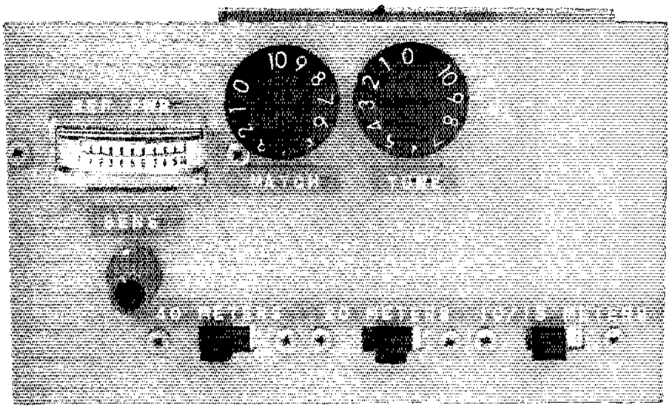

Are you weary of looking for expensive roller coils? Do tapped coils in ATUs (antenna tuning units) fail to provide the inductance resolution you need for matching a broad range of impedances? We are kindred souls if your answers to these questions are "yes." The roller-coil problem is even more acute for a QRPer: Tiny roller inductors that fit the small format of QRP gear are not available. The remaining option is a tapped coil and switch.

The circuit I shall discuss in this article is by no means new or original. The manner in which I am using it is, however, a bit uncommon. Fig 1 illustrates the circuit. Unlike other Transmatch circuits, this one is resonant at the operating frequency. Most tuners contain elements of L and C, which are used to cancel inductive or capacitive reactance in an antenna circuit. Circuit resonance is not a criterion. The popular T match that is used in most commercial Transmatches is an example of a nonresonant ATU. A resonant Transmatch offers the advantage of simplicity and harmonic reduction.

A Closer Look at the Circuit

Please refer to Fig 1. The main part of the circuit is L1 and L2, along with C1. Here we have a standard tuned circuit or resonator. L1 is the coupling link into the tuned circuit. As shown, C1 and L2 form a resonant 80-meter circuit. C2 has been added to permit matching the signal source (transmitter) to the load. A matched condition will prevail at some setting of C2. This is a very old trick that has been with us for decades.

There is considerable interaction between C1 and C2, since the greater the capacitance at C2, the less capacitance we need at C1 to maintain tuned-circuit

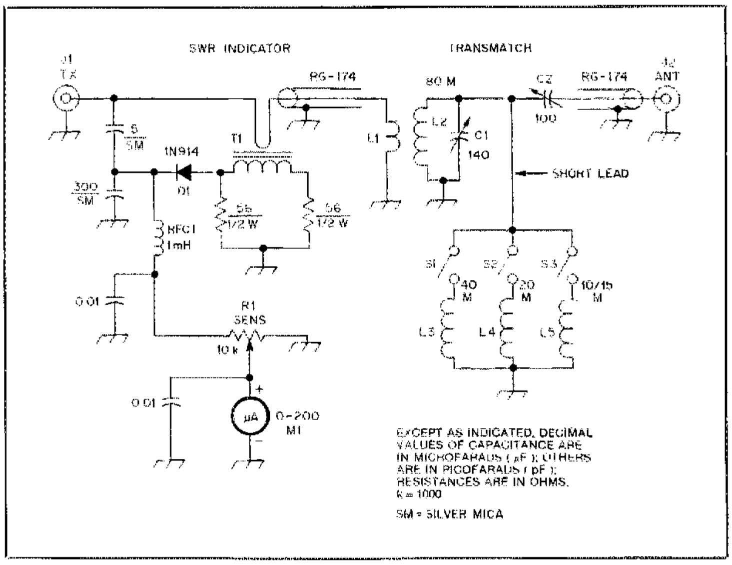

Fig 1—Schematic diagram of the SWR bridge and Transmatch. Fixed-value capacitors are disc ceramic unless noted otherwise. Fixed-value resistors are carbon composition.

C1—Miniature 100- or 140-pF air variable.
C2—10-100 pF trimmer with shaft (see note 1) or 100-pF air variable.
D1—Silicon high-speed switching diode, type 1N914 or equiv.
J1, J2—Single-hole mount phono jack or S0-239.
L1—6 turns of no. 22 insulated wire over ground end of L2.
L2—28-µH inductor. Use 70 close-wound turns of no. 22 enamel wire on a 7/8 × 2-inch length piece of PVC pipe.
L3—10-µH inductor. Use 30 turns of no. 26 enam wire, closely wound, on a 5/8 × 1-inch piece of PVC pipe.
L4—2.6-µH inductor. 16 turns of no. 20 enam wire, closely wound, on a 5/8 × 1-inch piece of PVC pipe.
L5—0.85-µH inductor. Use 9 turns of no. 20 enam wire on a 5/8 × 1-inch piece of PVC pipe. Space turns to occupy 5/8 inch.
M1—Small edgewise tuning meter, 200 µA. Surplus S meter used here with scale from page 35, July 1986 *QST* glued to meter face.
R1—Linear-taper, 10-kΩ potentiometer, carbon composition.
RFC1—Miniature 750-µH or 1-mH RF choke.
S1, S2, S3—SPST slide switch (see text).
T1—Toroidal transformer. Use 35 turns of no. 26 enam wire on an Amidon FT-50-61 ferrite toroid (µ = 125). Primary has 1 turn of no. 26 enam wire.

resonance. In other words, the C2 capacitance adds to that of C1. For this reason we must adjust C1 and C2 alternately as we tune for minimum SWR, just as with conventional ATUs.

How do we solve the problem of multiband operation? A simple solution is provided by adding L3, L4 and L5. These coils are switched in parallel with L2 by means of S1, S2 and S3. A single-pole, three-position wafer switch can be used in place of the individual switches, although it would limit the flexibility of the circuit. I will discuss this later. As is the situation when we place resistors in parallel, coils that are placed in parallel have a net value that is less than that of the smallest coil in the combination. Therefore, we simply add L3 to the circuit for 40-meter operation, L4 for 20 meters and L5 for 10- and 15-meter operation. The 30-meter band can be covered in the 40-meter range, and 12 meters falls into the 10-15 meter range.

The advantage in placing the smaller coils in parallel with the large one is that the L1/L2 turns ratio remains the same as when only the main coil is being used. L1 can be eliminated by tapping the coil six turns above the grounded end. I chose the link method because it is easier to deal with than a coil tap. I wanted to avoid the potential of shorted turns with small wire.

The main coil has an inductance of 28 μH. The effective circuit inductance is 7.5 μH when L2 and L3 are in parallel. L2 + L4 = 2.4 μH and L2 + L3 = 0.82 μH. If all four coils are placed in parallel the net inductance becomes 0.6 μH. The singular coil inductances are given in the Fig 1 caption.

SWR Indicator

You may eliminate the SWR-sensing circuit in Fig 1 if you have a separate SWR meter to use with this tuner. I included this circuit for my convenience when operating afield with QRP equipment. I did not include the circuitry for reading the forward power. My concern is for obtaining a matched condition between the transmitter and the antenna. Therefore, I need only the reflected-power information. T1 samples the RF current (reflected). D1 rectifies the current and produces a dc voltage that is indicated at M1. The ATU is adjusted for minimum needle deflection at M1. R1 is a sensitivity control that prevents the meter from reading off scale during tuner adjustments. The SWR bridge is designed for QRP operation, as shown. A transmitter power output of 1 watt or greater will provide full-scale deflection at M1.

Construction Data

Fig 2 shows the first-run constructional detail of the coil subassembly. You will note the presence of two shaft-driven compression trimmers. I later changed C1 of Fig 1 to a small APC style air variable. This was done to eliminate mechanical problems that resulted in very "touchy" adjustment of C1. The trimmers are 10-100 pF units with 1/8-inch OD shafts.[1] I drilled holes in the ends of two ¼-inch wooden dowel rods, then glued the trimmer shafts into the dowel rods with epoxy cement. This allowed the use of standard knobs with ¼-inch holes.

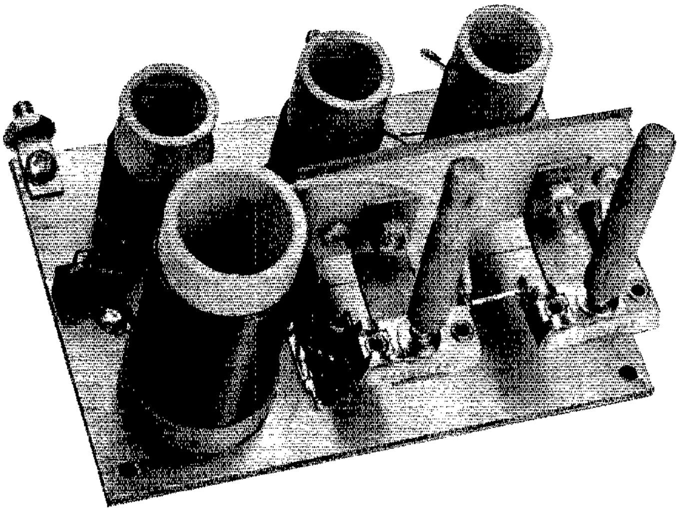

Fig 2—The ATU subassembly before C1 was replaced with a small air-variable capacitor. Holes are punched in the base plate (PC board material) to accommodate the OD of the coil forms. The coils are cemented into the holes with epoxy glue. A small shelf is soldered to the base plate to allow mounting C1 and C2. A plastic block insulates C2 from ground. Wooden dowel rod is glued to the capacitor shafts to allow the use of knobs with ¼-inch holes. The ends of the dowels are ground down to a true ¼-inch diameter.

Schedule-40 PVC tubing is used for the coil forms. PVC is not suitable for high-power use, since it will heat and melt in the presence of high RF voltage. PVC is entirely acceptable for power levels under 50 watts. L2 is wound on 3/4-inch PVC pipe, which has an OD of 7/8 inch. The remaining coils are wound on 1/2-inch PVC pipe (5/8 inch OD). All of the coils are mounted on the subassembly base plate by gluing them into holes (5/8 and 7/8 inch diameter) that are cut in the PC-board base plate. Epoxy cement is good for this purpose. The coils are spaced apart 1 inch, center to center. The base plate is made from double-sided PC board (2½ × 3¾ inches). The grounded ends of the coils are soldered to the base plate.

Fig 2 shows a 1½ × 2-inch shelf upon which the trimmer capacitors are mounted by means of metal L brackets. A plastic insulator is bolted to the shelf to allow C2 of Fig 1 to be isolated from ground. The PC-board shelf is soldered to the base plate, and a small triangular PC-board bracket is soldered between the bracket and base plate (at each end of the shelf) to strengthen the shelf. Two no. 6 spade bolts are used to affix the subassembly to the main chassis of the ATU. You may use brass or aluminum for the base plate and shelf if you prefer.

I made my chassis and panel from PC-board material. The sections are soldered at the joints to form the main frame. The assembled unit is shown in Fig 3. The dimensions are (HWD) 3¼ × 5¾ × 3 inches. A 1 × 5-3/8 strip of PC-board is soldered across the back of the chassis to contain J1 and J2 of Fig 1. Two strips (½ × 3 inches) are used at the sides of the main frame to serve as panel braces. I polished the copper on the PC-board material, then coated it with clear lacquer to prevent tarnishing. The panel is sprayed with gray automotive primer paint. I first sanded the panel to provide a rough surface. This helps the paint to adhere better than it would on the smooth surface. Gray Dymo™ tape labels identify the control functions. Four adhesive-backed rubber feet are affixed to the bottom of the chassis.

I used a technique that some call "ugly construction" when I built the SWR circuit. A neater job will result if you assemble the parts on a PC board, although the performance will be the same. I used a multilug terminal strip to contain most of the SWR-bridge parts. Other components have mid-air joints.

I used inexpensive slide switches for S1, S2 and S3 of Fig 1. Miniature toggle switches may be substituted, or you may prefer to use a single rotary switch, as dis-

[1]Notes appear on p 28.

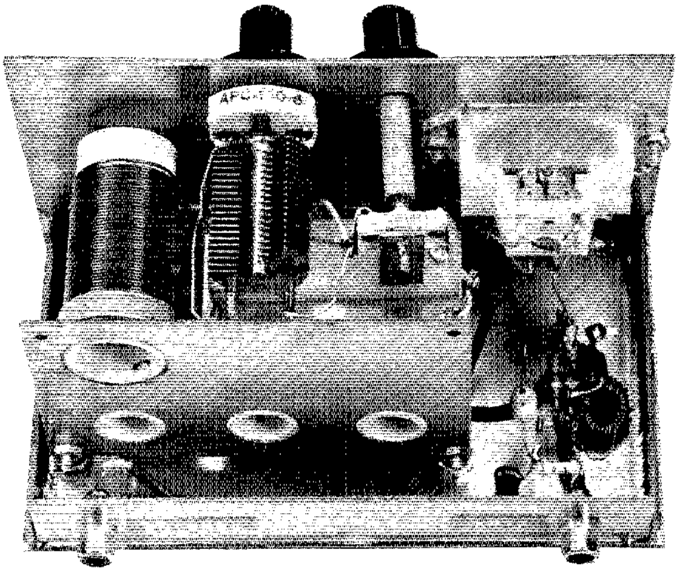

Fig 3—Interior view of the assembled ATU. "Ugly construction" (see text) is used for the SWR-bridge circuit, lower right. The subassembly, chassis and panel are made from pieces of single- and double-sided PC board. The seams are soldered to hold the sections together.

cussed earlier. Trimmer C2 may be replaced with a 100- or 140-pF air variable. If this is done, you will need to isolate the stator and rotor from ground. The circuit will function satisfactorily if you use two 100-pF capacitors (C1 and C2).

Circuit Performance

I tested this ATU at power levels from 1 to 15 watts. I used resistive loads from 15 to 1000 ohms, and obtained an SWR of 1:1 in all cases. No arcing occurred at trimmer C2. I later connected the ATU to my 80-meter dipole (coaxial cable feed) and ran it through its paces from 80 through 10 meters. Despite the complex impedance the feed line presented above 3.5 MHz, I was able to obtain an SWR of 1:1 on all bands.

Adjustment is done by setting the coil switches for the proper amateur band. With RF power applied to the circuit, adjust C1 for the lowest SWR attainable. Next, adjust C2 slightly and readjust C1 for minimum indicated SWR. Repeat this process until the SWR is 1:1. *Caution*: Use the greatest amount of capacitance possible at C2, consistent with a 1:1 SWR. Although smaller values of capacitance at C2 will result in an SWR of 1:1, the loss through the ATU increases at such settings. All Transmatches introduce some loss, but it is insignificant (less than 1 dB normally) for the most part.

Some Final Thoughts

Keep all RF leads as short as you can. This will prevent unwanted stray inductance, which can lower the tuned-circuit Q. Long RF leads, such as those marked "RG-174" in Fig 1, should be made from coaxial cable. RG-174 is miniature coaxial line that is suitable for short runs and for power levels up to 40 or 50 watts at the lower amateur frequencies.

There is no reason why the circuit of Fig 1 can't be adapted for high-power use. The coils would need to be made with large-diameter wire, and the coil forms should have good high-voltage, low-loss properties. Lexan™ or fiberglass tubing[2] is good material for the coil forms. Surplus ceramic coil forms are also suitable. C1 and C2 of Fig 1 must have wide plate spacing for high power, since substantial RF voltage is present at the top of L2. S1, S2 and S3 need to be high-quality RF ceramic switches if QRO use is contemplated. Fair Radio Sales in Lima, Ohio sells surplus RF power switches.[3]

You may use toroidal coils for your QRP ATU. This will enable you to make the tuner smaller. For example, L2 would have 35 turns of no. 24 enamel wire on an Amidon FT-82-63 core. L1 would consist of 3 turns of no. 24 wire over L2. For L3 use 24 turns of no. 24 wire on an FT-50-63 toroid. L4 would have 23 turns of no. 24 wire on an Amidon T-50-2 toroid, and L5 would consist of 15 turns of no. 24 wire on a T-50-6 core. There is no reason why you can't design a PC board that can contain the four toroidal coils, plus the SWR bridge. This would result in a low-profile, compact ATU.

I wrote this article in order to share some old ideas that may have been forgotten by some of you. I hope you have found the circuit and construction hints interesting and useful.

Notes

[1]Trimmers with shafts are available from Hosfelt Electronics, 2700 Sunset Blvd, Steubenville, OH 43952. Sales line: 800-524-6464 (catalog available).

[2]Plastic rod, tubing and sheeting (many types of plastic) are available by UPS or truck line from U.S. Plastic Corp, 1390 Neubrecht Rd, Lima, OH 45801. Sales line: 800-537-9724 (catalog available).

[3]Fair Radio Sales, Inc, Box 1105, 1016 E Eureka St, Lima, OH 45802, tel 419-227-6573.

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☐ anyone who has copies of *Radio News* or *Radio Amateur News* from the early '20s, especially the article "Radio on the Farm." Russell Erickson, N0ERR, 4699 W 69th Ave, Westminster, CO 80030, tel 303-430-1821.

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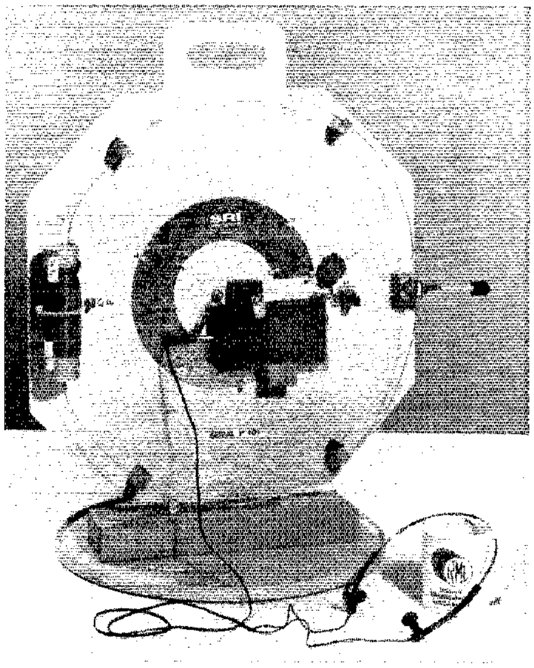
The Coplanar-Twin-Loop Antenna

Build this compact, unidirectional HF receiving antenna for ground- and sky-wave interference rejection and direction finding!

By O. G. Villard, Jr, W6QYT
SRI International
333 Ravenswood Ave
Menlo Park, CA 94025



Conventional, compact loop receiving antennas exhibit little directivity on certain sky-wave signals because some signal components arrive at different vertical angles. As a result, directional bearings obtained with conventional loop antennas can be blurred, and can fluctuate with time.

This article describes the design and construction of a compact, portable receiving antenna with a unidirectional null. Null depth is 20 dB or so. I call this antenna the *coplanar-twin loop* (CTL) because of its physical configuration. It consists of two concentric loops instead of one (see the title photo). When station bearings are reasonably well separated, a CTL is capable of greatly reducing sky-wave interference, even if an interfering signal is on exactly the same frequency as the desired signal. This is something a notch filter or Q multiplier cannot do. Accordingly, the designation "spatial notch filter" seems appropriate for the CTL's function. The CTL also adds a new dimension to "fox hunts": *sky-wave* direction finding (see the sidebar entitled "How the CTL Responds to Propagation Modes").

CTL Description

The CTL works, no matter how many vertical-plane modes are present, as long as all the modes travel along the shorter great-circle path from the transmitter to the receiving site, and their arrival angles are below 45 to 50°. (This is usually the case when the received signals originate more than 400 km from the receiving site.)

For receiving ground-wave and low-angle sky-wave signals, the azimuth-plane pattern of the CTL is basically cardioidal (a heart-shaped, unidirectional pattern). The pattern is somewhat sharper than a classical cardioid, though, and has nulls (or near-nulls) at 90°, 180° and 270°. These low-angle nulls can be seen in Fig 2 (slightly filled in, as this pattern shows CTL response at a somewhat higher wave angle). This added directivity is especially helpful in locations such as cities, where there are multiple local inter-

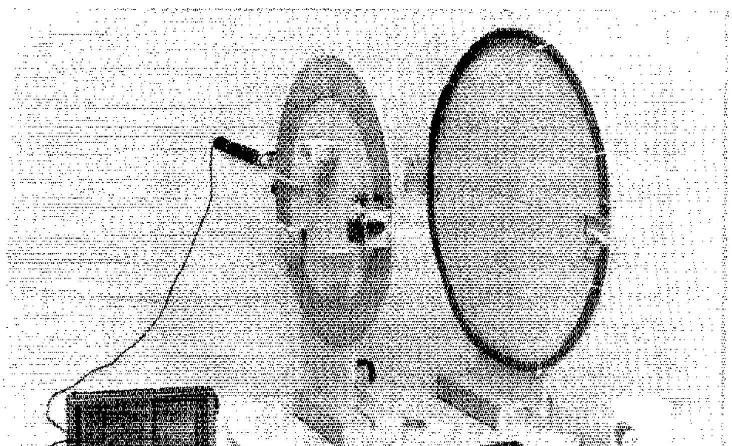


Fig 1—Photograph of an offset-twin-loop antenna for 15 MHz. This model uses offset loops and a coaxial-choke balun to isolate the feed line from the antenna.

Sky-Wave Signal Characteristics

Ionospheric propagation complicates direction-finding and signal rejection by nulling because of polarization rotation and the presence of signal components at multiple vertical angles. These circumstances are more troublesome when, for practical reasons, an antenna's size must be small compared with the wavelength (which must be the case if the antenna is to be portable).

Near most types of ground, the vertically polarized component of an incoming sky-wave signal is considerably stronger than the horizontal component. Nevertheless, the horizontal component cannot be ignored, especially when operating in the upper floors of wooden buildings or other tall structures with relatively low signal attenuation. Many antennas, such as conventional loops, will respond to both vertically and horizontally polarized signals, but their directive patterns are usually quite different for the two. A null in the pattern in one plane is not generally a null for the other. With the CTL, however, in the null direction the component loops are oriented end-on. The planar design makes CTL sensitivity to horizontally polarized signals in this direction so low that it can be ignored.

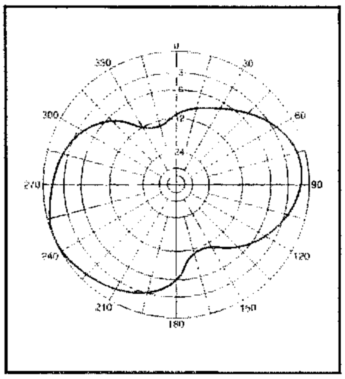


Fig A—Measured azimuth-plane radiation pattern of a conventional loop antenna receiving a multimode signal. This pattern was measured during the same period and on the same signal as the CTL pattern shown in Fig 2.

CTLs do respond to horizontally polarized sky-wave signals from other directions. This response does no harm beyond filling in the pattern nulls which would otherwise appear at 90° and 270° (these are observable in the reception of ground-wave signals).

When the I loop is detuned, the R loop functions as a simple vertical-loop antenna.†, †† Fig A shows the polar pattern of a simple vertical loop when receiving a sky-wave signal. Nulls are filled in when signals are horizontally polarized.

†O. G. Villard, Jr, K. J. Harker and G. H. Hagn, "Interference-Reducing Receiving Antennas for Shortwave Broadcasts," Final Report, Jan 1987, Contract IA 22082-23, US Information Agency, Voice of America, 601 D St NW, Patrick Henry Building, Washington, DC 20547.

††O. G. Villard, Jr, "Portable Unidirectional HF Aerial for Reducing Co-Channel Multihop Sky-Wave Interference," *Proceedings of the Fourth International Conference on HF Radio Systems and Techniques*, April 1988, pp 141-144, Institution of Electrical Engineers, London, England.

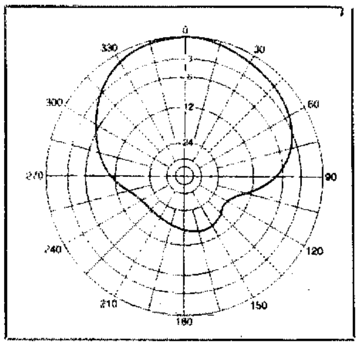


Fig 2—Measured azimuth-plane radiation pattern for a coplanar-twin-loop antenna while receiving a ground-wave signal from an elevated local source. The antenna was located 3 feet above ground for this measurement.

ference sources in different directions. In addition, the ability of the CTL's 180° null to reject signals over a wide range of vertical angles often makes possible near-complete rejection of ground-wave signals that consist of several vertical components.

A hybrid schematic diagram of the CTL shown in the title photo appears in Fig 3. For convenience and portability, a small receiver is included with the loop. This combination is particularly convenient for exploration of local signal fields, both indoors and out. It is especially useful for finding the best location for reception indoors, where both direction of arrival and directional discrimination are strongly affected by reradiation from conductors. Since reradiation fields depend on the details of building construction and furnishing, the best location for receiving must be found by trial and error. This is particularly easy to do when the receiver and loop are a single package.

Advantages of a self-contained device—apart from portability—include the avoidance of feed-line pickup or RF energy conduction along power lines. Larger receivers than that shown can be used with a CTL, if the loops are scaled up appropriately in size. It is desirable—though not essential—that the radio be only an inch or so thick, because this keeps most of the electrical components in the plane of the loops.

The CTL design does have drawbacks. The penalties of good performance in an antenna structure of small size include the reduced sensitivity that results from increased losses, and diminished aperture (energy-collecting area). Relatively narrow bandwidth is also a characteristic of reduced-size antennas, and the CTL exhibits this trait. The effects of losses and small aperture are compensated in the CTL design by making the loops resonant. Reduced bandwidth is overcome by using tunable loops.

How the CTL Works

The CTL consists of two resonant loops, one inside the other, having a common center and lying in a common plane. (It is also possible to use two loops of nearly the same size, concentric and side-by-side, as shown in Fig 1.) The smaller loop is connected to the receiver (as explained later) and is therefore called the *R* (receiver) *loop*. The outer loop is not connected to anything else, thus it's dubbed the *I* (independent) *loop*. It is roughly analogous to a parasitic element in a two-element broadside array or Yagi antenna, but its action is quite different.

The R loop of a CTL is a single-turn, low-impedance loop made of a wide strip of metal. It is tuned by means of a standard medium-wave-band tuning capacitor (350 to 600 pF—C2 in Fig 3). R2 is included in the R-loop assembly to allow variation of the amount of signal supplied to a receiver, as I'll explain later.

The R loop responds primarily to magnetic fields. The I loop, on the other hand, has a relatively high impedance. The I loop responds well to both electric and magnetic fields. Its tuning capacitor has a maximum capacitance of about 20 pF. Both loops are tuned to resonance at the operating frequency. The low-impedance (R) loop is set first and needs no further adjustment for a given band. The I loop, however, must be retuned whenever the operating frequency is altered by more than 10 kHz or so, depending on the desired null depth. The I loop is loaded by L1 and tuned by C1. The Q of the I-loop assembly is controlled by R1.

Directional Properties of the CTL

The null direction of a properly adjusted CTL is in the plane of the loops (instead of

How the CTL Responds to Propagation Modes

There are two fundamentally different situations encountered in practice with sky-wave signals: single and multimode propagation. (Polarization effects and upper-ray propagation are less important and can be ignored here for simplicity.) In the first situation, an ordinary loop—or the R loop of a CTL by itself—will give deep bidirectional nulls suitable for discriminating between two signals when their directions differ. The only difficulty is that this propagation mode is not encountered most of the time. When two or more modes are present, an antenna such as the CTL is needed to give good unidirectional rejection.

The way in which single and multimode propagation varies with time is illustrated in Fig B. This shows a typical daily variation of the major modes for a fixed distance on two bands (14 and 28 MHz). Path length is assumed to be about 4000 km. In the early morning, 28 MHz is usually not open and 14 MHz generally supports only one-hop propagation. (The elevation angle of this hop is small, because of the path length). Under such conditions, a simple loop—especially one with its tuning capacitor in a horizontal segment of the loop—gives a figure-eight pattern†, and is therefore useful for DFing. This is because a single-mode, low-angle, sky-wave signal is—as far as a simple loop is concerned—equivalent to a ground-wave signal.

As the sun rises farther, 14 MHz supports multimode propagation. Under such conditions, a simple loop antenna will give bearings that "wander." This is a situation in which the CTL works very well.

†H. Whiteside, and R. W. P. King, "The Loop Antenna as a Probe," *IEEE Transactions on Antennas and Propagation*, Vol AP-12 (May 1964), No. 3, pp 291-297.

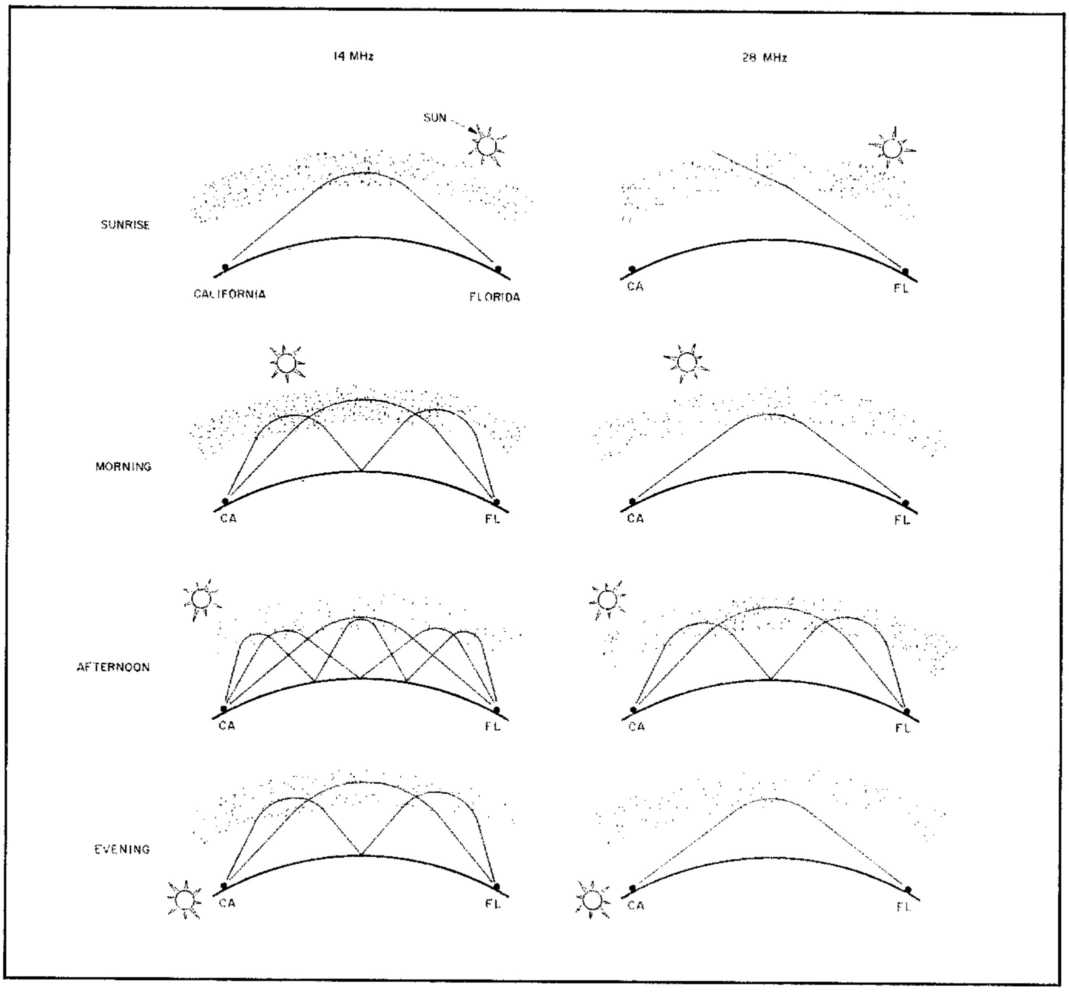


Fig B—Typical vertical-angle propagation modes on 14 and 28 MHz over the course of a day. A CTL antenna performs considerably better than a conventional loop antenna for receiving signals with more than one vertical mode.

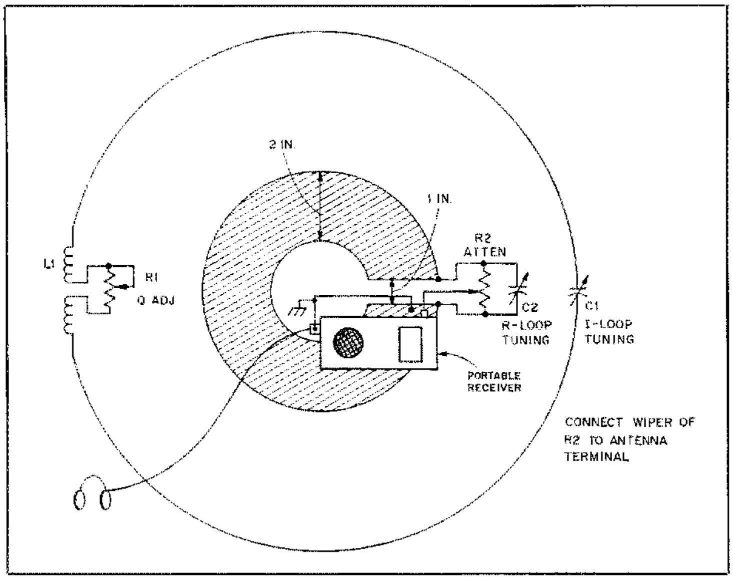


Fig 3—Hybrid schematic of a CTL antenna. The loops can be supported by a single sheet of plywood (or any lightweight nonconductor), or they may be built as shown in Fig 1. A small portable receiver can be connected directly to the R loop (as shown in the title photo) or operated separately from the CTL. If the antenna and the radio are mounted independently, the radio ground must be connected to the end of the R loop as shown. In either case, all other antennas (such as built-in whips) should be disconnected from the radio when the CTL is in use.

Parts list for a 7- to 21-MHz CTL antenna

C1—5- to 20-pF receiving variable.
C2—300- to 600-pF receiving variable (RS 272-1337).
L1—23 turns of no. 18 insulated wire wound on a 1-inch diam wood core approx 6 inches long (approx 8 μH for 15-MHz reception). Open at center for connection of R1.
R1—50-Ω carbon-composition potentiometer.
R2—5-kΩ carbon-composition potentiometer.
I loop—Approx 50 inches of no. 18 insulated wire.
R loop—9-inch OD, 2-inch wide piece of thin sheet metal.

Relative Loop Positions in a CTL Antenna

It is easiest to obtain a good front-to-back ratio when the two loops of a CTL are concentric, of roughly the same size, and spaced apart a distance of one third or one half their diameter, with their planes parallel (see Fig 1). However, with the coplanar arrangement shown in the title photo, the loops are less disturbed by field gradients associated with standing waves created by nearby reflecting objects. (This is because when coplanar loops are in a field having an intensity gradient along a line roughly perpendicular to the plane of the loops, both component loops respond to this gradient in more nearly the same manner than if they were parallel and spaced some distance apart, as in Fig 1.)

As an example of insensitivity to local effects, the portable antennas shown in the title photo and Fig 1 can be used to estimate signal arrival direction when operated inside a small car!

being at right angles to that plane, like conventional loop antennas). Let's assume that a signal arriving from the null direction has vertical components whose elevation angles are no higher than 50°. The function of the I loop is to generate a local magnetic field that cancels the incident field and produces a "shadow" in the total magnetic field at the position of the R loop. When I-loop tuning and station direction are correct, this shadow completely surrounds the R loop (as shown in Fig 4) so that the R-loop output goes to zero.

The position and depth of the shadow (the region of field cancellation) at the R loop depend on the azimuth direction of the incoming signal. Once a magnetic-field shadow has been generated around the R loop, that loop is effectively isolated from the outside world insofar as the nulled signal is concerned. When changes occur either in signal direction or in loop direction with respect to the signal, the I-loop current changes, the region of incident-signal cancellation around the R loop becomes incomplete, and energy can be picked up by the R loop.

For relatively small changes in vertical angle of arrival in the null direction, the I loop's output, and the shadow "darkness" (the degree of incident-signal cancellation), change very little. As a result, once adjustments are made to produce a null in a given direction, the null is independent of elevation angle over a considerable range of angles (Fig 5). At sufficiently high elevation angles, however, the null depth decreases (as it must if there is to be a useful reception in the direction opposite to the null).

Incident signals cause current to flow in the I loop. This current generates a magnetic field. When the I loop is tuned near resonance, the local magnetic field it generates has the correct phase to cancel the incident magnetic field at the position of the R loop. For this cancellation to occur, the locally-generated field must also be of the correct magnitude. This is controlled by either adjusting the axial spacing between the loops, or the Q of the I loop (by adjusting R1).

The I loop generates a local electric field in addition to the desired magnetic field. The electric field of the I loop (which could disrupt the R-loop response) is kept from affecting antenna performance by keeping the R-loop impedance low.

Building the CTL

The parts that make up each loop of the CTL should be as nearly in the same plane as possible (see the title photo and Fig 1, and the sidebar entitled "Relative Loop Positions in a CTL Antenna"). Physically small components are preferable to large ones. C1 should have a relatively small capacitance, although the exact value is not critical—10 pF at 15 MHz is about right for the middle of the HF range (from about 7 to 21 MHz). C1's value can be altered proportionally as the frequency is changed. Once C1 is set, L1 is adjusted by adding or removing turns so that resonance can be found in the middle of the range covered by C1. Band changing with the CTL is discussed in detail later.

The I loop should have only one turn. Improved front-to-back ratio can be obtained if the I-loop conductor is made of two wires spaced roughly an inch apart, and connected at the ends. This increases the electrical width of the conductor and improves the I loop's sensitivity to electric fields. The I loop should be larger than the R loop; the size difference is not critical. Loop spacing can be much closer than that shown in the title photo; 1½ to 2 inches is a good distance.

Since high Q is needed, plug-in loading coils are probably best for L1 if the antenna is to be used over a wide frequency range (more than a 3:1 ratio). Switch-selected separate coils are preferable to one coil of which turns are short- or open-circuited when frequency is changed.

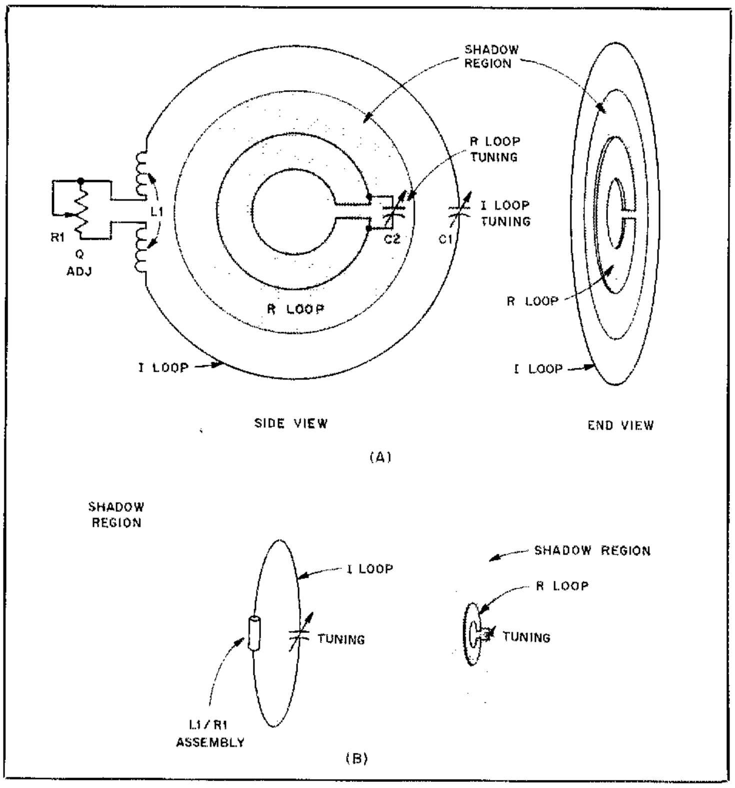


Fig 4—Current flowing in the I loop as a result of an incoming signal creates a shadow in the magnetic field around the inner (R) loop. If the I and R loops are in the same plane (as shown at A), the magnetic-field shadow only occurs around the R loop itself, inside the I loop. If the loops are offset, however, shadow regions exist around the R loop and in a position the same distance away from the I loop as the R loop, but in the opposite direction, as shown at B.

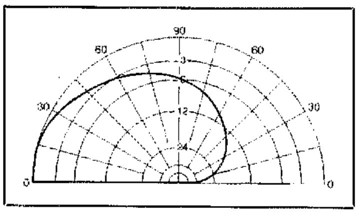


Fig 5—Measured elevation-plane radiation pattern of a CTL antenna located near ground level.

It is important that the tuning capacitors be located in the center of one of the vertical sides of each loop, and that these sides be adjacent to each other. The R loop can have multiple turns if desired, although one should be wide, as shown in the title photo.

Building a CTL is straightforward. Plywood and dowels are about the easiest materials to use for constructing the framework. A hand saw and a drill make the frame building easy. Small blocks of plywood can be used to set the I loop away from the board (giving clearance for the loop and L1, and keeping losses to a minimum). A dab of silicone sealant where the I loop crosses each block will hold the loop in place. Use the title photo and Fig 1 for reference in building the CTL.

Adjusting and Using a Coplanar-Twin-Loop Antenna

The use of lightweight, good-quality headphones—such as those shown in the title photo—is strongly recommended. Changes in signal level resulting from loop and receiver rotation can more readily be distinguished when headphones are used. (Headphones provide an acoustic path of constant length and attenuation.) Because the R loop has a low impedance, there is little hand-capacitance effect, and presence or absence of the headphone wires has little or no effect on receiver and antenna operation. Even touching the R loop with a finger has little effect. The general proximity of the body to the assembly can, for all practical purposes, be ignored, as long as nothing comes within a few inches of the I loop.

The antennas shown the title photo and in Fig 1 are designed for the 15-MHz broadcast band, and will cover the 14-MHz amateur band without modification. The loops are usually operated in the vertical position. To prepare the CTL for operation at a given frequency, first detune the I loop by means of C1 by setting it to maximum or minimum capacitance (see Fig 3). Initially, set R1 to minimum resistance. Then, tune the R loop (with C2) to peak the desired signal. Usually, no further adjustment of C2 is needed unless the operating frequency is changed by a few hundred kilohertz.

Next, tune the I loop to resonance at the signal frequency as follows: Assume that the direction of the received station is known. Orient the loops with their common plane in that direction, and with the loading coil of the I loop on the side closest to the desired station. A pronounced dip in receiver output will occur when C1 is correctly tuned. With the CTL pointing in the opposite direction, the decrease in signal strength is all but unnoticeable. Because the dip will be deepest when the loop plane is precisely aligned with the station direction, readjust loop direction as you approach a signal-strength null while tuning C1. Signal-strength null depth can be in excess of 20 dB, so C1 must be tuned with care to get the best rejection.

Increase the value of R1 from minimum

CTL Performance with High-Angle Signals

The CTL rejects incoming vertical-plane signal components very well from 0 to about 45° in elevation (see Fig 5). This range usually includes the most important angles from the standpoint of long-distance propagation. From 45 to 90°, the amount of rejection falls off. Signals from transmitters at short ranges, delivering only high-angle components, are not rejected as well. In those cases, it is possible to obtain signal rejection by placing the CTL on its side. The antenna is then sensitive to horizontally polarized signals. In that position, the antenna can be rocked or tipped so that its null provides the best rejection. The pattern null is wide in azimuth in this configuration.

Because vertical-plane modes fade independently, the strongest one at any given time will usually yield a good drop in signal strength when the antenna is positioned and tuned correctly. By successive observations, frequently you can estimate which propagation modes are active at a given time, even when there are several present simultaneously. Low-angle signals from distant stations are easily identified in this way. The amount of attenuation on low-angle signals resulting from nearby obstacles, such as trees and buildings, can also be estimated this way.

(while readjusting loop direction and I-loop tuning slightly, if necessary) until the null depth on a particular station is as deep as you can make it. An R1 value of a few ohms is about right. Outdoors, with favorable propagation, the null can be made extremely deep. As propagation conditions change over the course of a minute or so, the null depth typically decreases somewhat. Once the proper setting for R1 is found, there is usually no need for readjustment unless the operating band is changed.

As C1 is tuned through its range, sometimes there is a setting at which the receiver audio output increases. This is most noticeable if R1 has been initially set to zero. When this happens, increase the value of R1. When R1 is close to the optimum value, only a dip in signal strength will be found as C1 is tuned through its range.

As mentioned previously, the purpose of R2 (Fig 3), is to vary the amount of signal supplied to the receiver. (Unfortunately, few broadcast receivers have provisions for disabling the AGC and controlling gain manually. AGC smooths out amplitude changes and makes direction judgement difficult, especially in the case of sky-wave signals with fluctuating amplitudes.) When the CTL is initially adjusted, R2 should be set to reduce signal input to the receiver to somewhere below the point at which AGC action is pronounced. Once the antenna has been adjusted, R2 can be set to minimum resistance, and need not be adjusted further. If your receiver has defeatable AGC, there is no need to adjust R2; just disable the AGC during antenna tuning.

Proximity of the radio to the metal comprising one side of the R loop capacitively couples the radio ground to that side of the loop. Improved results can sometimes be obtained if the radio's ground is physically connected (with a piece of wire) to the same side of the loop. The best point of connection is close to the tuning capacitor, C2. The radio's chassis ground can usually be accessed at either the earphone jack or the external power-supply jack. Some small portable radios become unstable when operated in close proximity to metal. If this is a problem, move the radio to the space between the loops and install a separate ground connection to the radio as previously described.

Once tuning is complete, turn the antenna so that the desired signal lies in the direction of maximum response. Alternatively, the antenna can be rotated so that the null direction coincides with that of an undesired signal. Useful sky-wave signal discrimination can usually be obtained when the angular separation between stations is as small as 45°.

As a result of the resonant-loop, wide-metal-strip design, the sensitivity of the setups shown in the title photo and Fig 1 is surprisingly high—in fact, it is comparable to that of the receivers' built-in whip antennas. To prevent overloading in areas where very high field strengths are encountered, it may even be necessary to couple the radio's antenna connection to the loop via a small (10-pF) capacitor in series with the wiper of R2.

Indoor and Outdoor CTL Operation

Best results are obtained when the antenna is operated outdoors, in a location that is reasonably clear of reflecting objects. Familiarize yourself with the CTL tuning procedure outdoors; it is not necessary to go more than a few feet outside a building. A "reasonably clear" area can be a parking lot—proximity to automobiles has surprisingly little effect at HF, because cars are usually small compared with the wavelength, and are insulated from the ground by their tires.

CTL height above ground is not important. Best interference rejection is often obtained when the antenna is physically close to the ground. (Indoors, this means close to the floor of a room, especially when the building is made of reinforced concrete.) Indoors, the best place to operate a CTL is close to outside walls and, above all, to windows. If there are several windows side by side, the best place for reception is in the middle of the window area.

Although CTL performance—as measured by directional discrimination—suffers when the antenna is used indoors, the degradation is not as serious as you might expect. In general, some degree of directional discrimination is possible wherever a signal of usable strength can be found indoors using a receiver with a built-in antenna.

When a CTL is operated indoors, the following performance changes usually occur, in addition to a reduction in average signal level:

- The indicated direction of arrival may be more related to the direction to the nearest window than the direction to the station.
- Once a null has been obtained on a particular signal, it will tend to drift more rapidly than when outdoors—that is, the amount of rejection decreases appreciably over a minute or two. This is caused by reflections from local conductors. The original rejection level can be restored, but a slight change in azimuth and/or tuning setting is usually required.
- More than one null (often two) in the otherwise unidirectional pattern may be observed.

Move the CTL around and find the spot where these effects are least noticeable. Many reflections encountered indoors have a surprisingly short range. A location change over a distance of a few feet often makes a significant difference.

Band Changing

The R loop can be tuned over about a

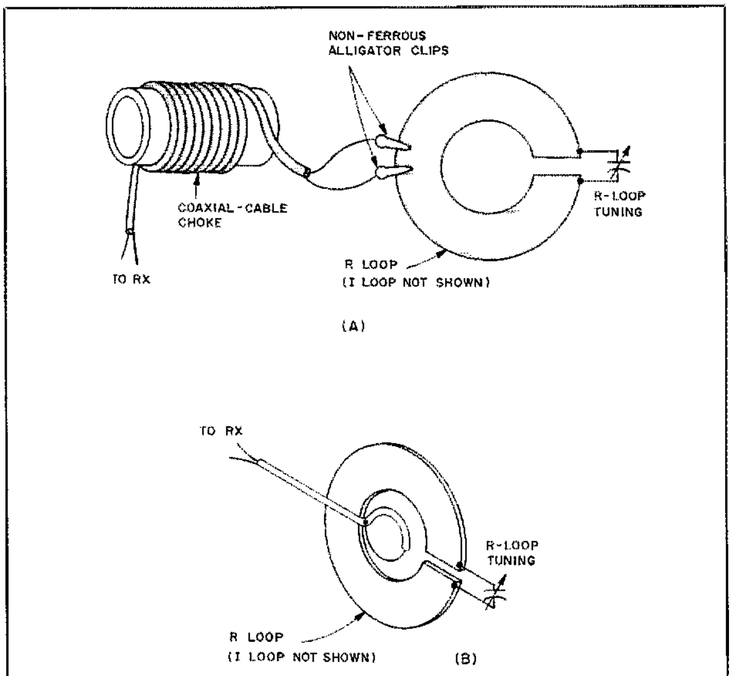


Fig 6—Two methods of connecting a coaxial feed line to a CTL antenna. At A, the feed line is wound over a wooden dowel in solenoidal form. At B, a shielded link is used to couple energy from the loops into the feed line. No direct connection to the CTL is required for this feed method.

three-to-one frequency range (such as 7 to 21 MHz), without band switching, because its tuning capacitor is quite large. For operation at lower frequencies, switch-selected additional turns made of insulated hookup wire can be added to the R loop. These can be wound right over the metal strip, if desired.

Using the CTL with a Separate Receiver

If you want to use the CTL with a separate receiver (instead of a small portable receiver like that shown in the title photo), there are a few approaches to use in attaching a coaxial feed line. One approach is to connect a coaxial cable across the high-current part of the R loop, as shown in Fig 6A. A convenient means for reducing RF current flow on the outer conductor of the coax is to use a small-diameter coax and to wind a portion of it in the form of a solenoidal RF choke, also shown in Fig 6. A coupling loop like the one shown in Fig 6B is another good way to attach a coaxial feed line.[1]

Summary

Although the amount of energy received by a coplanar-twin-loop antenna is considerably less than that of a good Yagi antenna on a tall support, the CTL performs adequately for most amateur HF interference rejection and DF work. If desired, a CTL can be operated by remote control on a rooftop or tower much more easily than a Yagi can be brought indoors!

Acknowledgment

I am grateful to Dr Robert R. Everett for drawing to my attention the instability of some small receivers when operated in contact with sheet metal.

[1]D. E. Barrick, "Miniloop Antenna Operation and Equivalent Circuit," *IEEE Transactions on Antennas and Propagation*, Vol AP-34 (Jan 1986), pp 111-114.

Reference

O. G. Villard, Jr., "Interference-Reducing Antennas for Short-Wave Broadcast Listeners," *IEEE Transactions on Broadcasting*, Vol 34 (Jan 1988), pp 159-166.

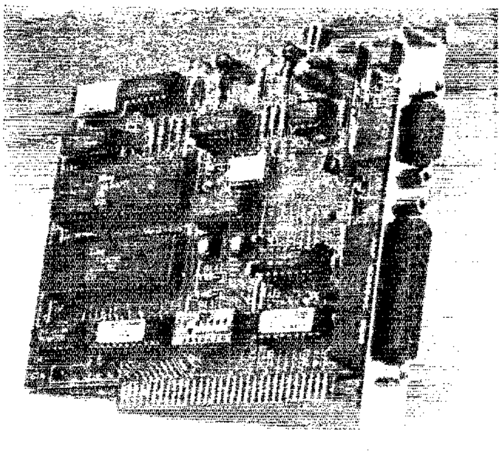
O. G. "Mike" Villard is a Senior Scientific Advisor at SRI International, a Professor Emeritus of Electrical Engineering at Stanford University and a former trustee of the Stanford Amateur Radio Club, W6YX. Mike has authored more than 22 QST *technical articles over the last 38 years. Mike earned the ARRL Merit Award in 1955 for "...technical contributions in the fields of wave propagation, single sideband telephony, and selective circuits." Mike has been associated with developments in meteor-scatter propagation, backscatter sounding, long-delayed echoes, magnetospheric HF propagation and ionospheric radar. He was instrumental in the widespread growth of SSB after World War 2, and designed a tunable AF circuit commonly known as the Select-o-Ject.*

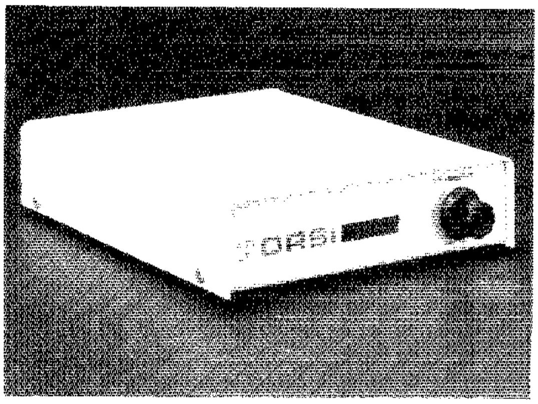
New Products

PACKET RADIO PLUG-IN TNC AND HF MODEM FOR IBM PCs

☐ Digital Radio Systems, Inc (DRSI) has introduced the PC*Packet system for the IBM® PC/XT/AT and compatible computers. PC*Packet consists of a half-length, plug-in PC board that provides the capabilities of two conventional TNCs. The PC*Packet board has two ports. One port has a 1200-bps CMOS crystal-controlled AFSK modem that connects directly to a VHF FM transceiver; the second port is configured for use with an external modem that uses RS-232-C or TTL signal levels. When used with the DRSI HF*Modem, the PC*Packet system provides two-port (HF/VHF) operation, featuring the ability to connect to stations on both ports—simultaneously. A version of PC*Packet with two built-in VHF 1200-bps modems is also available.

The software included with the PC*Packet system features a split-screen, menu-driven terminal program, TSR background AX.25 device driver, a stand-alone TNC emulator and a calibration utility program. The terminal program offers pop-up windows, on-line help information, a scrollable buffer to review received text, ASCII and YAPP binary file transfer, printer support and more. For the more technically inclined, the PC*Packet system includes the developer's software documentation for the low-level TSR driver, and information on how to write an original software application for the system. Prices for the components of the PC*Packet system are: PC*Packet system (including PC board, terminal program, AX.25 protocol support software, RS-232-C serial port and 1200-bps modem), $139.95; HF*Modem with LED bar-graph tuning indicator and selectable 200, 600 or 1000-Hz shift, $79.95; TNC-232 (RS-232-C adapter for TNC-2 and clones), $24.95. Cable sets for the PC*Packet system are also available. A package of two cables (a 5-foot shielded RS-232-C cable and a cable for connecting the PC*Packet board to the HF*Modem) is $12.95, and a cable for connecting the PC*Packet board to a VHF FM transceiver is $12.95. The PC*Packet system is available from DRSI, 2065 Range Rd, Clearwater, FL 34625, tel 813-461-0204 or 800-999-0204.—*Rus Healy, NJ2L*

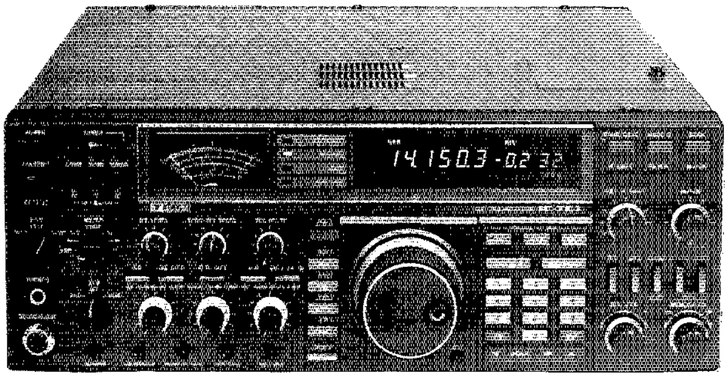




Conducted By Mark Wilson, AA2Z
Senior Assistant Technical Editor

ICOM IC-761 160- to 10-Meter Transceiver

Reviewed by Tom Miller, NK1P



With the introduction of the IC-761, ICOM has once again proven their ability to complement operator convenience with superior performance. The IC-761's standard features include a newly designed internal antenna tuner, memories and scanning, general coverage receiver, internal power supply, internal iambic keyer, 500-Hz CW filters and much more.

The first thing that most people notice about the IC-761 is that it's in a *big* box. Unlike most of the previous ICOM models, the '761 has large controls and switches that are easy to find and grab ahold of. With the internal power supply and antenna, the radio weighs in at a hefty 38.6 pounds. Don't worry about trying to find a place for this transceiver in your car, though—there is no provision for connecting it to an external 13.8-V dc supply.

Frequency Control

A large, white, fluorescent frequency display dominates the top center of the front panel. There should be no complaints about the legibility of this display—it's large and easy to read. Some users commented that they think the display is too bright even in a bright room. There is no dimmer switch—the '761's operating and service manuals contain no evidence of one—and operating the '761 in a darkened room is actually hard on the eyes. Here's a plus for display-accuracy fanatics, though: The IC-761 has a *front-panel* display-calibration control!

The IC-761's frequency display resolves frequencies only to the nearest 100 Hz (0.1 kHz) even though the '761's synthesizer tunes in 10-Hz steps at the '761's slowest tuning speed. (There are enough digits on the fluorescent tube's frequency field to *display* frequencies to 0.01-kHz digits, and you can light *all* the digits in the field from the rig's keypad [more on this later], but the receiver's central processing unit ignores the extra information.) How about including 10-Hz display resolution, ICOM?

An optional voice synthesizer provides audible confirmation of operating frequency. The frequency display indicates the carrier frequency in AM, FM, SSB and CW modes (CW signals must be tuned to the proper pitch for display accuracy); the mark frequency is indicated in the RTTY mode. However, the '761's control program doesn't keep the rig tuned to the same carrier frequency when jumping between modes. Fig 1, from the IC-761 service manual, describes this characteristic better than words. Yes, jumping to CW or RTTY from LSB, AM or FM changes the IC-761's frequency display by −600 Hz; jumping to USB from LSB, AM or FM changes the display by −3 kHz.

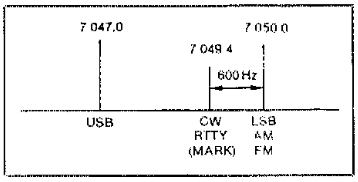


Fig 1—Carrier frequency versus mode selection for the ICOM IC-761 (from the IC-761 service manual).

Receiver or transmitter offset tuning (up to ±9.9 kHz) is displayed to the right of the operating frequency. Operating mode (USB, LSB, CW, RTTY, AM or FM) is displayed above the frequency readout. Indicators for SPLIT operation and VFO A or VFO B selection are located below the frequency readout. Other indicators: SCAN lights when a scan function is selected; MEMO lights when a memory mode is selected; NARROW lights when the narrow CW or RTTY filter is selected; GENE lights when the general-coverage mode is selected.

The IC-761 has two "VFOs"[1] and is capable of split operation. The radio tunes in 10-Hz steps at its slowest speed. Tuning speed is a comfortable 5 kHz per revolution when the knob is turned slowly and 25 kHz per revolution when it is turned rapidly. A third speed, 500 kHz per revolution, is available when TS (tuning speed) is pressed. A LOCK switch inhibits the main tuning dial (only) to prevent an accidental QSY. The large main tuning knob is weighted and has a silky smooth feel. The manual shows how to adjust the brake pressure on the tuning knob shaft to suit individual preferences.

You aren't limited to using the main tuning knob to change frequencies. A numeric keypad located just to the right of the main tuning knob may be used for direct frequency entry. For example, if you want to QSY to 28.885 MHz, press 2 8 8 8 5 0 ENTer. The keypad has the same resolution as the frequency display: It allows direct entry of frequencies only to the nearest 100 Hz even though the tuning knob can tune in 10-Hz steps—another candidate for a fix. Leading zeroes must be included during entry of frequencies below 1 MHz; there is no decimal-point key. A nice feature is that you don't have to enter trailing zeroes if you want to move to an even multiple of 1 MHz. For example, press 1 4 ENT to move to 14.0 MHz.

To change bands, you can enter the new frequency on the keypad, or you can use the UP and DOWN switches located below the keypad. When the '761 is in the general coverage mode, these switches move the frequency up and down in 1-MHz steps. In the ham band mode, they move the operating frequency to the next higher or lower amateur band (including 10, 18 and 24 MHz).

Use of the UP/DOWN switches proved frustrating. In the general-coverage mode, pressing these switches moves you up or down exactly 1 MHz (for example, 7.885 to 6.885 to 5.885 and so on). In the ham

[1]D. Newkirk, "View: DigiVFO," Technical Correspondence, *QST*, Sep 1987, p 43.

Table 1

ICOM IC-761 160-10 Meter Transceiver, Serial no. 01440

Manufacturer's Claimed Specifications	*Measured in the ARRL Lab*
Frequency coverage: Receiver, 100 kHz to 30.0 MHz; transmitter, 1.8 to 2.0, 3.45 to 4.1, 6.95 to 7.5, 9.95 to 10.5, 13.95 to 14.5, 17.95 to 18.5, 20.95 to 21.5, 24.45 to 25.1, 27.95 to 30.0 MHz.	As specified.
Modes of operation: USB, LSB, CW, FM, AM, RTTY.	As specified.
Frequency display: 7-digit white fluorescent.	
Frequency resolution: Not specified.	100 Hz.
Power requirement: 100 to 120 V ac, 650 VA max on transmit, 80 VA max on receive.	
Transmitter	*Transmitter Dynamic Testing*
Transmitter output power: Max 100 W PEP on SSB, 100 W on RTTY, CW and FM, 40 W on AM.	Typically 125 W PEP on SSB, 115 W on CW, RTTY and FM, and 63 W carrier on AM. Power output varied slightly from band to band. Minimum SSB/CW/RTTY output power: 7.6 W.
Spurious signal and harmonic suppression: Greater than 60 dB below peak power output.	See Fig 2.
Third-order intermodulation distortion products: Not specified.	See Fig 3.
CW keying waveform: Not specified.	See Fig 4.
Transmit-receive turnaround time (PTT release to 90% audio output with an S9 signal): Not specified.	20 ms.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity (preamp on): SSB, CW and RTTY: (bandwidth not specified) <0.5 μV for 10 dB S/N from 0.1-0.5 MHz; < 10 dB S/N from 0.5-1.6 MHz; <0.15 μV for 10 dB S/N from 1.6-30 MHz.	Minimum discernible signal (noise floor) with 500-Hz filter: *Preamp on*: 1.0 MHz: −125 dBm; 3.5 MHz: −140 dBm; 14 MHz: −139 dBm *Preamp off*: 1.0 MHz: −125 dBm; 3.5 MHz: −135 dBm; 14 MHz: −132 dBm
AM: (6.0 kHz bandwidth) <3 μV for 10 dB S/N from 0.1-0.5 MHz; <6 μV for 10 dB S/N from 0.5-1.6 MHz; <1 μV for 10 dB S/N from 1.6-30 MHz.	6.0 kHz bandwidth, test signal signal 30% modulated with a 1 kHz tone, preamp on: 1.0 MHz: 0.9 μV 3.5 MHz: 0.48 μV 14 MHz: 0.55 μV
FM: <0.3 μV for 12 dB SINAD from 28-30 MHz.	Preamp on: 0.25 μV for 12 dB from SINAD at 29 MHz.
Receiver dynamic range: 100 dB (preamp on), 105 dB (preamp off).	Blocking dynamic range†: *Preamp off*: 3.5 MHz: 126 dB; 14 MHz: 131 dB *Preamp on*: 3.5 MHz: 120 dB; 14 MHz: 122 dB Two-tone, third-order intermodulation distortion dynamic range†: *Preamp off*: 3.5 MHz: 100 dB; 14 MHz: 102 dB *Preamp on*: 3.5 MHz: 95 dB; 14 MHz: 96 dB Third-order input intercept: *Preamp off*: 3.5 MHz: 15 dBm; 14 MHz: 21 dBm *Preamp on*: 3.5 MHz: 2.5 dBm; 14 MHz: 5 dBm
S-meter sensitivity (μV for S9 reading): Not specified.	*Preamp on*: 58 at 1 MHz; 10 at 1.9 MHz; 10.5 at 14 MHz; 8.5 at 28 MHz *Preamp off*: 58 at 1 MHz; 26 at 1.9 MHz; 27 at 14 MHz; 29.5 at 28 MHz
Squelch sensitivity: <0.3 μV.	Min, 0.7 μV; max, 0.5 μV.
Receiver audio output: >2.6 W at 10% distortion with 8 ohm load.	2.76 W at 10% total harmonic distortion (THD) with an 8 ohm load.
Color: Black.	
Size (height, width, depth): 5.9 × 16.7 × 15.4 inches.	
Weight: 38.6 lbs.	

†Blocking dynamic range and third-order IMD dynamic range measurements were made at the ARRL Lab standard signal spacing of 20 kHz.

band mode, however, you end up on each band's "initialization frequency." The initialization frequency is about 50 kHz up from the bottom band edge. For example, if you're operating SSB on 21.255 MHz and press the DOWN switch, you'll move to about 14.050 MHz. This characteristic is annoying, especially if you do a lot of band changing (in a contest, for example).

Fortunately, there's another way to change bands. The IC-761's 32 memories store operating mode and filter selection, as well as frequency, and all 32 memories are *tunable*. Once you get used to the memory system, it's like having 32 other "VFOs" in addition to VFO A and VFO B. During a CW contest, I found it convenient to program the first six memories for the low end of each band, 160 to 10 meters, and use the memory selection rotary switch at the lower right corner of the front panel as my band switch.

The '761 can scan all 32 of its memory channels. If you like, you can scan only those channels with the same operating mode as the main VFO, or you can scan between the frequencies stored in channels one and two. A switch accessible through the bottom panel determines whether opening the squelch gate will suspend or terminate scanning.

The '761 is capable of remote control by means of a serial port located on the back panel. ICOM uses a LAN-type system called Communication Interface-V (CI-V). According to ICOM literature, remotely controllable functions include frequency, mode, VFO selection and memory operation. There isn't any specific information on remotely controlling the '761 in the instruction manual or the service manual.

Good news: The operating program for the IC-761's microprocessor is contained in ROM, not in RAM. This means that when the transceiver's memory-backup lithium cell is exhausted, the transceiver *still works.* In ICOM's words, "The transceiver transmits and receives normally if the backup battery is exhausted but the transceiver cannot memorize frequencies."

Receiver

Signals can enter the receiver chain either from the SO-239 ANTenna connector or through the RECEIVE ANT IN phono jack, allowing use of separate receiving and transmitting antennas. Signals then pass to a 20-dB attenuator, a preamp or directly to the first mixer (a doubly balanced pair of 2SK125 JFETs operating at 13.8 V). The corresponding front-panel switch positions are labeled PRE, ATT OFF and 20dB. The preamplifier works—the ARRL lab measured a change in the minimum discernible signal (MDS) of 5 to 7 dB with the preamp on. It would be nice to have a choice of attenuation, though. There are times, especially on 160, 80 and 40 meters, when 10 dB or 30 dB are more appropriate choices.

The IC-761 employs a quadruple conversion scheme for SSB, CW, RTTY and AM, and triple conversion for FM. Intermediate frequencies are 70.4 MHz, 9.0 MHz, and 455 kHz for FM, with a fourth IF of 9.0 MHz employed in all other modes. (The return to 9 MHz allows the inclusion of passband [variable bandwidth] tuning, IF shift and other features.)

The '761 certainly doesn't lack when it comes to filters. Different combinations of filters can be selected by pressing the FILTER switch, located just above the IF shift and notch filter controls. As the radio comes from the factory, this switch provides bandwidths of 6.0 or 2.6 kHz for AM; 2.6 or 2.4 kHz for SSB; and 2.4 kHz or 500 Hz for CW and RTTY operation. FM operation is limited to a single bandwidth of 15 kHz. This range of selectivity is accomplished by choosing one of four filters in the second IF (9 MHz), and one of six in the third IF (455 kHz). The stock IC-761 is equipped with 2.4-kHz and 500-Hz crystal filters in the second IF and third IF. Optional filters for the second IF and third IF provide 250 Hz bandwidth for CW and RTTY. These filters were not installed in the review unit. There is also an optional 6-kHz second-IF filter for AM operation.

Some other receiver features worth mentioning include the QRM fighting team of passband tuning (PBT), IF SHIFT and the (audio) NOTCH filter. PBT and IF SHIFT work in the CW, SSB and RTTY modes. A single control is used for both PBT and IF SHIFT, and both functions cannot be used at the same time. PBT and IF SHIFT function differently, and both are useful. PBT narrows the passband from either the high side or the low side, while IF SHIFT moves the center frequency of the passband without changing the passband width. I found combining the use of the notch filter and PBT to be just about fail-safe when it came to adjacent channel interference.

Three controls are used for the noise blanker. The NB switch activates a noise blanker that is fairly effective against ignition noise and power-line noise. Although this blanker didn't work on all noise I encountered, it did work most of the time. NB LEVEL varies the threshold of the blanker. The third control, NB WIDE, is used for noise with long-duration pulses, such as the Soviet "Woodpecker" over-the-horizon radar. Again, this blanker was effective much of the time, but not all of the time. Receiver dynamic range is noticeably degraded when the noise blankers are in operation—an effect common to most receivers.

The AGC in the '761 is a joy to use. For casual SSB work with strong signals, the SLOW time constant position (fast attack, slow release) is the right choice. AGC action is smooth, and signals are easy to listen to. For CW and for SSB contesting and DXing, though, FAST AGC is the better choice. FAST AGC doesn't thump at all. Also, the AGC has depth—strong signals sound louder than weaker ones, making it easier to dig out weak signals sharing the passband with stronger ones.

The '761's clean receiver audio is compromised just a bit by a hissy audio power chip. Adjusting the rig's TONE control doesn't touch this hiss—a pity because the '761's quiet IF strip can't be fully enjoyed in the presence of such noise.

Transmitter

With harmonic suppression approaching 60 dB on all bands, the IC-761 is definitely one of the cleanest new rigs available (see Fig 2). This can be attributed to proper filtering and five relatively low-gain stages in the transmit amplifier chain. Of course, there is no need to tune up the '761—just set drive level and audio gain (if applicable) and you're ready to go. Fig 3 shows the transmit audio during two-tone testing.

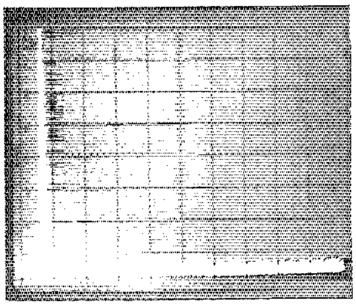


Fig 2—Worst-case spectral display of the ICOM IC-761. Horizontal divisions are each 2 MHz; vertical divisions are each 10 dB. Output power is approximately 110 W at 1.85 MHz. All harmonics and spurious emissions are at least 56 dB below peak fundamental output. The IC-761 complies with current FCC specifications for spectral purity.

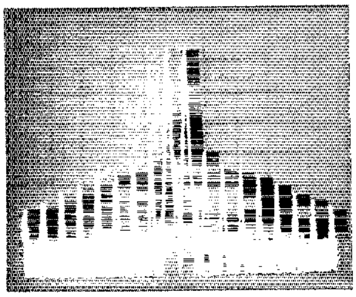
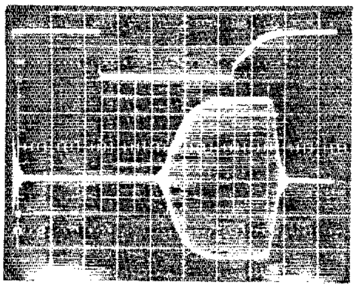


Fig 3—Spectral display of the ICOM IC-761 during two-tone intermodulation distortion (IMD) testing. Third-order products are approximately 37 dB below PEP output, and fifth-order products are approximately 45 dB down. Vertical divisions are each 10 dB; horizontal divisions are each 2 kHz. The transceiver was being operated at 100 W PEP output on 14 MHz.

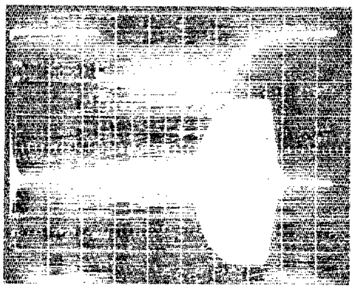
Antenna Tuner

If you're like me, with narrow bandwidth antennas, you'll appreciate the 160 through 10 meter built-in antenna tuner. ICOM claims a matching range of 16.7 to 150 ohms, and a maximum tuning time of three seconds. The internal tuner uses a tapped coil and two motor-driven variable capacitors, forming a T match.

To achieve the fast tuning specification,



(A)



(B)

Fig 4—CW keying waveform for the ICOM IC-761. The photo at A is with the IC-761 in the semi-break-in mode. The photo at B is with the IC-761 in the full-break-in (QSK) mode. In each photograph, the lower trace is the RF envelope; the upper trace is the actual key closure. Each horizontal division is 5 ms.

ICOM uses a clever scheme to preset the capacitors for each band. When initializing these presets, you transmit at low power and let the IC-761 find the right match on its own. Once a match is found, you open a cover on the top panel of the transceiver, flip the PRESET/AUTO switch to PRESET and adjust a pair of potentiometers (there is one pair per band) until four LEDs go out. Repeat the process for each band. From then on, when a band change is made, the tuning capacitors move to the preset positions and fine tune from there. The result is an automatic antenna tuner that works quickly and is almost transparent to the operator.

As with any automatic antenna tuner, there are times when it is not capable of finding a match. This is not a dead end in the case of the '761, as the preset potentiometers can be used to manually tune the T match capacitors. This procedure worked for me when I tried to match a 40-meter dipole on 160 meters! (No, I don't *normally* use my 40-meter dipole on 160.)

CW Operation

Another nice feature of this rig is the built-in iambic keyer. (Of course, you can still use the external key or keyer of your choice.) The keyer is enabled by pressing ELEC KEY located to the right of the noise blanker controls. A speed control is provided just above the enable switch, and a weight control is located inside the rig. Whether or not the internal keyer is used, key(er) connection is made via a ¼-inch stereo jack on the rear panel.

CW offset is set at 700 Hz. Some operators prefer a lower offset, and internal adjustment—to about 550 Hz—is possible.

Both full-break-in (QSK) and semi-break-in operation are available. The QSK mode sounds a bit thumpy because of sidetone transients, but receiver blanking is perfect. Unfortunately, the transmitted CW sounds choppy in QSK, especially at speeds of about 20 WPM and higher (see Fig 4). This occurs because of a delay between the time that the key line is closed and the transmitter RF output is generated. It is possible to compensate for this problem by adjusting keyer weighting.

Phone and RTTY Operation

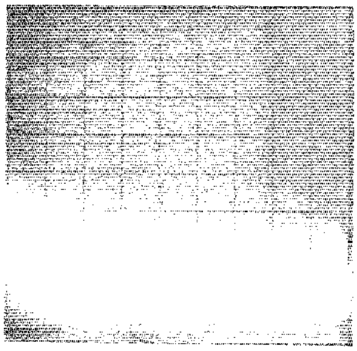
For phone ops, the IC-761 has a good sounding speech compressor (according to numerous reports) and a transmit audio monitor, which I think *all* rigs should have. At the beginning of the review, I used ICOM's SM-10 desk microphone. Many reports indicated that although the audio "wasn't objectionable," it sounded kind of "blah." (Several people who used the '761/SM-10 combination reported similar on-air comments, so the problem probably wasn't my voice.) Adjustment of the microphone's equalizer and compressor controls didn't improve the audio—in fact, many settings made the transmit audio sound awful. Note that the SM-10's built-in compressor has only LOW, MED and HIGH positions—but no OFF position! Later in the review period, I switched to a Heil HM-5 microphone. The Heil worked very well with the IC-761, and I received a number of excellent audio reports.

RTTY operation is also a snap, with capabilities for AFSK and true FSK included. For AFSK, all connections can be made through the microphone plug on the front panel or through the 8-pin ACC(1) jack on the rear panel. For FSK operation, a key line is provided (called RTYK) in the ACC(1) jack. Switches inside the rig select 850 or 170 Hz shift and reverse mark/space relationship.

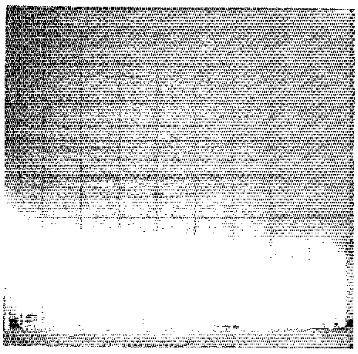
Synthesizer

ICOM has a relatively quiet synthesizer, as shown in the ARRL Lab phase-noise photos in Fig 5. In use, this translates to an absence of pops, clicks and birdies in the receiver. During contest periods, even on bands filled with strong signals, I did not notice any phase-noise problems.

The IC-761 is not without synthesizer-related problems, though. Synthesizer phase noise is relatively low partly because the acquisition time is relatively long. That is, when you change frequency, it takes a relatively long time for the synthesizer to lock. We're only talking milliseconds here, and the longer acquisition time is not apparent to the operator and causes no problems *except during QSK CW operation when the transmitter and receiver frequencies are offset more than 300 to 500 Hz.* During split-frequency QSK operation, the synthesizer lockup time is longer than the transceiver TR switching time. The transmitter puts out RF *before* the synthesizer locks. The result: The trans-



(A)



(B)

Fig 5—Spectral display of the ICOM IC-761 transmitter output during phase-noise testing. Power output is 100 W at 3.5 MHz (A) and 14 MHz (B). Each vertical division is 10 dB; each horizontal division is 2 kHz. The scale on the spectrum analyzer on which these photos were taken is calibrated so that the log reference level (the top horizontal line on the scale in the photos) represents −60 dBc/Hz and the baseline is −140 dBc/Hz. Phase-noise levels between −60 and −140 dBc/Hz may be read directly from the photographs. The carrier, which would be at the left edge of the photographs, is not shown. These photographs show phase noise at frequencies 2 to 20 kHz offset from the carrier.

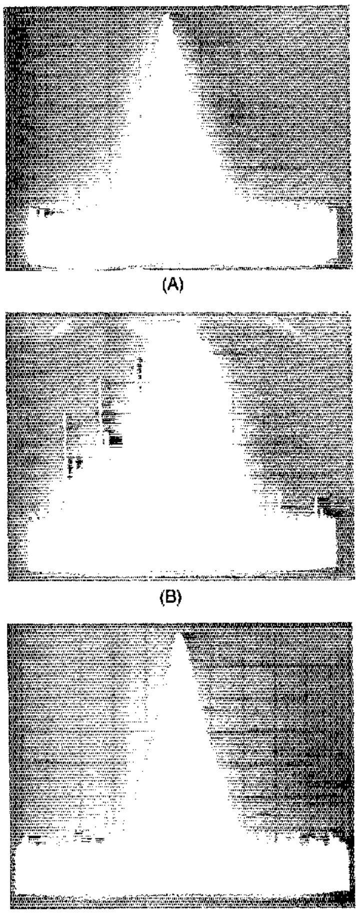


Fig 6—These spectral photographs taken in the ARRL Lab show CW keying sidebands when the IC-761 is used for full-break-in (QSK) CW operation. See text for further discussion. Vertical divisions are each 10 dB; horizontal divisions are 1 kHz. Bandwidth is 300 Hz. In all cases, the transceiver is in the CW position and is being keyed with a series of pulses 30 ms on, 30 ms off. The photo at A shows the transmitter output of the unmodified IC-761 operating full-break-in (QSK). The receiver is using VFO A and the transmitter is using VFO B; both VFOs are set to 14.0495 MHz. Everything looks normal. The photo at B shows what happens to the unmodified IC-761 during QSK operation when the transmit and receive frequencies are offset by as little as 500 Hz. In this photo, the transmitter is using VFO B, set for 14.0495 MHz; the receiver is using VFO B, set for 14.0490 MHz. Note that the signal is broader and that there are a number of discrete spurious signals near the carrier. The on-air signal sounds broad and has a noticeable chirp. The photo at C shows the results of ICOM's suggested modifications. Here, the IC-761 is operating full-break-in with the transmit and receive frequencies offset by 20 kHz. The signal appears normal, and the on-air sound is fine.

mitted signal sounds chirpy, and the transmitter puts out spurious signals. See Fig 6 for ARRL Lab spectral photos of this effect.

Let me emphasize that there is no problem with the unmodified IC-761 during CW semi-break-in operation or voice operation at any frequency split, or during QSK operation when the transmitter and receiver are on the same frequency. This problem only occurs during CW *QSK* operation at frequency splits greater than about 300 to 500 Hz.

Tom Moore, KF7GH, and Russell Dudley, KW5O, of ICOM acknowledged the problem and provided us with four modifications for the IC-761. These modifications are described in ICOM service bulletins 24287-002; 24287-005, 24387-001 and 7088-001. Two of the modifications (24287-005 and 24387-001) had already been incorporated in our IC-761 during production; the other two were performed by ARRL Lab Engineer Ed Hare, KA1CV. The remaining two modifications involve changing resistors on the main board and the PLL board, and readjusting a potentiometer.

Did the modifications work? Yes—to a degree. The modifications improve the situation dramatically at frequency splits up to 30 kHz or so. Up to about 30 kHz, the chirp and spurious signals are gone, and the radio is perfectly usable. At wider frequency splits, the synthesizer still has problems locking before transmitter RF output, and a very rapid chirp is noticeable on the signal, as are clicks several kilohertz either side of the main signal. Although the modifications don't solve the problem perfectly, they are a tremendous improvement and make the '761 usable for most split-frequency QSK operation.

If you have an IC-761 and want to attempt the modifications yourself, you'll need a copy of the IC-761 service manual, a dual-trace oscilloscope and some experience working on electronics equipment. According to ICOM's customer service people, they will modify—free of charge (except to-ICOM shipping costs)—any IC-761 with split-frequency QSK CW problems. This applies to all units—even those outside the normal warranty period. If you have questions about modifying your '761, contact ICOM's customer service department.

ICOM deserves recognition for being very responsive to fixing a major flaw in an otherwise fine radio. It's also reassuring that they stand behind their gear after the sale and update older transceivers at no charge.

Operation

Hooking up the IC-761 was easy. It's worth reading the manual first, however. The CW key jack is a two-circuit unit to allow the dot, dash and common connections required for the IC-761's internal keyer, and probably isn't compatible with whatever you're using with other radios. The wiring instructions for this jack are clear, however, and ICOM even includes a suitable plug. Assuming you've plugged your paddle into the rear panel KEY jack, the '761's electronic keyer circuitry makes a straight key unnecessary for key-down tests: When the keyer is not selected (ELEC-KEY button out), the paddle dot lever functions as a straight key.

If you plan to use a linear amplifier with the '761, you'll appreciate the fact that the amplifier key line terminates in a phono jack instead of being buried in a multi-pin connector. What you may not appreciate, however, is this warning in the instruction manual: "**DO NOT** attempt to switch greater than 50V DC, 0.5A." If you use an amplifier with a higher relay keying voltage (a Heath SB-220/221 or Alpha 77, for example), plan to add a relay or transistor switch between the IC-761 and your amplifier.

I must say I was intimidated at first by the apparent complexity of the '761's front panel. After spending some time reading the instruction manual with the rig in front of me, though, operating techniques quickly fell into place. Control feel and placement complement the rig's superior design, resulting in a quality piece of equipment. Since I find myself operating at a number of locations, having the built-in keyer and antenna tuner saved trunk space and reduced setup complexity.

The IC-761 received a thorough workout in several phone and CW contests. It performed very well under extreme conditions, and its superior receiver performance was noticeable. Even on 40-meter CW, it was usually possible to find a spot to call CQ—sandwiched in between a couple of strong stations!

The IC-761 includes an excellent general-coverage LF/MF/HF receiver. Its AGC works as well for reception of full-carrier AM stations as it does for CW, SSB and RTTY. Short-wave listening enthusiasts may find that the IC-761 exhibits a few rough edges, however. The transceiver's trait of not staying tuned to one carrier frequency during all possible mode changes is particularly annoying during reception of full-carrier AM signals as SSB—a technique in which sideband switching is routine for listeners intent on dodging interference. The transceiver's stock "AM wide" selectivity—6 kHz at −6 dB and 18 kHz at −50 dB—is a bit too wide for comfortable reception in crowded short-wave broadcast bands. (Addition of the optional 9-MHz AM filter [6 kHz at −6 dB and 18 kHz at −60 dB] may tighten up somewhat, although 4 kHz at −6 dB would be a better choice for both filters.) This isn't much of a problem, though, because the '761 does a superlative job receiving full-carrier AM signals as SSB signals, carrier tuned as close to zero beat as possible with the rig's 10-Hz tuning steps. (Note: In some spots throughout the world, IC-761 users may experience *tweet* interference in the medium-wave broadcasting band. You've heard of birdies, of course; *tweet* is the decades-old term for interference caused by harmonics of a receiver IF beating with incoming signals. Sound impossible? It's not: Tweet interference occurs in the IC-761 when the rig is tuned to Connecticut local broadcast station WRCQ, 910 kHz—twice the '761's second IF (455 kHz). Luckily, the tweet is close enough to zero beat to be inaudible with 'RCQ tuned on the nose—but its presence prohibits IC-761 owners wanting to listen to their 910-kHz locals from offsetting the '761's tuning for better recovery of high modulating frequencies.)

I really enjoyed using the IC-761 and found it an excellent transceiver, except for the problems with split-frequency QSK operation. It is easy to use, it looks great, and the controls feel good. ICOM has done an outstanding job with both the operating and service manuals. Both are easy to read and informative.

I would like to thank Bill Myers, K1GQ, Dave Newkirk, AK7M, and Mark Wilson, AA2Z, for using the IC-761 and providing comments that were incorporated in this review.

Price class: IC-761, $2700; SM-10 desk microphone, $140. Manufacturer: ICOM America, Inc, 2380-116th Av NE, Bellevue, WA 98004, tel 206-454-7619.

SOLICITATION FOR PRODUCT REVIEW EQUIPMENT BIDS

[In order to present the most objective reviews, ARRL purchases equipment "off-the-shelf" from Amateur Radio dealers. ARRL receives no remuneration for items presented in the Product Review or New Products columns.—Ed]

The following ARRL-purchased Product Review equipment is for sale to the highest bidder. Prices quoted are minimum acceptable bids and reflect a discount from the purchase price.

Sealed bids must be submitted by mail and be postmarked on or before September 27, 1988. Bids postmarked after the closing date will not be considered. Bids will be opened seven days after the closing postmark date. In the case of equal high bids, the high bid bearing the earliest postmark will be declared the successful bidder.

Please clearly identify the item you wish to bid on, using the manufacturer's name, model number, or other identification number if specified. Each item requires a separate bid and envelope. Shipping charges will be paid by the successful bidder, FOB Newington. The successful bidder will be advised by mail of the successful bid. No other notifications will be made, and no information will be given by telephone to anyone regarding final price or identity of the successful bidder.

Please send your bids to Kathy McGrath, Product Bids, ARRL, 225 Main St, Newington, CT 06111.

Kenwood TS-140S 160-10 meter transceiver, s/n 8101427, with 500-Hz CW filter and PS-430 power supply (sold as a package only; see Product Review, Jun 1988 *QST*). Minimum bid $784.

Kenwood TM-221A 2-meter FM transceiver, s/n 9020515 (see Product Review, Jul 1988 *QST*). Minimum bid $238.

Kenwood TM-321A 220-MHz FM transceiver, s/n 8090113 (see Product Review, Jul 1988 *QST*). Minimum bid $248.

Kenwood TM-421A 440-MHz FM transceiver, s/n 8090067 (see Product Review, Jul 1988 *QST*). Minimum bid $244.

New Products

MN ANTENNA ANALYSIS SOFTWARE FOR THE IBM PC

☐ Brian Beezley, K6STI, has dramatically enhanced the MiniNEC antenna analysis program developed by NOSC. MN (for IBM® PC and compatible computers) allows modeling of almost any antenna made of wire or tubing, at any frequency. Antennas can be modeled over real or perfect ground, or in free space. MN gives forward gain, front-to-back ratio, maximum sidelobe levels, beamwidth, vertical radiation angle, input impedance, SWR, element currents, far-field radiation patterns and near-field intensity. MN also allows performance comparisons between antenna designs.

MN is menu driven, and has extensive, easy-to-read documentation. Basic system requirements include an IBM PC or compatible with a single floppy disk drive, at least 300 kbytes of free memory (450 kbytes if the plotting routine is to be used during MN operation), a CGA, EGA or HGC card, and a text editor or word processor (for creating and modifying antenna files). A math coprocessor will speed up MN calculations by 15 to 20 times, but is not a system requirement. A hard disk is not necessary. The basic MN package includes MN.EXE (executable program file), sample antenna files, a demonstration plotting program, and documentation. The complete MN package consists of all the files in the basic package as well as MNPLOT.EXE (executable plotting routine for graphics cards), the complete antenna library (over 50 antennas), the plot library (antenna-file plots), a guide to plot comparisons, and additional documentation.

Antenna patterns can be plotted using the MNPLOT program. Azimuth- and elevation-plane far-field polar patterns can be plotted on the standard ARRL log-decibel grid (so that patterns generated using MNPLOT can be compared to those in ARRL publications), or patterns can be plotted on a linear-decibel grid. MNPLOT also allows plotting patterns in rectangular form. MN is provided on a single 360-kbyte floppy disk via first class mail. Price: Basic MN Package, $25; Complete MN Package, $75. If you purchase the Basic MN Package and order the Complete MN Package within 30 days, you'll receive full credit for the purchase of the Basic MN Package. More information and the MN software packages are available from Brian Beezley, K6STI, 507½ Taylor St, Vista, CA 92804.—*Rus Healy, NJ2L*

ARD HEAVY DUTY ANTENNA ROTATOR

☐ Looking for a *substantial* antenna rotator? Advanced Radio Devices has introduced the R9100—an RS-232-C controllable monster rotator capable of 10,000 inch-pounds of torque and 23,000 inch-pounds of braking capability. The R9100 has a 2000-pound vertical-load capability, weighs 230 pounds, and fits inside a Rohn 45 tower. Software to use the computer-control capability is included with the R9100. It allows you to enter a call-sign prefix on your computer keyboard, and turns the rotator to the correct beam heading automatically. The control unit for the R9100 has both analog and digital displays. The ARD R9100 is sold exclusively by EEB of Vienna, Virgina. Suggested price: $3975. For availability information, contact EEB at 800-368-3270 or 703-938-3350. ARD can be contacted at 103 Carpenter Dr, Sterling, VA 22170, tel 703-478-3100.—*Rus Healy, NJ2L*

Hints and Kinks

Conducted By David Newkirk, AK7M
Assistant Technical Editor

IMPROVING RIT AND SPLIT-FREQUENCY OPERATION IN THE HEATH HW-5400 TRANSCEIVER

□ I found CW operation in the HW-5400's "split-frequency" mode cumbersome because of a delay between key closure and RF output. A call to Heath® confirmed that this delay is inherent in the HW-5400 because time is required to reset the frequencies of various oscillators—in particular, the microprocessor clock—when changing from receive to transmit. Wanting to reduce the delay, I wondered if the oscillator-reset time could be shortened. (I also wanted to be able to operate at splits wider than those possible with the '5400's ±350-Hz RIT [receiver incremental tuning] range; increasing the RIT range by adding diode D701B per a later revision of the '5400's assembly manual did not increase the range enough for my purposes.)

Finally, I hit upon a solution: Use *two* microprocessor clock oscillators—one for receive and the other for transmit—and *switch between them* instead of tuning the '5400's crystal-controlled clock between transmit and receive frequencies. The oscillator circuit I use (Fig 1) was designed by Lyle Audiss, K6PJE, and has given good results. This LC oscillator operates at the same nominal frequency as the HW-5400's crystal-controlled clock (8.04 MHz) and can be switched in to serve as the clock on receive. Because the LC oscillator can be tuned over a wider range than the crystal oscillator, the LC oscillator allows a much wider RIT swing than that possible with the clock. (The clock

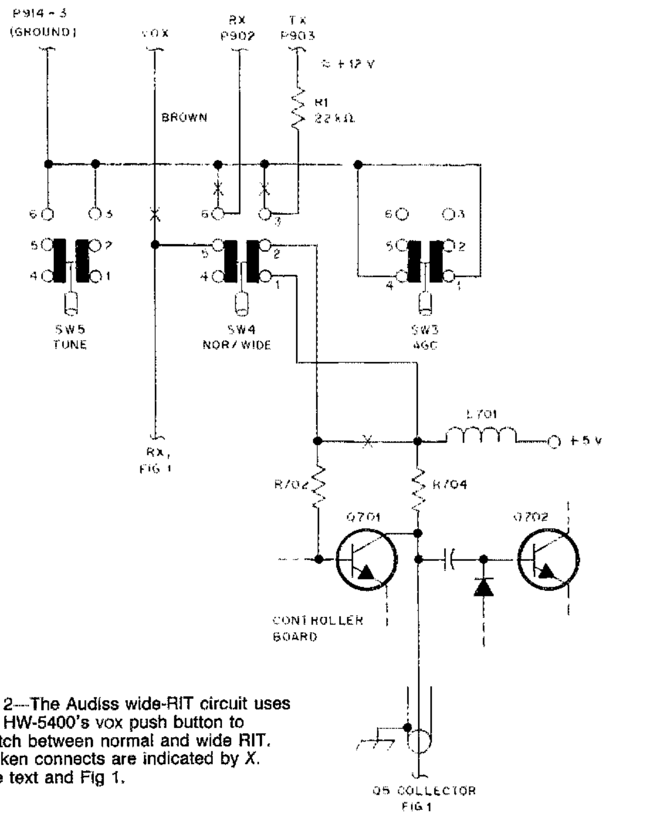


Fig 2—The Audiss wide-RIT circuit uses the HW-5400's vox push button to switch between normal and wide RIT. Broken connects are indicated by X. See text and Fig 1.

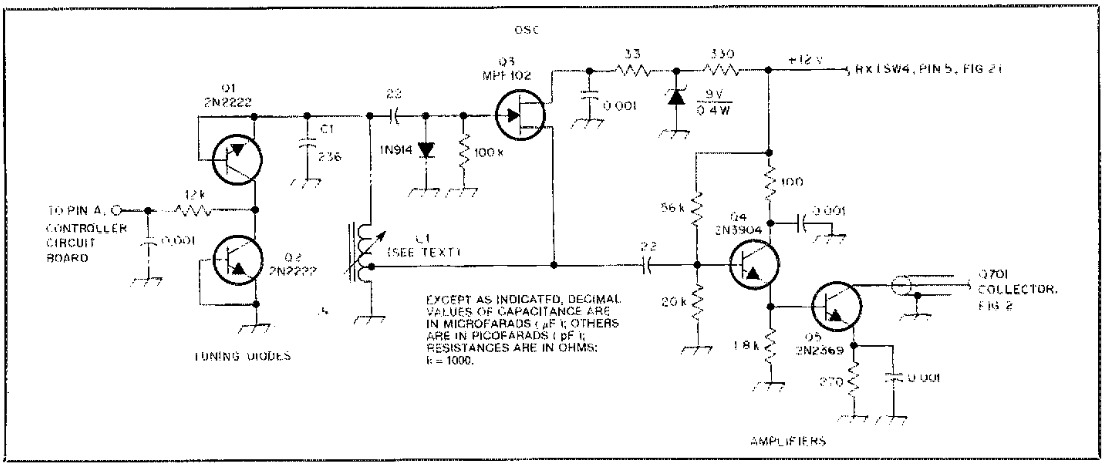


Fig 1—This oscillator allows Gary Audiss to use his Heathkit® HW-5400 transceiver at splits much greater than possible with the rig's RIT circuitry. Decimal-value capacitors are disc ceramic (16 V or greater); the 22- and 236-pF capacitors are NP0 or C0G discs. (Although Gary specifies a 236-pF capacitor at C1, you can use several standard-value capacitors in parallel to approximate that value.) Resistors are ¼-W, carbon-composition or -film units. See text and Fig 2.

[Q701 and its associated 8.04-MHz crystal] is retained as the microprocessor clock on transmit.) I use the HW-5400's VOX/PTT switch, SW4, to switch between normal and wide RIT (see Fig 2); I don't operate VOX, and using SW4 avoids the necessity of adding another switch to the rig's front panel. PTT operation of the HW-5400 is unaffected by this modification.

The wide-RIT oscillator circuit is built on a double-sided PC board about 1 × 1½ inches in size. L1 is wound on a junkbox slug-tuned form approximately 1/4 inch long and 1/8 inch in diameter. The winding consists of 17 turns of no. 28 enameled wire; place the tap at 5 turns from the ground end of the coil.

Disconnect the VOX lead (a brown wire) from terminal 5 of SW4, tape the end of the wire, and fold the wire out of the way. Disconnect terminals 3 and 6 of SW4 from ground (the wire that goes to pin 3 of P913). Install a 22-kΩ, ¼-W resistor in series with the TX line to SW4, pin 3. (This resistor drops the TX voltage [approximately 12] to the 5 V necessary for biasing Q701.)

Mount the wide-RIT oscillator board on a standoff at the corner of the Controller board (directly above the 8.04-MHz crystal). Connect the collector of Q5 (the wide-RIT oscillator's output transistor) to the collector of Q701 (on the '5400's Controller board) by means of a short piece of RG-174 coax. Connect point A of Fig 1 to pin A on the Controller board.

Assuming that you've successfully built and installed the wide-RIT oscillator board, and you've completed the necessary wiring modifications around SW4, the only step left is the adjustment of L1. With the HW-5400 on and receiving, switch SW4 to WIDE RIT and adjust L1 so that the RIT control swings the receiver tuning equally above and below the nominal transmit frequency. That's it! The problem I haven't solved is that of labeling SW4 to match the lettering on the HW-5400's front panel. Any ideas?—*Gary Audiss, N6SI, 6540 Birch Dr, Santa Rosa, CA 95404*

HW-5400 SPEEDY TUNE

☐ After working a major SSB/CW contest with my Heath HW-5400 transceiver, I realized that I need a faster and easier method of changing frequency than that allowed by the stock '5400. The circuit shown in Fig 3 is my solution to this problem. Dubbed the Speedy Tune, it provides rapid up/down frequency slewing and is controllable by a momentary, DPDT, center-off toggle switch. The Speedy Tune is easy to build and does not affect the '5400's manual tuning.

The Speedy Tune circuit is based on a 555 timer, U1. The 555 is connected as an astable multivibrator that free runs at eight times the tuning rate (in steps per second) desired. The multivibrator frequency is adjustable by means of RATE control R1. U2 delivers two pulse trains 180° out of phase which, when divided by binary counters U3 and U4, produce two pulse trains *90°* out of phase (in quadrature)—just as does the optical shaft-rotation encoder associated with the HW-5400's tuning knob. These signals are routed to the $\phi 1$ and $\phi 2$ inputs of the HW-5400's controller board by means of UP/DOWN switch S1.

My version of the Speedy Tune is built on a small piece of perfboard and mounted near the HW-5400's Controller board. (Power for the Speedy Tune is obtained from P703 on the '5400's Controller board: Pin 1 supplies 5 V dc and pin 3 is common.) S1 can be mounted on the '5400's front panel—to the lower right or left of the tuning knob—with room to spare. The Speedy Tune circuit may also be usable with any other optically-encoded tuning system that accepts TTL-level inputs from its shaft encoder.—*Dexter King, AB4DP, 6438 Pettus Rd, Antioch, TN 37013*

THE WHIPPY WHIP

☐ The 2-meter band bustles with repeater activity in the Denver area: Even with 15-kHz channel spacing, almost all the possible repeater frequencies are filled. Having many repeaters to choose from is great, but two aspects of repeater use give constant trouble: Inadequate antennas and battery packs on hand-held rigs. I've found a way to attack both of these problems at once: the Whippy Whip.

A hand-held rig works surprisingly well if used with a decent antenna; the "rubber duck" commonly used with hand-held rigs might better be called a "rubber dummy load"! The Whippy Whip is a move toward a decent antenna. It consists of a BNC connector and a length of 0.025-inch music wire (available at hardware stores; my wire cost 15 cents). Disassemble the BNC connector so that no insulation is left in contact with the center pin. Sandpaper the end of the wire and tin it lightly. Then, solder the end of the wire to the connector's hollow center pin. Assemble the BNC and cut the overall length of the antenna to ¼ wavelength at the center of the 2-meter repeater band (19 to 19½ inches). (Make the wire a half inch or so longer than necessary to allow the wire end to be bent into a small loop with needle-nose pliers. Don't use the Whippy Whip without adding this loop because the end of the wire is dangerously sharp.)

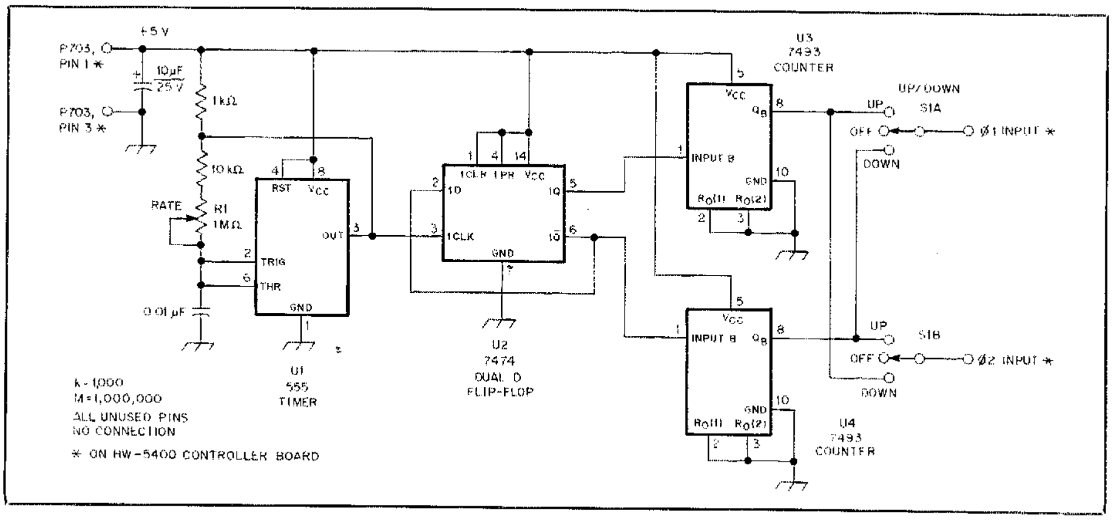


Fig 3—Dexter King's Speedy Tune circuit adds up/down frequency slewing to the Heath HW-5400 transceiver. R1 allows adjustment of the slewing rate.

With the Whippy Whip in place, you can make many contacts impossible with a rubber duck. Because the Whip is a significantly better antenna than the duck, you may often find that you can use your handheld at its low-power setting and get more QSOs per charge out of the rig's battery pack. Not bad for a buck's worth of parts! By the way, I find the Whippy Whip to be every bit as convenient as a rubber duck because it can be looped into a circle or put into a pocket. It literally springs into action when released!—*Nate Bushnell, KD0UE, 7175 S Grant, Littleton, CO 80122*

STRAY CAPACITANCE AFFECTS INDUCTANCE MEASUREMENTS

☐ As I calibrated my version of the L-Meter,[1] measurement errors confused me until I realized what was happening. Although a coil of wire exhibits inductance, there is also *distributed capacitance* between the turns of the coil. Because the L-Meter (an oscillator) depends on tuned-circuit resonance to measure inductance, the inductance *and distributed capacitance* of the inductor under test are factors in its inductance measurements.

When an inductor is measured on a reactance bridge or Doyle Strandlund's gadget,[2] the inductor's capacitive reactance cancels part of its inductive reactance. This results in an inductance reading less than the actual inductance of the inductance under test. Distributed capacitance has the opposite effect in measurements made with the oscillating L-meter: The measured inductance of the component under test appears to be greater than the actual inductance of the part.—*Herbert T. Bates, KA0CAG, 1622 Fairview Ave, Manhattan, KS 66502*

BLENDING CIRCUIT-BOARD FABRICATION TECHNIQUES FOR SUCCESS

☐ In his August 1987 article on homemade circuit boards,[3] Doug DeMaw mentioned the unsuitability of mechanically etched boards for use with ICs or other components with close pin spacings. (Generally, mechanical etching isn't precise enough to make traces suitable for the 0.1-inch pin spacing standard with ICs.) I've been getting around this limitation by making a gridded sub-board for the IC and mounting to the main (mechanically etched) circuit board with the piggyback method described in Doug's article (see Fig 4). Jumper wires connect the IC sub-board pads to the main circuit board; glue holds the IC sub-assembly in place.—*John Evans, K3SQO, Box 84, RD #1, Kingsley, PA 18826*

[1]Alf Reinertsen, "The L-Meter," *QST*, Jan 1981, pp 28-29.
[2]Doyle Strandlund, "Amateur Measurement of R+jX," *QST*, Jun 1965, pp 24-27.
[3]Doug DeMaw, "Homemade Circuit Boards—Don't Fear Them!," *QST*, Aug 1987, pp 14-16.

ETCH-RESIST PENS FOR HOMEMADE CIRCUIT BOARDS

☐ Because I've been fabricating circuit boards at home for some time, Doug DeMaw's circuit-board article[4] was of more-than-usual interest to me. In particular, I've been involved in "longhand" PC-board production (a general term for boards produced with resist applied by hand with a brush or marking pen) for quite some time.[5] Most problems with boards made by the longhand method are caused by uneven ink flow from the pen. Marcus referred to this problem in a *CQ* article.[6] This uneven-flow problem can be corrected by opening the pen and adding a solvent that is compatible with the ink. (Usually, the ink vehicle is an alcohol-based solvent.)

The ink in most felt- or fiber-tip pens is stored in a fiber cylinder enclosed in a thin plastic sheath. Add 10 to 15 drops of alcohol or a similar solvent (rubbing alcohol [70% isopropyl], lacquer solvent [denatured ethyl alcohol] and butyl acetate [thinner for model paints] are satisfactory) to the cylinder end that contacts the pen tip. (Stop adding alcohol if it appears that the next drop will cause leakage from the bottom of the cylinder.) Replace the ink cylinder in the pen and allow a few minutes for the rejuvenated ink to migrate into the pen tip. Now, the pen should produce opaque black lines without smearing. If the lines appear to be almost *too* fluid, that's ideal. (By the way, overapplication of alcohol to the ink cylinder can cause leakage through the pen's tip vent hole. Watch out for this so you don't generate profanity when a vent drop hits the board and spoils your work!) Using this method, I've successfully rejuvenated *10-year-old* pens!

[4]See note 3.
[5]Robert J. Grabowski, "longhand printed-circuit layout," comments, *ham radio*, Jun 1979, p 6.
[6]Alan Marcus, "A Printed Circuit Board Primer," *CQ*, Oct 1982, pp 44 and 47.

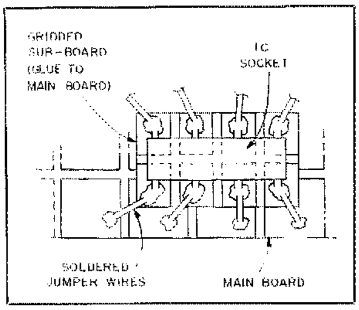


Fig 4—John Evans gets around the incompatibility of mechanically etched boards and ICs by mounting his ICs on gridded, single-sided sub-boards. (Here, the main board is also gridded for clarity.) The sub-boards are mounted to the main board using the piggyback technique described by Doug DeMaw. See text.

The best resist pens I've found for circuit-board work are produced in Germany and sold in art stores under the name Staedtler Lumocolor. Medium (no. 317) and fine (no. 318) points are available. (I recommend the no. 318 pen for most circuit-board work.) These pens contain a high-quality waterproof ink and can be opened by removing the top cap (pliers may be necessary in some cases). Most of these pens can be used for circuit-board fabrication *without* the solvent-addition treatment just described.

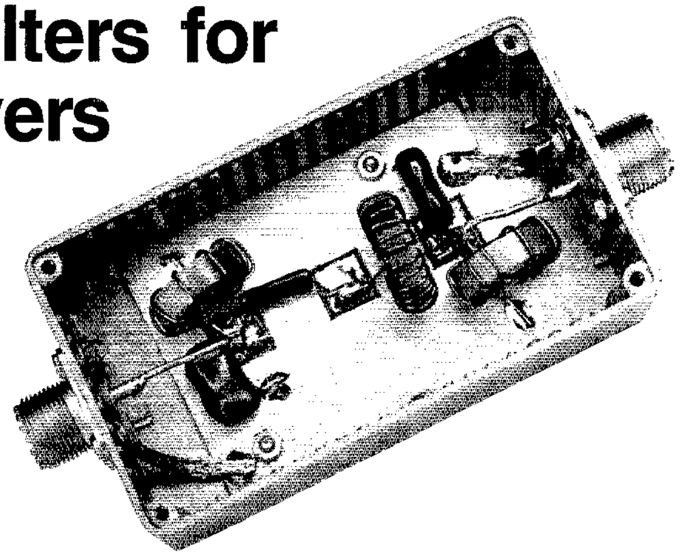
For builders who do not have easy access to an art supply store, I recommend the 0.4-mm, extra-fine-point version of Sanford's® Sharpie® marker. This model has a removable top that allows easy access to the ink cylinder. Many supermarkets stock this pen with stationery supplies or laundry products.

Two types of *medium*-point Sharpie pens are available. That labeled PERMANENT MARKER is definitely better for circuit-board work than the no. 3000 "highly water-resistant" model; the permanent marker has the further advantage of easy "openability." (The tip end of the permanent pen is pressed into the barrel assembly portion and held snug with several small rings. If the two parts are simultaneously bent slightly and pulled, the two pieces separate, allowing easy removal of the fiber ink cylinder. Once you've disassembled one of these pens, shave the rings with a file or knife to make subsequent assembly/disassembly cycles easier.) The second-choice (no. 3000) pen is cemented shut; if you must use one of these, I suggest sawing off the top end of the pen to add solvent to the ink cylinder. Reassemble the pen with tape if you do this.

My *ham radio* letter suggests use of a commercial metal-marking lacquer (DYKEM®) as etch resist for the portion of the circuit-board copper intended to remain as a ground plane. If you have trouble locating this product, I recommend thin lacquer, model paint or fingernail polish as a substitute. Be sure the resist you use flows easily so that it can be worked quickly. Also, the resist should be easily removable after etching. (I suggest using acetone as resist-removal solvent.)

Be sure to take proper safety precautions when working with any of the chemicals I've discussed here: Don't breathe their fumes and keep them out of contact with your skin. Further on the subject of chemicals, I add this: As a retired chemist, I cheerfully object to the characterization of home etched-PC-board fabrication as requiring "messy chemicals." *Chemicals* aren't messy, but *the people who use them* may be!—*Robert J. Grabowski, W5TKP, Rte 1, Box 388, Ozark, AR 72949*

Band-Pass Filters for HF Transceivers



Do your multiple-transmitter Field Day or contest efforts suffer from intrastation interference? These handy and inexpensive filters can help!

By Lew Gordon, K4VX
PO Box 105
Hannibal, MO 63401

One of the more aggravating aspects of competitive Amateur Radio operation comes when you're all set up for Field Day or a DX contest in a multiple-transmitter category and you discover an intrastation interference problem. All that planning and anticipation appears to be headed down the drain! Frustrations and tempers immediately mount: Someone yells "Eighty meters is wiping me out!" or someone else screams "Every time you transmit, all I hear is noise!" Anyone who has participated in a Field Day operation with more than one transmitter can probably relate to this situation.

Although interference caused by receiver front-end overload from adjacent transmitters has existed since the earliest days of multiple-transmitter operations, the mutual interference problem has been exacerbated in the last few years by widespread use of all-solid-state synthesized exciters. These rigs have not only greatly expanded operating ease and capabilities, but recent designs are providing receivers with greater stability, sensitivity and selectivity, and, as new devices and techniques are introduced, greater dynamic ranges than have previously been possible.

There is a shortcoming in the new generation of transceivers, however: Phase noise.[1] Reducing phase noise is a problem that radio design engineers have been attacking for years with varying degrees of success. Not only is phase noise transmitted (and propagated by the ionosphere) along with your signal on the band on which you are operating, but some noise energy is also transmitted on adjacent bands. Adjacent-band phase-noise interference is not usually a major problem unless stations are operating in close physical proximity, as is the case in Field Day or multitransmitter contest operations.

In seeking a solution to the intrastation interference problem that I could apply in my multitransmitter DX-contest station, I first entertained the idea of constructing large, high-power-handling band-pass filters for each transmitter. These filters would not only reduce the transmitted noise spectrum from each exciter, but would reduce receiver front-end overload problems as well, because each operating position would transmit *and* receive through a band-pass filter. I quickly retreated from this idea, however, as the expense of the components required to handle 1500 W of RF while providing an acceptable SWR to the transmitter would be excessive.

After considering the problem for a while, it occurred to me that the phase-noise spectrum is not generated in the amplifiers, so filters between the exciters and amplifiers, constructed with components that could handle 100 W of exciter output, would do the job nicely. In addition, this scheme would provide filtering during receiving, helping to reduce front-end overload problems. The best part is that even if you use all new components, the cost of these filters should not exceed $10 each. All that's necessary for tune up is a dip meter and a general coverage receiver. These filters were first described in an article I wrote for the *National Contest Journal*.[2]

Filter Design and Construction

The filter design I chose is a three-section Butterworth band-pass filter (See Fig 1). I chose this design to minimize insertion loss, produce a flat response across each band and maintain a 50-Ω impedance. The impedance match is very important with solid-state transceivers, if maximum power output is to be obtained from the exciters. I derived the component values in Table 1 by iterating the design formulas until standard-value capacitors could be used without compromising insertion loss, bandwidth, or performance.

A single-sided 2- × 4-inch PC board is used to mount the components for each filter. Three square pads, each approximately 0.4 inch per side, are required

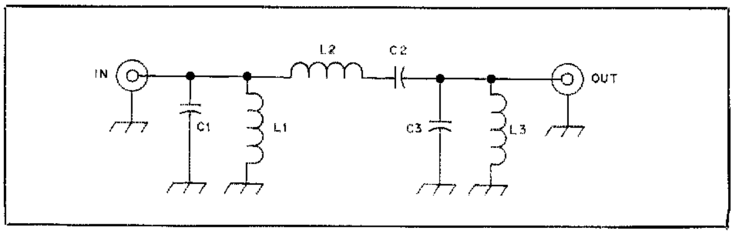


Fig 1—Schematic diagram of the three-pole Butterworth band-pass filters.

[1]Notes appear on p 23.

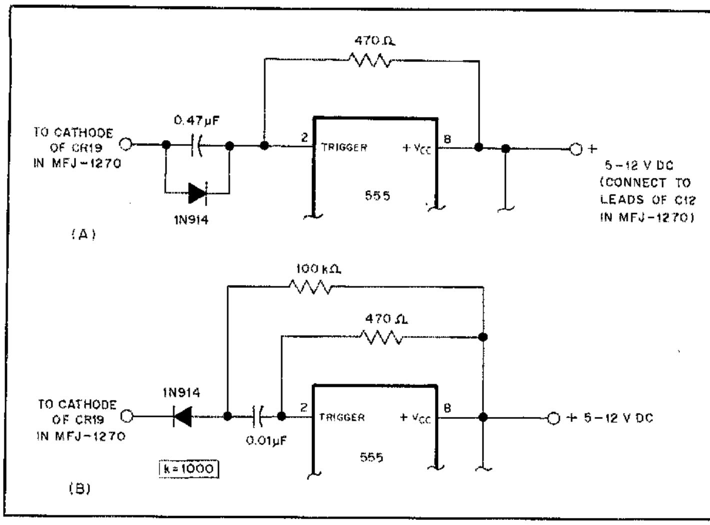


Fig 5—Frederick Losch's TNC connect alarm didn't always sound the alarm when his TNC connected, so he modified part of the original circuit (A) as shown at B. Frederick further reports that the 555's ability to drive more than one piezoelectric buzzer can be put to good use when multiple alarm buzzers are desired (one at the TNC and another at a remote location, for instance). He cautions, however, that electromagnetic transients picked up by long buzzer wires can cause false triggering of the alarm.

IMPROVING THE TNC CONNECT ALARM

☐ February 1988 *QST* carried a very timely TNC-connect-alarm circuit.[7] My version of the connect alarm did not trigger reliably, so I modified the circuit as shown in Fig 5. Now, it works every time. *—Frederick D. Losch, KA9CCZ, RR#4, Box 207, Winchester, IN 47394*

"NO HOLES" STANDBY SWITCH MODIFICATION FOR THE HEATH SB-220/221 AMPLIFIER

☐ Most of the standby-switch modifications I've seen for the SB-220/221 amplifier require drilling holes in or modifying the amplifier itself. I prefer to keep my ham equipment in its original condition, though, because this helps in reselling the equipment later.

My solution to this problem requires that no holes be drilled—in the amplifier, that is! *My* standby switch is mounted external to the amplifier in a Radio Shack® aluminum box (no. 270-235). The switch opens the SB-220's antenna-relay line to place the amplifier in standby. The pictorial/schematic at Fig 6 shows how I installed such a switch with my Kenwood TS-530S transceiver and SB-220 amplifier. Bought at my local Radio Shack store, the components necessary to add the switch cost under $7.*—Christopher B. Hays, NTØW, 3675 Estates Dr, Florissant, MO 63033*

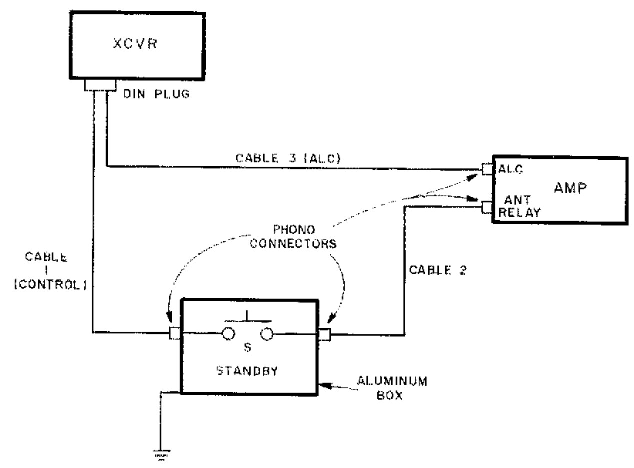


Fig 6—Christopher Hays added this standby switch to his SB-220 amplifier by breaking the '220's antenna-relay control line outside of the amplifier box. Cables 1, 2 and 3 consist of shielded wire (Radio Shack patch cords are suitable; RG-174 coax and phono connectors would provide better shielding). Standby switch S is a SPST push-button type (Radio Shack no. 275-1565), but a toggle is suitable. Hints and Kinks recommends that you keep your transceiver and amplifier turned off when unplugging or plugging in the connecting cables in your standby-switch installation. Otherwise, the open-circuit voltage on the SB-220's relay control line (about 125 V dc) can appear on the exposed center pins of the phono plugs on the transceiver ends of cables 1 and 2.

CORRECTION TO THE IC-735 POWER CONTROL HINT

☐ Missouri Section Traffic Manager John Turner, NDØN, points out two errors in "Smoother Power Control with the ICOM IC-735 Transceiver" (*QST*, June 1988, pages 48 and 49). In step 2 of the modification, "pin 6 of jack 3" should read "pin 4 of jack 3." In step 3, "pin 1 of jack 6" should read " pin 6 of jack 6." John also reports that the colors of the POC and SQLL wires can aid in their identification: The POC wire (pin 4 of jack 3) is brown and the SQLL wire (pin 6 of jack 6) is white.*—AK7M*

[7]George Kammerer and Pat MacLeod, "A TNC Connect Alarm," Hints and Kinks, *QST*, Feb 1988, p 39.

Technical Correspondence

Conducted By Paul K. Pagel, N1FB
Senior Assistant Technical Editor

The publishers of *QST* assume no responsibility for statements made herein by correspondents.

MATCHING RECEIVERS TO TRANSMISSION LINES

☐ Properly matching receivers to transmission lines is much more complicated than matching transmitters to the line. The latter is relatively simple—just obtain the largest power transfer. With receivers, the goal is a low system noise figure. The relative cost of measurement techniques is a good indicator of the difficulty involved. Lab-quality devices for measuring power transfer cost hundreds of dollars, and noise-figure measurement equipment costs run into the thousands.

Fortunately, good receivers are optimized for 50-ohm source impedances. (If they weren't, they wouldn't look good in *QST* product reviews!) Notice I said *source impedance*, and not *input impedance*. Just because a receiver is designed to work well with 50-ohm sources doesn't mean it has a 50-ohm input impedance. In fact, the receiver input impedance may be far from 50 ohms, particularly if the noise figure is pretty good and obtained with an FET amplifier. As a result, feeding a receiver with an antenna matched to 50-ohm coaxial cable usually works pretty well, at least on HF.

The mismatch is also important if you have a big station with stacked beams. The mismatch could upset carefully designed combining and phasing schemes. There are two common solutions to the input-mismatch problem. One is to minimize the feed-line loss by mounting the preamplifier at the antenna. The second approach is to use a better preamplifier design with a good input return loss or SWR. An example of the second approach is the 432-MHz preamp designed by Chip Angle, N6CA, and described in the recent editions of the *ARRL Handbook*. These designs generally use some form of low-loss feedback.

The difference between noise-figure matching and power-transfer matching explains why using a receiver to tune a Transmatch doesn't always work. When you tune the Transmatch for maximum signal, you are often tuning for a maximum power transfer into a load, which often isn't 50 ohms. The receiver noise figure is probably degraded, but that usually is difficult to tell on the MF/HF bands because of atmospheric noise. In fact, amateur receivers often have 20 or 30 dB more sensitivity than is required on the lower-frequency bands.

The RF selectivity of the input filters of the receiver is another consideration. Hopefully, the filters were designed to operate with a 50-ohm input termination. Like amplifiers, the filters don't necessarily present a 50-ohm input impedance, even when adjusted for lowest loss and terminated in a 50-ohm load! Even so, receiver input filters need to see the design input impedance to operate properly. (Input filters are often omitted from low-noise VHF preamplifiers in order to obtain the lowest possible noise figure.)

Receivers operating in the MF/HF spectrum often do just fine when the antenna system is properly adjusted for transmitting purposes, assuming that the antenna contains a single driven element. Antenna systems using phased arrays may provide better receiver performance with a front end designed for low input SWR or high input return loss. Because of inevitable construction errors and connector impedance mismatches, it may not be worthwhile to obtain return losses greater than 30 dB (SWR below 1.07 to 1). *—Zachary Lau, KH6CP, ARRL Lab Engineer*

DIRECT-CONVERSION RECEIVER NOTES

☐ Gary Breed has achieved close to the optimum expected performance from a direct-conversion (D-C) receiver.[1] His article brought back memories of my D-C SSB projects of several years ago.[2,3] Gary obviously went through laborious considerations of op-amp performance, because the op amps (NE5534s) largely determine the receiver noise figure. Three years ago, Bruce Trump of Burr-Brown wrote a paper which, among other things, quantified op amp noise figures v source impedances for various op amps.[4]

The NE5534 is an outstanding op amp for the price. It's used in expensive professional audio-recording equipment because of its low noise and excellent linearity. Many people don't know that it is available in a quad version, the NE5514, which is preferable to the TL084s that Gary uses in the all-pass networks. Also, there is a low-noise version of the NE5534, the NE5534A, available from Signetics. Gary's receiver can be improved by replacing the NE5534s with NE5534As, the TL081 with an NE5534, and the TL084s with NE5514s. The '5534 and '5514s have lower noise levels, better linearity and higher saturation levels than the TL op amps. All of these qualities contribute to a higher dynamic range.

After reading Gary's article, I began rethinking D-C SSB receivers. These receivers offer freedom from spurious responses, simplified design and can be configured easily to detect USB and LSB simultaneously. There is no reason why D-C receivers cannot be built with performance levels approaching—or even exceeding—that of superhets. A major problem of D-C SSB receivers has been insufficient rejection of the unwanted sideband. Here's a technique for improving the unwanted sideband rejection of D-C receivers. I call it the "Doubly-Nulled D-C SSB Receiver."

A block diagram/schematic is shown in Fig 1. By adding another quad op amp to Gary's existing circuit, unwanted sideband rejection of over 50 dB is possible. LSB and USB are detected simultaneously using the traditional phasing method. For additional sideband rejection, the undesired sideband signal is attenuated (about 30 dB), phase inverted and used as a second cancellation signal in a second summing amplifier. (As shown in Fig 1, the second summing amplifiers are actually difference amplifiers.)

After I discussed this technique with Gary, he tried it and got an additional 6 dB of unwanted sideband rejection. This limited improvement is caused by the bandpass ripple of the all-pass sections in the receiver. The ripple is attributable largely to gain variations, which in turn result primarily from the feedback resistors in the all-pass filter sections. Much better filter gain linearity is possible if 0.1% integrated resistors are used instead of the 1% 10-kilohm resistors specified. The fact that all eight feedback resistors have a value of 10 kilohms indicates that a single 0.1% integrated multiresistor IC could reduce the filter parts count. Alternatively, trimmer potentiometers could be installed to replace some—or all—of the feedback resistors. Furthermore, the additional nulling stages shown in Fig 1 could be added for outstanding unwanted sideband rejection.

The narrower bandwidths needed for CW allow optimization of sideband rejection across the CW passband only. Consequently, for CW receivers, greater unwanted sideband rejection can be expected.

Simultaneous LSB and USB detection allows for an interesting twist to receiver

[1]G. Breed, "A New Breed of Receiver," *QST*, Feb 1988, pp 16-23. See also Feedback, *QST*, Apr 1988, p 47.
[2]Signetics Applications Note AN1981.
[3]R. Zavrel, "ICs Simplify Design of Single-Sideband Receivers," *EDN*, Apr 3, 1986.
[4]B. Trump, "Maintaining Accuracy in Signal Processing," Proceedings of WESCON, 1985.

design. The sideband selection switch can have three positions: LSB, USB and DSB! A stereo audio amplifier would allow you to listen to LSB in one ear, and USB in the other, presenting quite an interesting effect when tuning across the band! Then, when you want to concentrate on one signal, switch over to a mono SSB mode.—*Robert J. Zavrel, Jr, W7SX, ARRL TA, 3080 Olcott St, Suite 200d, Santa Clara, CA 95054*

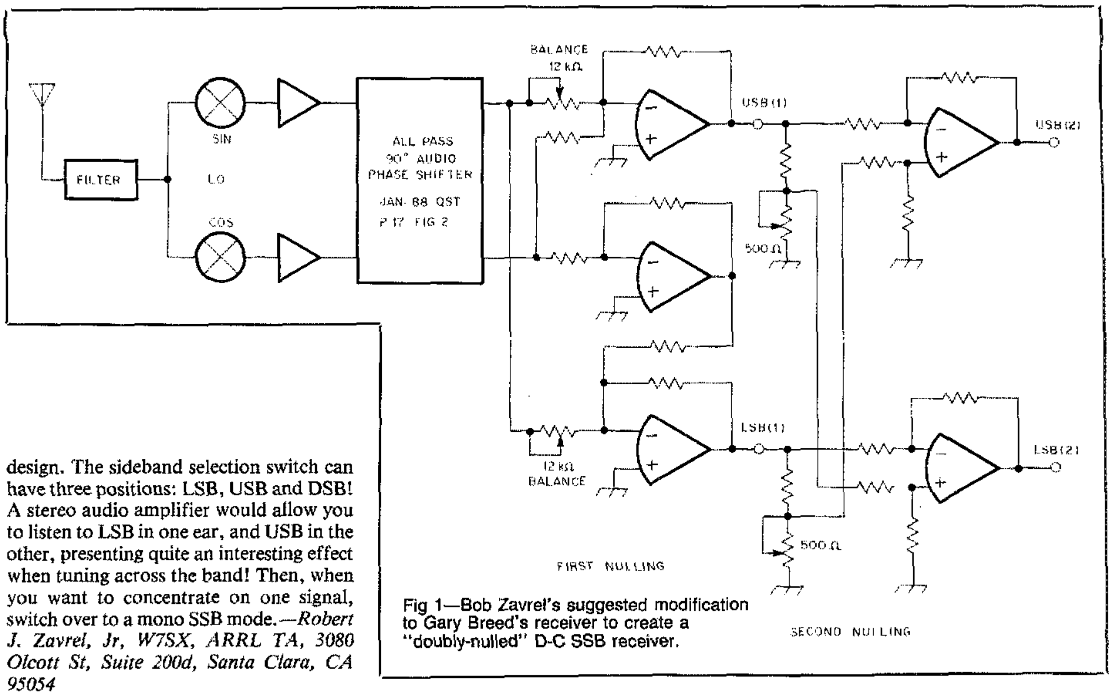


Fig 1—Bob Zavrel's suggested modification to Gary Breed's receiver to create a "doubly-nulled" D-C SSB receiver.

A POSSIBLE 2N3553 SUBSTITUTE

☐ The 2N3553 transistor is quite popular as an RF amplifier for HF QRP rigs. I first recall it being recommended by Doug DeMaw (W1FB) and Wes Hayward (W7ZOI) in *Solid State Design for the Radio Amateur.*[5] I have since seen it specified in several circuits in *QST* and elsewhere. This transistor is relatively inexpensive (under $3 in single-unit quantities), but it is available to most builders only by mail order.[6]

I've built several 1½-W QRP transmitters based on the Universal QRP Transmitter design using the 2N3053, which is available at Radio Shack (RS 276-2030) for less than a dollar. I've not used the transsistor on any band above 30 meters, but it performs flawlessly there. The 2N3053 appears to be a good, cheap, readily available alternative to the 2N3553 in HF QRP rigs.—*Gary E. Myers, K9CZB, 28W135 Hillview Dr, Naperville, IL 60565*

[The specifications for the 2N3553 and 2N3053 are compared in Table 1.—Ed]

Table 1
Comparison of the 2N3553 and 2N3053 Specifications

	2N3553	*2N3053*	*Units*
V_{CEO}	40	40	V dc
V_{CB}	65	60	V dc
V_{EB}	4.0	5.0	V dc
I_C	1.0	0.7	A dc
P_O	7	5	W
F_T	500	100	MHz

[5] W. Hayward and D. DeMaw, eds, *Solid State Design for the Radio Amateur*, 2nd edition (Newington: ARRL, 1986).
[6] RF Parts, 1320 Grand Ave, San Marcos, CA 92069, tel 800-854-1927. (Shipping and handling, $5; see their ads in *QST*.)

DTMF DECODER NOISE SENSITIVITY

☐ If you're having strange and unexplainable difficulties with the proper operation of certain DTMF (dual-tone, multifrequency) decoders, what follows may be of interest to you.

Many of the popular DTMF decoders use digital high/low frequency filters. These decoders include the Teltone® M947, M957, et al, and the SSI 202, 203 and 204 units. The specification sheets for these devices indicate that the *wideband noise* on the 5-V power supply line should not exceed 10 mV P-P. They're not kidding! If you don't have the power-rail noise below the 10-mV level, the decoder will often fail to decode an input signal for no readily explainable reason.

Achieving a wideband (from audio to over 100 kHz) noise level of less than 10 mV requires more than casual attention. Proper operation can normally be achieved by using a 10-mH RF choke in series with the 5-V power source (see Fig 2), and by placing a 4-μF (or greater value) tantalum capacitor directly across the V_{DD} and V_{AG} pins. It also helps to locate the DTMF receiver away from computer address and data buses on a PC board.

For those of you not interested in fussing with a part that has this kind of wideband noise sensitivity, the Mitel MT8870 offers about 30 dB more noise tolerance for just a few dollars more. However, the Mitel device is still sensitive to power-supply noise in the audio range, so good bypassing of the power supply bus is essential.—*Joe Mehaffey, K4IHP, 6950 Hunter's Knoll, Atlanta, GA 30328*

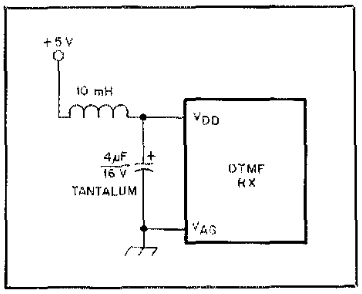


Fig 2—Noise on the dc supply line can cause mysterious malfunctions of some popular DTMF decoder ICs. The added RF choke and bypass capacitor help keep power-rail noise to an acceptable level.

COMMODORE USER'S GROUP ADDRESS

☐ In "Pictures By Packet,"[7] I noted that the address of the Commodore User's Group of Kansas City (CUGKC) was listed as unknown. I'm the Disk Librarian for the CUGKC. Interested readers can contact the CUGKC at PO Box 36492, Kansas City, MO 64111. The Koala Pictures disk referenced in the article may be obtained by mail for $10, including shipping and handling; specify disk "KP." A disk containing the club library catalog is also available for $5.—*Neil Preston, WB0DQW, 1019 Noel Ct, Lee's Summit, MO 64081*

[7]C. Pratt and V. Yarbrough, "Pictures By Packet," *QST*, May 1988, pp 15-17.

DX-60 SWITCH UPDATE

☐ In the September 1987 issue of *QST*, Gus White provided some information on replacing the Heath® DX-60 transmitter FUNCTION switch.[8] I was unable to purchase the recommended Centralab® switch (PA 077-0018) locally. Gus suggested I contact Centralab.

Kim Motl, Customer Service Representative of MEPCO/Centralab, Inc, indicated that she's had many requests for the switch and provided me with the following cost breakdown: For 1 to 9 pieces, $62.67 each; 10 to 25 pieces, $34.86 each; 25 or more pieces, $18.13 each. Also, they've a minimum charge order of $250.—*Howard Hartzell, Jr, WA3YKD, RD 2, Mifflinburg, PA 17844*

[8]G. White, "DX-60B Switch Replacement," Technical Correspondence, *QST*, Sep 1987, p 43.

[Here's an opportunity for a parts distributor to provide a service to DX-60 owners.—Ed.]

Note: All correspondence addressed to this column should bear the name, call sign and complete address of the sender. Please include a daytime telephone number at which you may be reached if necessary.

New Products

HEATH DUAL-BAND HAND-HELD TRANSCEIVER

☐ Heath® has introduced the HWS-24-HT dual-band 144- and 440-MHz hand-held transceiver. The '24-HT features two VFOs, 20 memory channels, frequency entry via front-panel keypad or rotary switches, a vacant-channel-search feature, automatic power turn-off circuitry and tone-operated squelch. Semi-duplex capability is provided on either band between the two VFO frequencies, or between one VFO and a memory channel. Full-duplex capability is available during cross-band operation.

Other features of the HWS-24-HT include optional 100-kHz tuning steps, VFO and memory-channel scanning modes, switch-selectable tone-squelch frequencies, frequency lock, PTT inhibit and a DTMF pad for repeater and autopatch use. Included with the HWS-24-HT are a NiCd battery pack, wall charger and an extra battery shell. Price class: $450. For more information, contact Heath Company, PO Box 8589, Benton Harbor, MI 49022, tel 800-253-0570.—*Rus Healy, NJ2L*

VEHICULAR CALL-SIGN DISPLAYS

☐ Sign On, of Merrick, New York, makes vehicular call-sign displays in two varieties: A magnetic sign for metal vehicle panels, and a suction-cup mounted version for inside-window mounting. The flexible, vinyl 2 × 8-inch in-window signs are available in white lettering on black, blue and red backgrounds. Magnetic signs, also 2 × 8 inches, are available in black, blue or red lettering on a white background. Price: $8.50 per sign, postage paid; volume discounts are available. For more information, contact Sign On, Dept PT, 1923 Edward Ln, Merrick, NY 11566.—*Rus Healy, NJ2L*

Feedback

☐ Please refer to "A Simple Tuning Indicator," *QST*, Jul 1988, pp 28-31. On p 29, Fig 1, +12 V should be shown connected to the common point of pin 8 of U2, the wiper of R12, the cathode of D5 and the emitter of Q9. In Fig 2, p 30 (in the upper-right corner of the PC-board pattern), the trace connecting the commoned wipers and one end each of R8 and R12 to pin 11 of U1 is not needed (see Fig 1). (That pin of the IC is not internally connected, however, and the presence of the trace in the prototype units presents no problems.) On p 31, Table 1, the third entry in the fourth column should be 850, not 250. Also, the fifth entry in the third column should be 1360, not 1350. In Fig 3, p 30, U5 and U6 should be labeled DS1 and DS2, respectively. (*Tnx Norman Monro, K4FRY*)

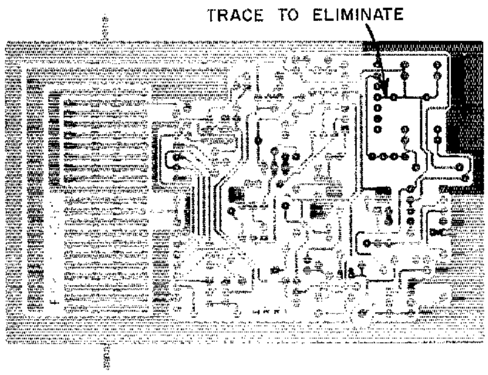


Fig 1—Correction to the PC-board layout Fig 2, p 30, of "A Simple Tuning Indicator." The trace indicated may be physically removed from an existing PC board, or the trace on the original PC-board pattern can be eradicated before copying.

Strays

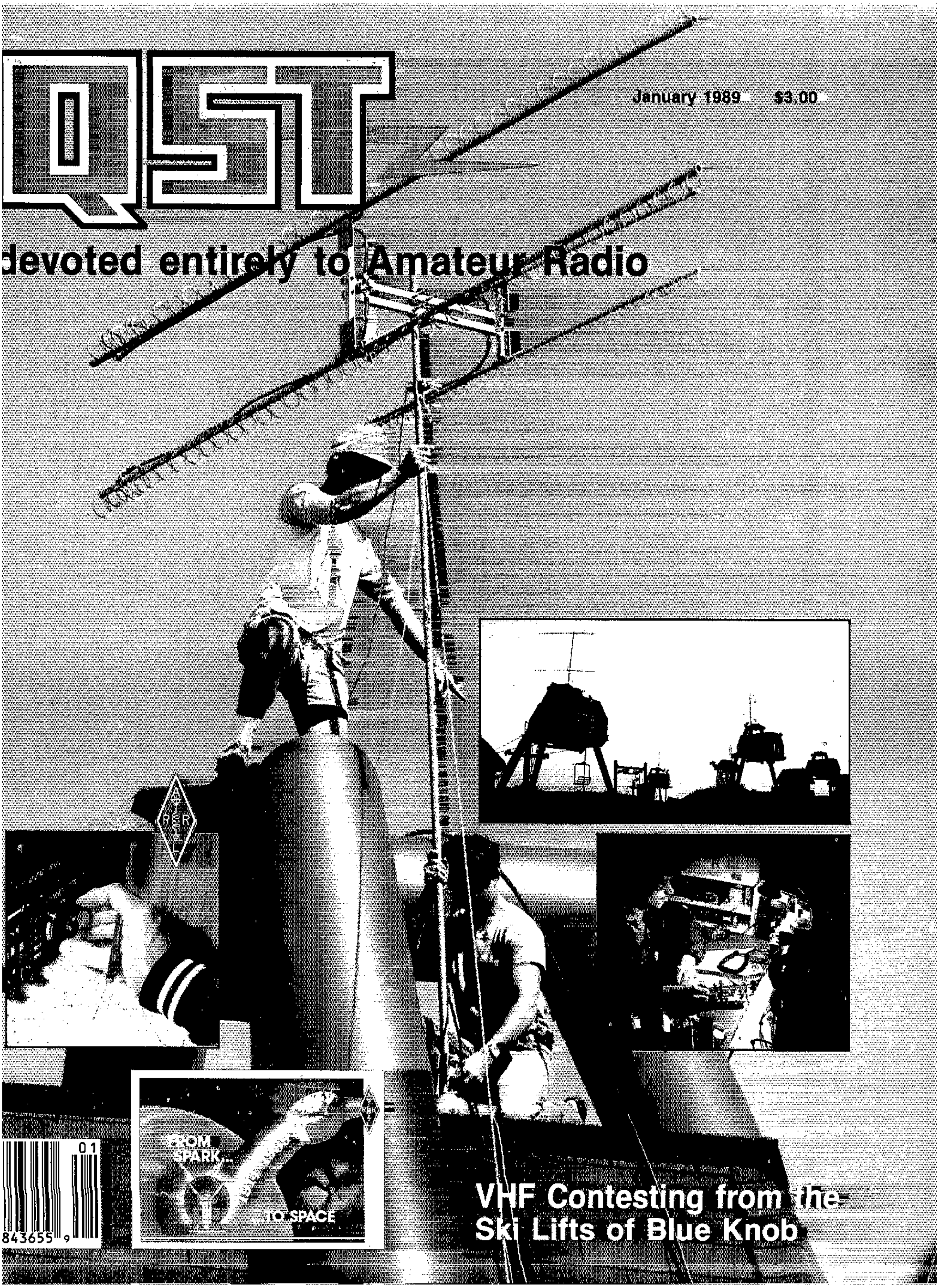
***QST* congratulates...**

☐ the following radio amateur on 60 years as an ARRL member:

- Glen F. Peterson, W0ELY, of Minneapolis, Minnesota

☐ the following radio amateurs on 50 years as ARRL members:

- Wilfred T. Siddle, W4ELB, of Birmingham, Alabama
- Harry R. Hyder, W7IV, of Tempe, Arizona
- Theodore P. Cocores, W6CSP, of South Lake Tahoe, California
- Otto M. Arnquist, W5NT, of Dallas, Texas
- Camille S. Marie, W3EPR, of Pikesville, Maryland
- Earl W. Smith, W1BML, of Groton, Connecticut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OUR COVER

VHF contesting from a mountaintop is especially attractive during September's warm days and cool nights. These photos show the W1XX contest team in action at the Blue Knob ski area in rare grid square FNØØ. Turn to page 97 for complete results of the ARRL September VHF QSO Party. *(photos by David Love, KA3JRI)*

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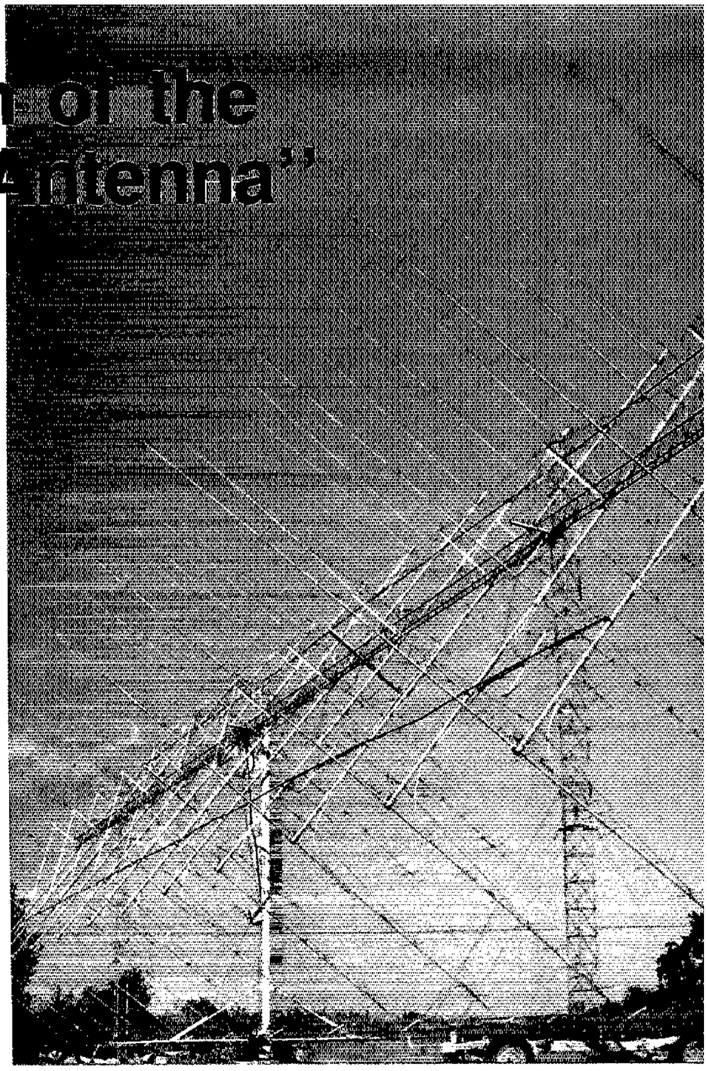
OPERATING

DEPARTMENTS

The Evolution of the "Mighty Big Antenna"



Even a decade ago, EME was out of reach for all but a few amateurs. Today, with even a modest 2-meter signal, you can work some of the bigger stations off the moon—W5UN, for one! Here's a look at Dave's antenna system.

By Dave Blaschke, W5UN
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Dave Blaschke, W5UN, is a truly ambitious man. He designed and built one of the world's largest 2-meter EME (earth-moon-earth) arrays—32 Yagis—at his home in Texas. He later expanded the array to 48 Yagis. In this article, Dave describes the history of the array, how he built it, and some of his operating achievements with his EME array, or—as he calls it—the "Mighty Big Antenna."

I first got the idea of building a *large* 2-meter EME array—a "Mighty Big Antenna" (MBA), as I have come to call it—while I was driving to the Dayton HamVention® in 1984. I stopped to pick up my friend Lance Collister, WA1JXN, at the airport in St Louis, Missouri; then we drove to Dayton. A large part of the next few hours was spent discussing two of our favorite subjects: 2-meter EME and large antennas. We discussed how we might overcome the physical support limitations that seemed to make a 4 × 4-Yagi 2-meter EME array the maximum practical size that a ham could build without having it fall down in the first high wind.

Even though our discussion was based on one of those wild dreams we hams sometimes have during convention season, it was during the trip to Dayton that we first discussed the design methods that I would ultimately use in the construction of the MBA. I couldn't build anything larger than the 16-quagi array that I was using then, because I lived on an average-size city lot. My dream would have to wait.

After the convention, we went home, time passed and our discussion about big antennas was pretty much forgotten. Two months later, I learned that I was to be transferred to a new job assignment in Houston, Texas. This would happen, I was told, sometime in early 1985. In the meantime, I would be spending three months in Anaheim, California, on a temporary job assignment. The time in Anaheim gave me the opportunity I needed to think about, design, and plan construction of the MBA—a 32-Yagi 2-meter EME array.

During late 1984, I began to locate, collect and assemble all the hardware needed to build such an array. One of the major decisions I made during this time was to purchase special long-boom Yagi antennas designed by Mike Staal, K6MYC, and made available through KLM. Mike had heard of my interest in constructing a super-large EME array while he was developing a new antenna similar to, but larger than, the popular KLM 16LBX. Mike and I discussed the properties of the special Yagis, and I decided to use them. The gain of this Yagi over the 16LBX seemed worthwhile, and the volume price discount for 32 antennas made the overall cost a little more reasonable. Mike modified the feed points of the new beams to allow the use of 75-Ω CATV Hardline, which I planned to use for phasing lines. While waiting for the Yagis to arrive, I started to assemble the power dividers and the other parts.

Upon finishing the Anaheim job assignment in September, my wife and I went to Houston to begin looking for suitable real estate on which to build our new home. Of course, there would have to be enough room for the antenna farm! We finally found the right spot: about 25 miles south of Houston, near the small community of Manvel.

While our new house was being built, I got down to the serious business of preparing the antenna farm. Concrete foundations were poured for all the antennas that I planned to build. (These antennas included 20, 15 and 10-meter Yagis on a self-supporting tower, a 40-meter beam on a 200-foot guyed tower, 80- and 160-meter antennas, and—last but not least—the 2-meter MBA.) In all, about 20 cubic yards of concrete were poured for tower foundations and guy supports.

Building the "Mighty Big Antenna"

I must admit that building the MBA was a massive project to undertake. Its design and construction tested all the skill and knowledge that I had gained from constructing large arrays in the past. Building the MBA totally consumed all of my spare time during the four months from April through August 1985 (that was when the preliminary project was completed and the MBA was first put on the air.) The array construction also kept me in good physical condition—once I got over the initial soreness from the intensive physical activity, that is! I owe a lot of credit to my son Mark. He came home from college in May, just in time to help me with some of the heavier construction work. Mark spent quite a few hours assembling the Yagis. Even though Mark is not an Amateur Radio operator, he contributed without complaint.

One of the more difficult aspects of this project was making the adjustment to doing a lot of outdoor work in Manvel's summer climate. Humidity is almost always high here—usually greater than 75%—even during the heat of a summer day. Often the humidity is above 90%, and temperatures above 90°F are common. These conditions can extend past sunset. (Of course, that's exactly the way it was most evenings while I was outside working on the antenna!) I lost a few pounds and learned to tolerate a lot of perspiration, but looking forward to hearing those often-dreamed-of loud echoes returning from the moon far outweighed such minor sacrifices!

The MBA Support Structure

I originally built the MBA as a 32-Yagi antenna, with plans in the beginning to perhaps expand the array to 48 Yagis at some time. I made design allowances that would permit this upgrade without major structural changes. I built the 32-Yagi array around what I call a fish-spine-frame support structure. This structure was expanded to hold 48 Yagis in 1987 (see Fig 1).

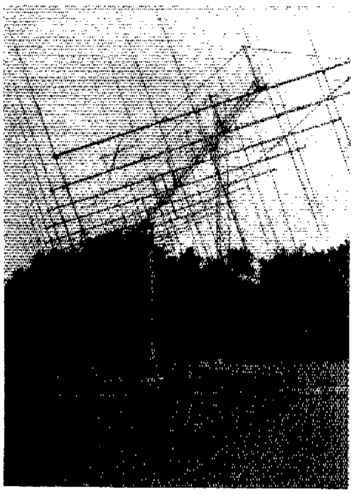

Fig 1—End view of W5UN's 48-Yagi 2-meter EME array. The array was originally built as a 32-Yagi antenna and was expanded to its present size in 1987. *(All photos by W5UN)*

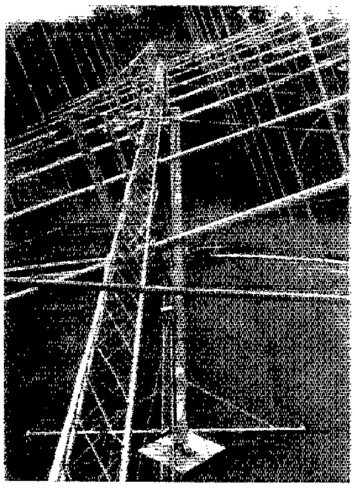

Fig 2—The main boom of W5UN's 48-Yagi 2-meter EME array is made of 152 feet of Rohn 25 tower. This photo was taken from atop one of the mobile-platform support masts, about 35 feet above the ground.

The main boom, visible in the title photo and Fig 2, is made of 152 feet of Rohn 25 galvanized steel tower. It is supported and held in place on the mast and end supports by hinges (see Fig 3). The Yagis mounted on the frame each have 31-foot-long, 1¼-inch-diam tapered-aluminum booms. The frame structure also supports all the coaxial phasing lines, power dividers and other related components.

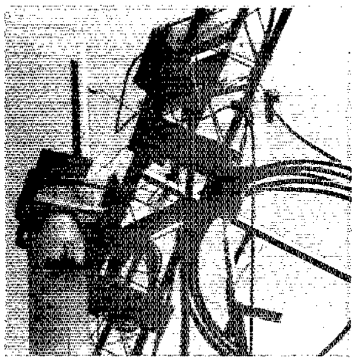

Fig 3—The main boom attachment point to the rotating mast of the MBA. The Rohn 25 boom is attached to the mast via a home-made hinge and is elevated by a winch system. Part of the cable and pulley system is visible above the boom.

Twelve 3-inch-diameter, 38-foot-long aluminum cross arms are attached to the main boom. Four Yagis are fastened to each of these arms—two above and two below the main boom on each arm, all equally spaced. I purchased the cross-arm tubing from a local irrigation-tubing supplier. The arms are very lightweight, and have a wall thickness of 0.050 inches. Each cross arm is supported with 3/4-inch EMT-conduit braces. For additional strength, 1/8-inch-diam cables extend to the ends of the cross arms from above their centers. I added the extra supports to keep the cross arms from sagging from the weight of the Yagis mounted on them, and to prevent wind-induced flexing of the cross arms. During the first three years that the antenna has been in place, it has survived winds as high as 100 mi/h with no structural damage, but the long booms of the Yagis do flex somewhat in such strong winds.

Before I started to design the array, I determined that it was essential for this array to have adequate physical strength to survive high winds. Because Manvel is located in "hurricane alley," high winds can occur during the late summer and early fall. Tie-down anchors were designed and installed to keep the array from rotating or swaying in the wind. Even so, on several occasions, the array has remained untied and in use when winds were over 40 mi/h. During these conditions, I've been able to hold the array on target, with no sign of drifting or windmilling.

The Rotating Mast

The main support mast is constructed from a 33-foot length of 5/16-inch-wall 8-inch ID pipe, as shown in Fig 4. The bottom of this mast rotates inside a six-foot length of 10-inch ID steel pipe that is embedded in a concrete foundation capped at the bottom with a flat steel plate. A

Fig 4—The lower part of the rotating main mast used in the MBA. The trash can covers the winch used in the elevation-rotation system. Part of the cable and pulley arrangement used for elevation positioning is visible above the mast strut.

Teflon® sheet between the bottom of the mast and this flat plate acts as a bearing surface for rotation. A split-sleeve collar on the concrete foundation holds the lower part of the rotating mast in a vertical position. This collar is covered with sheet Teflon to provide a bearing surface for smooth mast rotation.

Once the rotating mast pipe was installed in the foundation, I filled the space between the 10-inch pipe and the 8-inch mast with automotive antifreeze. This provides additional lubrication and keeps rain water and condensation out of the bearing. The concrete foundation for the rotating mast is 5 feet square and 7 feet deep.

The Mobile Support Platforms

The mobile support masts are each constructed from 30 feet of Rohn 45 tower mounted on mobile platforms. The mobile platforms are the key to the success of the MBA's mounting and rotating system. They are stripped-down chassis from two junked pickup trucks: a 1947 Ford (see Fig 5) and a 1951 International. Any old automobile frames would probably have worked in this application, but construction was simplified by using vehicles with solid front axles. Most modern automobiles have independently suspended front wheels, which would make them unstable in this application. [In this case, there's something to be said for "old" technology!—*Ed.*]

I bought the old pickups at one of the local wrecked-car yards, brought them home, stripped them down and equipped them for their new roles. The Ford is now

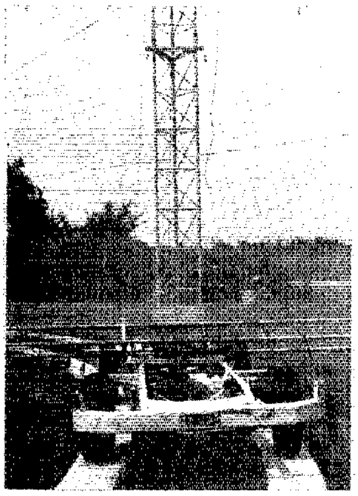

Fig 5—The 1947 Ford pickup chassis used as one of the two mobile platforms in W5UN's 2-meter EME array.

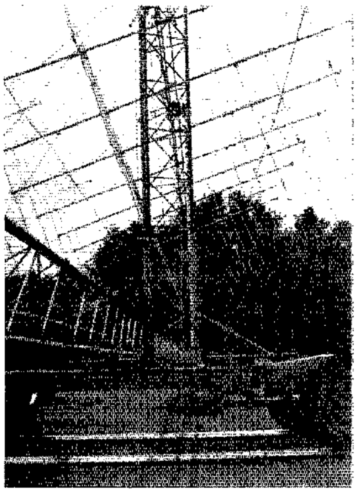

Fig 6—Side view of the 1947 Ford pickup chassis that drives the array. The drive motor is attached to the truck's modified drive shaft and stock rear differential. A 360° azimuth rotation takes over six minutes, but precise antenna aiming is possible with this system.

powered by a 400-inch-pound-torque reversible electric motor equipped with a friction-plate brake that engages when power is removed from the motor. This brake holds the antenna in position when it is not being rotated, and stops the antenna "on a dime"—a requirement for precise aiming. The motor is visible in Fig 6. The International truck chassis is unpowered—it's just pulled "along for the ride." In the original 32-Yagi MBA version, I used only the Ford pickup chassis for support and rotation duty. The second mobile platform was added during the expansion to 48 Yagis.

The array azimuth-rotation motor is connected via a short drive shaft and a flexible coupling to the Ford's rear differential gears. "Driving" the array in this manner permits smooth and precise azimuth rotation. Both of the pickup chassis are kept on the track by two 56-foot lengths of Rohn 25 tower that extends outward from the rotating mast. Guys connected between the rotating mast and the truck chassis hold them at a constant position with respect to the rotating mast. The guys also minimize flexing of the Rohn 25 arms during array rotation.

The rear axles of the trucks are not exactly perpendicular to their respective chassis—they've been offset slightly to permit perfect front- and rear-wheel tracking along the circular track. (I had to make this modification to the truck chassis shortly after the system was first tested. Without it, the rear wheels slipped sideways as the array turned.) Many people have asked me how steering of the front wheels is done. The truth is, I let the wheels go where they want to—without locking them into place. Experience has shown that the front wheels will go where they need to go: right on track.

The Track

The track on which the mobile platforms roll has a circumference of 355 feet. This circular track is centered on the rotating mast. At first, the track was unsurfaced. This was okay in dry weather, but when it rained, the track turned to mud, causing the mobile platform tires to slip and slide. Azimuth rotation of the antenna became all but impossible under such conditions. At times, in fact, rotation was impossible.

After about a year of frustrating operation with the unsurfaced track, I decided to install a concrete surface. Ed Stallman, N5BLZ, my son Mark and I poured 24 cubic yards of concrete for the track in the summer of 1987. The concrete track has two 16-inch-wide, 4-inch-thick concentric circular strips that match the wheel spacing of the mobile platforms. The track handles the weight of the mobile platforms without difficulty; the weight from each platform wheel is less than 150 pounds.

System Mechanical Workings

The turning radius for the MBA is approximately 76 feet, which means that *almost a full acre* is necessary for 360° azimuth rotation. The time required for a full rotation is about 6½ minutes. This works out to less than one degree of angular movement per second (about 11 inches along the track), which is slow enough to permit positioning the array

Moon Tracking with the MBA

To measure array azimuth and elevation positions, I use precision potentiometers driving A/D converters and LED displays in the shack. Because the MBA has an azimuth-plane beamwidth of only 2.4°, good positioning accuracy is essential. For the azimuth system, a chain-driven gear set with a 5:1 ratio rotates a 10-turn potentiometer (see Fig A). (One 360° revolution of the mast causes the potentiometer to make five revolutions.) This arrangement permits the mast to travel a few degrees outside the 0 to 360° range without hitting the potentiometer stops. The potentiometer has a worst-case linearity error of less than 0.25%, so azimuth direction can be resolved to within less than one degree. Elevation angle is read using a single-turn precision potentiometer mounted into the boom with a pendulum attached to the potentiometer shaft.

Both the azimuth and elevation rotation systems are controlled by an HP-41CX calculator. The calculator does moon-position computations, reads the antenna position and turns the az/el positioning motors on and off. This makes moon tracking at W5UN fully automatic. When using this system, I usually turn on the HP-41 and control circuit power when the moon rises and let the calculator do the positioning until the moon sets.

For anyone contemplating using a similarly automated tracking system, I strongly urge that az/el limit switches be installed on the array to prevent rotation past the stops, just in case the computer or some other component in the system fails.—*Dave Blaschke, W5UN*

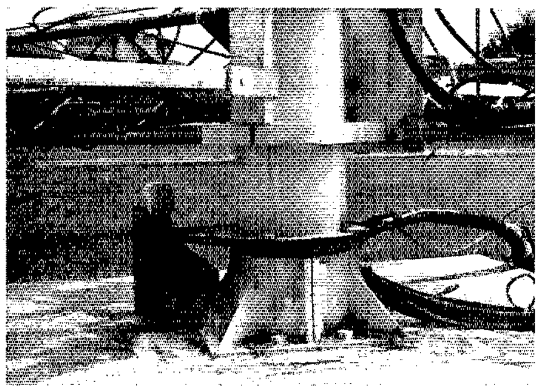

Fig A—The lower end of the rotating mast shows details of the reduction-geared azimuth-position-reading system. Also visible are the homemade split-sleeve collar that keeps the mast in place, and the brackets holding the radial-arm supports.

within 1/10° of its target (usually the moon). That is about as close as I can accurately measure with the position indication system I use (see the sidebar, "Moon Tracking with the MBA"). Elevation positioning is accomplished by using a winch-and-hinge system, as shown in Fig 4.

I was concerned from the beginning of this project about the design of the winch elevation-rotation method. After all, it had to be capable of uniformly raising and lowering a 152-foot-long boom, with all the cross arms and Yagis attached, and it had to do this without causing any twisting or misalignment. As it turns out, the method I use works very well. The heart of the elevation-rotation system is a winch mounted on the center mast, with cables routed through a pulley system to lift arms on the boom at the center and both ends of the array. When power is applied to the winch, cable tension is applied equally, via the pulleys, to the lift arms, causing the boom to pivot on its mounting hinges. The only mechanical limitation imposed by this type of elevation system is that the Rohn 25 boom must be rigid enough to resist twisting as the array is elevated. It works fine, even with 48 Yagis.

"Smoke Testing" the MBA

After assembling the original 32-Yagi array, I immediately tested it to make sure all was well. Initial testing of the array gave results that were encouraging *and* disappointing. With the array feed point over 200 feet from the shack, a low-loss feed line is essential. When the array was completed, however, I did not yet have the 1-5/8-inch Hardline that I planned to use, so I temporarily connected 250 feet of RG-8 coax, knowing full well that the feed-line loss would be significant. I discovered—much to my surprise—that the loss of the RG-8 was almost 9 dB! That meant that my 1500-W amplifier was delivering only 200 watts to the array feed point! The received signals were also affected, but a GaAsFET preamp at the antenna kept the received-signal attenuation from crippling the system.

My echo testing method consisted of sending single long dashes and then observing the signal strength of the returning echoes on an HP-400 ac voltmeter connected to my receiver audio output (with the AGC off, of course). Even with 9 dB of feed-line loss, my first echo tests produced reflected signals 2 to 4 dB above the noise level.

The First QSO

Shortly after connecting the coax to the array, I called Lance, WA1JXN, on the telephone and set up a schedule with him. Moonrise at his QTH would occur in a few minutes. My first QSO using the MBA was a 2-way SSB contact with Lance on 144.105 MHz, at 0500 UTC on August 5, 1985.

During the first week of operation, I replaced 175 feet of the RG-8 with ¾-inch, 75-Ω CATV Hardline. This reduced the cable losses to only 3.5 dB. Even though it wasn't 1-5/8-inch Hardline, it sure was an improvement over the previous feed line! With this arrangement, the strength of returning echoes was measured at 5 to 10 dB above the noise level. Occasionally I observed signal peaks that were more than 20 dB out of the noise. (The 1-5/8-inch Hardline has since been installed, and feed-line losses are now less than 1 dB.)

For reference purposes, I routinely monitor noise levels from the sun and other noise sources using the array. The MBA typically yields about 14.5 dB of quiet sun noise (as compared to the noise from a 50-Ω reference resistor—the reference resistor generates about 1.1 dB more noise than the quietest spot in the sky). The MBA gives about 12 dB of noise from Sagittarius, in the Milky Way, and about 10 dB when pointed toward Cassiopeia. Making extra-terrestrial noise source measurements on frequencies as low as 144 MHz is difficult and somewhat imprecise, but by making and logging these measurements on a regular basis, I can determine if the array performance is degrading over time.

The gain of the 48-Yagi MBA, by my estimation, is about 32.5 dBi. I determined this from the following information: The gain of each of the 32 Yagis is approximately 17 dBi (14.85 dBd), and the array gain increases by about 2.8 dB each time the number of Yagis is doubled. When phasing-line losses are considered, this 32.5-dBi figure agrees closely with gain computations based on the azimuth- and elevation-plane beamwidths that I have measured.

With the original 32-Yagi MBA, I worked a lot of stations. Many who answered my random CQs were using single Yagis and low power (less than 200 W). When conditions were excellent I could work stations running 150 W to good, single 14-dBd-gain Yagis. I was often able to work stations running less power and smaller antennas when schedules were prearranged. Stations using small and medium-sized OSCAR-type antennas have reported hearing my echoes from the moon, but very few such stations were worked with the original array.

I ran some tests with the 32-Yagi system to characterize the minimum receiving setup required to hear my echoes, and I found that while running 1500 W output, I could copy my own echoes using my ICOM IC-251, without a preamplifier, and with a 6-dB attenuator in the feed line between the array and the receiver. This encouraged me, because the front-end sensitivity of my IC-251 is poor. Since upgrading the array to 48 Yagis, results have been even better. I've occasionally heard my own echoes from the moon while running *less than 1 W output*!

Operating Highlights

When the 32-Yagi MBA first went on the air in 1985, I hoped that I could meet several operating goals. My main objective was to work stations not specifically equipped for EME communications. The MBA has allowed me to meet that goal quite often. I've worked many stations running low power to single antennas—the first of which was W2RS (Ray Soifer). Ray was running 150 W to a single 3.2-wavelength-boom, 19-element Yagi. Ray had never made an EME contact before working me. (Incidentally, since that initial contact, Ray has become an enthusiastic "QRP" EME operator and has worked several other well-equipped stations on 2-meter EME. Look for Ray's article on "QRP" 2-meter EME in an upcoming issue of *QST*.) I have since worked Ray on random calls (he has answered my CQs) several times.

Other operating highlights during the past three years include giving many stations their first EME contact. During this time, over 1,000 different stations in 75 countries have been worked. I've had a great deal of fun on 2-meter EME, logging more than 2700 QSOs since first firing up the MBA. I can truthfully say that I have enjoyed every single contact.

The most thrilling contacts for me have been the ones with stations in rare places that I least expected to hear. Memorable contacts include TI2BEV, OX3AX, UL7BAT, VP9IB, ZS4TX/A22, T70A, EA6FB, EI7M, OY9JD, LA6HL/TF, and KC3RE/TA3. All of these contacts represented new countries for me on 2 meters. I was honored to be the first to establish EME contact with stations in these countries. An interesting thing about EME: The distance is about equal, no matter what the call or country. I like to think of all EME QSOs as the *ultimate* DX.

My long-range goal is to work DXCC on 2-meter EME. Most people probably don't realize just how difficult this goal will be to achieve. At my current new-country-worked rate, it will take me several lifetimes to get to DXCC, so things will need to speed up.

I hope that a new interest is sparked in 2-meter operators in far-off lands when they hear about the W5UN MBA. I often receive comments and questions about EME from DX stations that I work on the HF bands, so it appears that many of them may be considering giving EME a try (let's hope so!). Perhaps there *is* a chance to get that DXCC!

Summary

Since the MBA was expanded to 48 Yagis in 1987, small stations who had trouble working me before have become much easier for me to hear. Single-Yagi stations running 150 W are able to routinely hear and work me without prior scheduling. I believe that some stations with good-performing OSCAR antennas are also now within EME range.

I'd like to hear from any and all who are interested in trying to make 2-meter EME contact. I can usually be found on the 14.345-MHz EME net (beginning around 1700 UTC) on Saturdays and Sundays. I can be reached at my home address (given at the beginning of the article). Also, I often call CQ on 144.008 MHz when my time and moon conditions permit.

The best time for those of you with smaller stations to listen and call is at your local moonrise or moonset, depending on whether you are east or west of me. (Stations to the east have best conditions around local moonset, and those to the west have peak times around local moonrise.) When the moon is just above the horizon (as you view the moon), ground gain can help increase reflected signal strength from the moon by as much as a few decibels under some conditions. When the moon is more than 12° above the horizon, ground-gain enhancement rarely occurs, so moon position plays an important role in the success of smaller stations attempting EME communications.

Acknowledgments

I want to extend my thanks to all who have worked W5UN via the moon. Special thanks to Lionel Edwards, VE7BQH, who faithfully continues his role as net control for the 2-meter EME net, making station scheduling easy. I also thank WA1JXN. Lance conspired with me to locate and obtain critical materials used in both of our EME antenna systems. Thanks to Ed, N5BLZ, and my son Mark, who gave many hours of their time and effort helping me build and upgrade the MBA system.

Dave Blaschke was first licensed as W5WZQ, and has been active for 36 years. Before taking up 2-meter EME, Dave spent most of his ham time DXing and contesting (he finished first and second twice each in the 1960-63 ARRL CW November Sweepstakes contests). He has earned DXCC, 5BDXCC and WAZ awards, is on the DXCC Honor Roll, and is a life member of ARRL. Dave still needs only Albania to have worked them all—anybody in ZA-land want to try EME?

W5UN Mighty Big Antenna: Vital Statistics

Array type: 48 Yagis (4 high, 12 wide); approx 32.5 dBi gain.
Beamwidth (azimuth × elevation plane): Approx. 2.4 × 6°.
Dimensions (H × W × D—not including mast): 38 × 152 × 31 feet.
Yagi type: 17-element, 31-foot boom, 14.85-dBd gain.
Total volume: Approx 179,000 cubic feet.
Main boom: 152 feet of Rohn 25 steel tower.
Array weight (not including mobile platforms or radial-arm tower sections attached to platforms): Over 1200 pounds.
Main mast section: 33-foot-high, 8-inch ID pipe; 5/16-inch wall.
Concrete track: 110-foot-diam; two 16-inch-wide, 4-inch thick strips.
Mobile platforms: Two stripped pickup truck chassis.
Mobile platform boom supports: Two 30-foot sections of Rohn 45 steel tower.
Feed line: 200 feet of 1-5/8-inch air-dielectric Hardline; <1 dB loss.

A Speaker Amplifier for Hand-Held Transceivers

Does background noise make it difficult for you to hear your hand-held talking to you? By spending a couple of enjoyable hours at the workbench, you can build this simple amplifier to boost your transceiver's audio output.

By Leonard Van Prooyen, K8KWD
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My introduction to 2-meter mobile operation (many years ago) was with a converted GE Progress Line transceiver. This was a popular tube-type, trunk-mounted commercial radio that was available on the surplus market. Together with its control head, speaker and cables, it was quite a "boat anchor." That radio had one feature I really enjoyed: a transistorized speaker/amplifier that could boost the receiver audio level above traffic or vehicle noise.

When I got rid of the Progress Line radio, I missed that speaker/amplifier. Most hand-held transceivers and portable radios in use today supply 200 to 300 milliwatts of audio, which doesn't quite cut it under high background noise conditions. While looking over some linear IC application notes, I spotted a device that I could use to build a replacement for my old GE speaker/amplifier—the National Semiconductor LM383.

The LM383 is an audio-power amplifier IC. Only four resistors, five capacitors and a couple of homemade parts need be used with this chip to build a high-performance speaker/amplifier that is capable of producing up to 8 W of audio output. The project is simple to build, and it can be completed on a weekend afternoon.

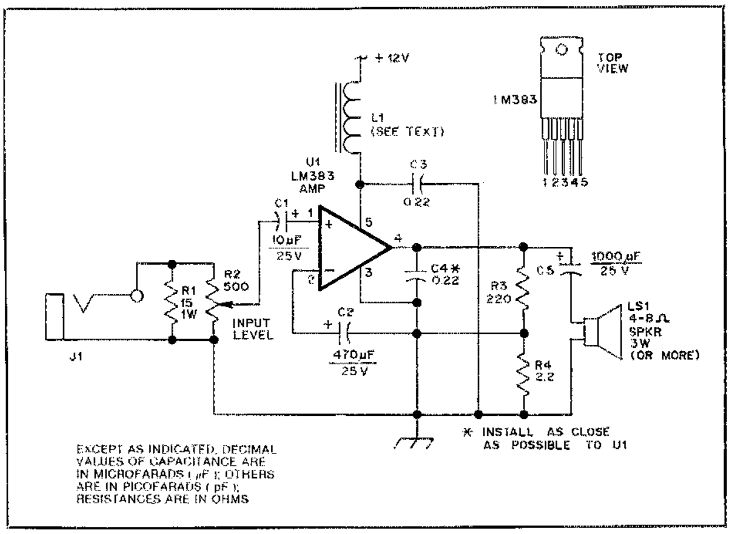

Fig 1—Schematic diagram of the amplifier circuit. A heat sink is required for U1. C4 should be installed as close as possible to pin 4 of U1. L1 is an alternator-whine choke and can be homemade (see text).

(In the parts list below, part numbers in parentheses are Radio Shack.)
C1—10 µF, 25 V (272-1012).
C2—470 µF, 25 V (272-1018).
C3, C4—0.22 µF, 50 V (272-1066).
C5—1000 µF, 25 V (272-1019).
J1—1/8-inch phone jack (274-251).
L1—See text.
LS1—8-Ω, 5 W (21-549).
R1—15-Ω, 1 W (271-003).
R2—500-Ω, ¼-W trimmer potentiometer (271-226).
R3—220 Ω, ¼ W (271-1313).
R4—2.2 Ω, ¼ W; four 10-Ω, ¼-W resistors (271-1301) in parallel (see text).
U1—LM383 audio amplifier IC (276-703).

Circuit Notes

The amplifier circuit (Fig 1) follows that shown in National Semiconductor's application notes for the LM383. The LM383 is a fairly high-gain device: Too much audio drive will destroy the LM383 (as a couple of friends of mine who made copies of this amplifier found out). I added R1 and R2 to protect the IC. R1 is essentially a load resistor for the hand-held transceiver's audio output. R2 can be composed of two fixed resistors in a 10:1 divider arrangement, but using a potentiometer makes it easy to set the amplifier's maximum gain.

C4 kills any oscillations that can make U1 "history." R4, a 2.2-ohm resistor, can be made of four 10-ohm resistors in parallel if you can't find a 2.2-ohm resistor.

When powered from the vehicle's electrical system, the amplifier's +12 V power source requires a filter (L1 of Fig 1) to eliminate alternator whine. If you can find a junked car radio, a suitable choke can probably be obtained from it. Many old Delco® radios have a suitable choke, mounted outside the radio, in the +12 V supply line. A satisfactory choke can be made from two 8d, 1½-inch-long nails and some no. 18 enameled wire. The two nails make up the choke core. Simply wind about 100 turns of the wire around the core and secure the coil windings with a layer of electrical tape.

Construction

First, get a suitable speaker and enclosure, if you don't have them in your "junk box" already. The speaker should be capable of handling three watts (or more) continuously. Because the speaker/amplifier is to be used in a vehicle, the enclosure should be fairly compact. I used a Radio Shack® mobile extension speaker (21-549). The speaker (an 8-Ω, 5-W unit) is housed in a rugged, black enclosure and comes complete with an under-the-dash mounting bracket and ten feet of cable equipped with a 1/8-inch-diameter plug. A surplus two-way radio speaker, often supplied complete with a mounting bracket, is another eligible candidate. Such speakers can be found at most hamfest flea markets for a couple of bucks. Just make sure the speaker in the enclosure isn't damaged.

The LM383 requires a heat sink. For the unit I built, I made a U-shaped heat sink for the LM383 that would also hold a terminal strip for mounting some of the other components; see Fig 2. (A close-up photo of the components mounted on this bracket is shown in Fig 3.) I made the bracket from a ¾- × 4-inch piece of 16-gauge aluminum. The bracket's dimensions allow it to fit inside the speaker's enclosure while clearing the speaker itself. The dimensions of your bracket may be different to suit your enclosure.

The LM383 can be mounted directly on the heat sink because the mounting tab is at ground potential. If the speaker enclosure is metal, you can mount the LM383 and the terminal strip directly to the inside of the enclosure. If you use a U bracket as I did, prewire the components on the bracket and then install it in the speaker housing.

Except for the placement of C4, component layout is not critical. C4 should be connected as close as possible to pin 4 of U1. Most of the components can be mounted near U1 using point-to-point wiring to and from the terminal strip.

Figs 4 and 5 show the way I mounted the components inside the Radio Shack speaker enclosure. J1 is a 1/8-inch phone jack that can be installed on the side or back of the speaker enclosure. R1 and R2 can probably be connected directly to J1. C5, the output capacitor, will probably be physically large. I found space for C5 in a corner of the speaker enclosure and secured it in place with Duco® cement; epoxy glue is a good substitute. In another corner of the

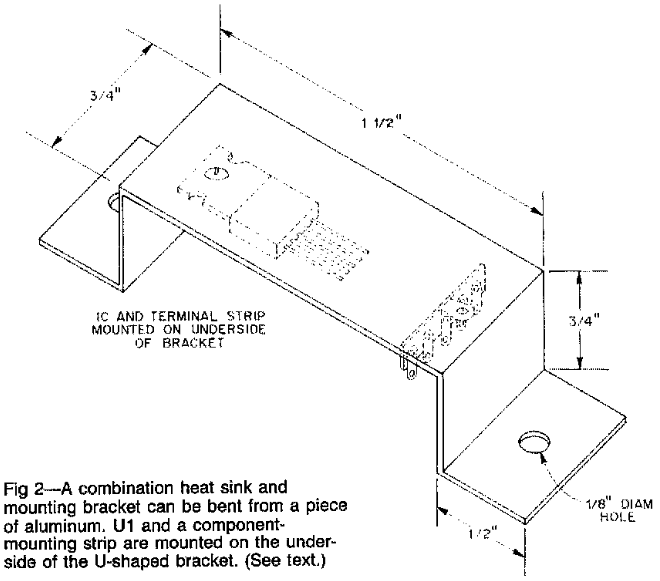

Fig 2—A combination heat sink and mounting bracket can be bent from a piece of aluminum. U1 and a component-mounting strip are mounted on the underside of the U-shaped bracket. (See text.)

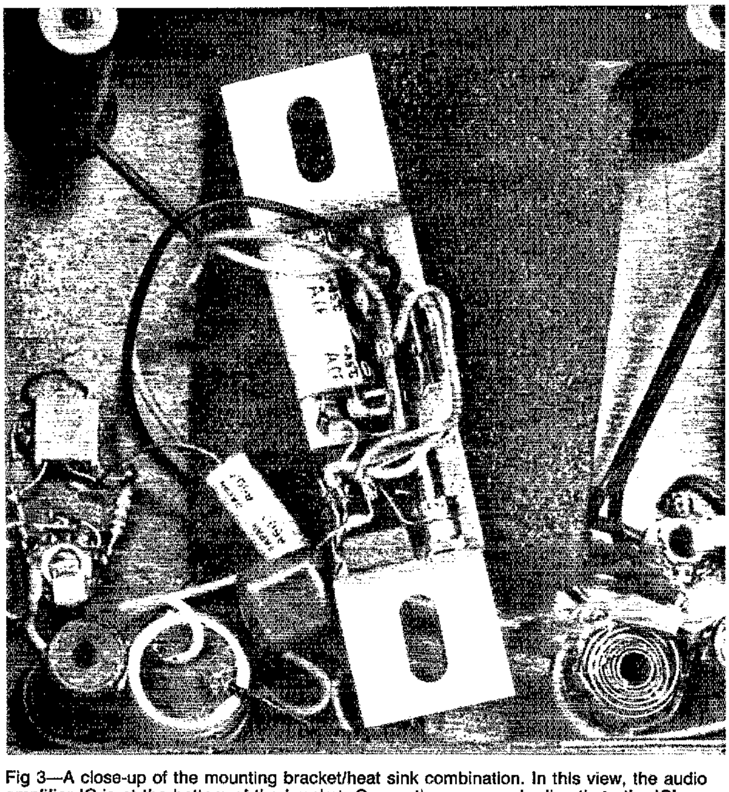

Fig 3—A close-up of the mounting bracket/heat sink combination. In this view, the audio amplifier IC is at the bottom of the bracket. Connections are made directly to the IC's pins, which are bent back over the body of the IC. C5 and L1 are to the left and right, respectively, of the bottom of the bracket. The INPUT LEVEL potentiometer is at the left and immediately above J1. The jack above and to the right of L1 connects directly to the speaker, bypassing the amplifier; this jack is not shown in Fig 1.

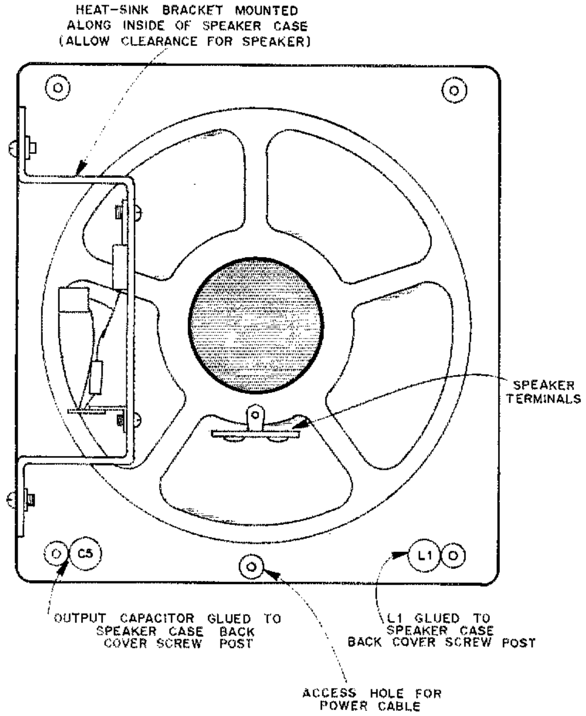

Fig 4—Parts placement of the components in the speaker enclosure. See text for details.

enclosure, I found space for L1 and glued it in place, too. Depending on your installation, a couple of items you might add to the speaker/amp are a power switch and pilot light.

For power connections, I ran short lengths of red and black no. 16 wires from the positive and negative points in the circuit through a ¼-inch hole in the enclosure and terminated the wires with a two-pin male Molex connector. A knot in the wires on the inside of the enclosure serves as a strain relief. If your speaker enclosure is metal, be sure to place a rubber grommet in the hole.

The power cable from the vehicle is fitted with a matching female connector that makes it convenient to remove the speaker/amplifier from the vehicle. Don't use a power cable without a fuse! I use a 2-A in-line fuse in the + 12 V lead of the vehicle's power cable; it's attached to the vehicle's radio connection on the fuse block. This is usually a switched (ignition switch) source of + 12 V. Connect the − 12 V lead to a good ground point on the vehicle.

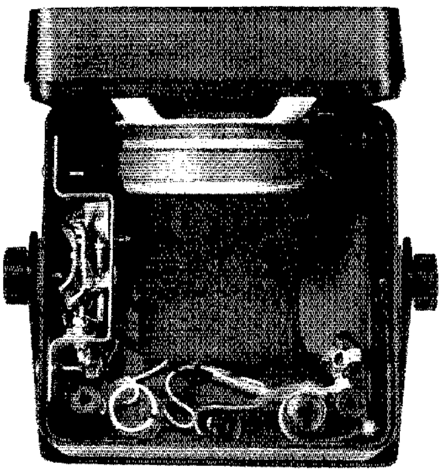

Fig 5—An inside view of the speaker/amplifier. The heat sink/mounting bracket is at the left. The dc power cord exists through a hole at the middle of the bottom of the cabinet between C5 and L1.

Operation

Most hand-held transceivers use either a 1/8-inch or 3/32-inch phone jack for the external speaker output, and many of the new speaker/microphones also have provisions for an external speaker output. Simply plug in a cable fitted with a male 1/8-inch phone plug at the amplifier end, and a connector for the radio's external-speaker connector. (I didn't find it necessary to use a shielded cable.) Use the transceiver's volume control to set the output level. I adjust R2 (see Fig 1) so that setting the hand-held transceiver's volume control about ⅓ open produces a comfortable audio output level from the speaker/amplifier. This setting allows me to control the amplifier output by using the transceiver's volume control, and I don't worry about overdriving the amplifier.

Thirty years ago, at the age of 14, Leonard Van Prooyen received his Novice license, KN8KWD. Six months later, he upgraded to Technician. His early interest in radio led him to get his FCC First Class radiotelephone ticket at the age of 17. By working part-time as a TV repairman, two-way-radio repairman, broadcast engineer and disc jockey, Leonard financed his way through Michigan State University and earned his BSEE degree.

After graduating from MSU, Leonard took a position with the Lutheran World Federation Broadcasting Service in Addis Ababa, Ethiopia. There, he helped build a high-power shortwave station (ETLF), relying heavily on material that appeared in the ARRL Handbook. *The station used two 100-kW transmitters and several curtain arrays. While in Ethopia, Leonard assisted in investigating and refining backscatter-propagation measurement techniques.*

After his tour in Ethiopia, Leonard returned to the US and worked as a radio engineer, including a brief stint at WRC (NBC, Washington) as chief engineer. In 1973, he returned to MSU and worked as a radio engineer for the University's various broadcast services. During his second stay at MSU, Leonard's vocational interests expanded to include digital systems and computers. He's currently employed as a computer-systems engineer doing logic design for computer control systems.

Leonard's Amateur Radio interests primarily include RTTY and packet-radio operation, with some HF DXing and 2-meter FM activity to round things out.

Adding 160-Meter Coverage to HF Amplifiers

Getting an HF amplifier going on 160 needn't involve guesswork or fried components once you've got a handle on what has to be done. Here's what you need to know to do the job right.

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If you have ever tried to use the 80/75-meter band for local communications on winter evenings, you have probably experienced situations in which propagation was almost nonexistent for paths shorter than 120 miles or so. The group of friends that I talk with on 75 meters was plagued by these "winter doldrum" conditions, so a few of us put up 160-meter antennas to see if communication could be improved. We discovered that when the 75-meter band was essentially useless for short-haul propagation, the 160-meter band often provided good communication.

There were some trade-offs to using the 160-meter band: Most of us had to put up compromise antennas—like the end-fed Marconi—that would fit on a city lot. Such antennas are not as efficient as full-size dipoles; the only practical way to compensate for the lack of efficiency is to increase power. We discovered another characteristic of 160 meters: a peculiar type of fading that takes a 100-W signal down into the noise for 10 to 20 seconds every couple of minutes. Again, the solution to this is to increase power.

Most commercial HF Amateur Radio amplifiers manufactured in the last 20 years do not cover 160[1] because maximum legal-limit power has been permitted there only since 1984. The easiest way to increase power on 160 meters nowadays is to sell the old 80- through 10-meter amplifier and buy an amplifier that covers 160. Instead, I decided to add 160-meter coverage to my Heathkit® SB-220 amplifier. A successful amplifier modification would net me knowledge, experience and the sense of a job well done—plus the 600-or-so-dollar difference between the cost of an SB-220 and a new amplifier that covers 160!

The modification succeeded. Since putting my own SB-220 on 160, I have been involved in modifying six more amplifiers to cover the band. These experiences indicate that 160-meter coverage can be added to similar amplifiers by applying the theory and practice I used to modify my SB-220. This article describes that theory and practice.

[1]Notes appear on page 28.

The Basics of Adding 160

To make an 80-meter amplifier work on 160 meters, the circuit reactances—capacitors and inductors—must generally be doubled in value. This includes components in the amplifier's input and output resonant circuits, the anode RF choke, and bypass capacitors. The filament RF choke—if there is one—usually need *not* be doubled in reactance, as will be explained later.

Some of the amplifier circuit reactances can be doubled (relative to those employed on 80) without affecting operation of the amplifier at HF; others cannot. For instance, additional bypass capacitors can be left in place for operation on 80 through 10 meters, as can the inductance added to the stock anode RF choke. Components that tune the amplifier's input and output circuits to 160 meters, though, must be switched out for operation at HF.

If the amplifier manufacturer has provided extra band-switch contacts, switching 160-meter components in and out of line is a piece of cake—but such contacts *don't* exist on the SB-220 and many other HF amplifiers. Because of this, the switching must be done with relays controlled by a front-panel switch (S1A in Fig 1A). One S1 position selects 80-through-10-meter operation; the other selects 160 meters—*with the amplifier's main band switch set to 80 meters.*

Fig 1 shows all of the circuit modifications necessary to add 160-meter coverage to a Heathkit SB-220 amplifier. The Fig 1 caption lists all the parts you need to put an SB-220 on 160, but does not explain specification, selection and construction of critical parts—information *you must have* to successfully put an SB-220 or other HF amplifier on MF. We'll cover that information next.

Component Ratings

The ratings of the components used in this project deserve special attention because we are dealing with surprisingly high RF currents and voltages. For example, the RF circulating current in the amplifier output network is much higher than the dc anode current (in this case, 0.8 A) might imply.

Capacitor current ratings: The capacitors used must possess sufficient voltage and current capability *at 1.8 MHz.* (Just because a 500-pF TV doorknob capacitor is rated at 20 kV dc does not mean that it can handle even 530 V RMS at 1.8 MHz. At 1.8 MHz, the reactance of 500 pF is about $-j177\ \Omega$. Applying 530 V RMS across such a capacitor results in an [apparent] current flow through it of about 3 A—enough current to cause severe heating of the capacitor dielectric, rapid capacitance shift and destruction of the capacitor.) RF-current-rated capacitors include transmitting micas and ceramics, and air- or vacuum-dielectric capacitors.

The RF (circulating, or flywheel) current in an amplifier's output pi network is roughly equal to network Q multiplied by the amplifier's dc anode current. In the case of an SB-220, the output network circulating current is about 12×0.8 A, or 10 A. The output-network tuning capacitor must be able to withstand this current. When the tune padder (C55A) is switched into the circuit on 160 meters, *and the tuning capacitor is set to minimum capacitance,* C55A must be able to withstand at least 90% (9 A) of the RF circulating current in the network. It's safest to assume that the tune padder must handle 100% of the network circulating current. As specified in the Fig 1 caption, C55A consists of two 150-pF, 5-kV, or three

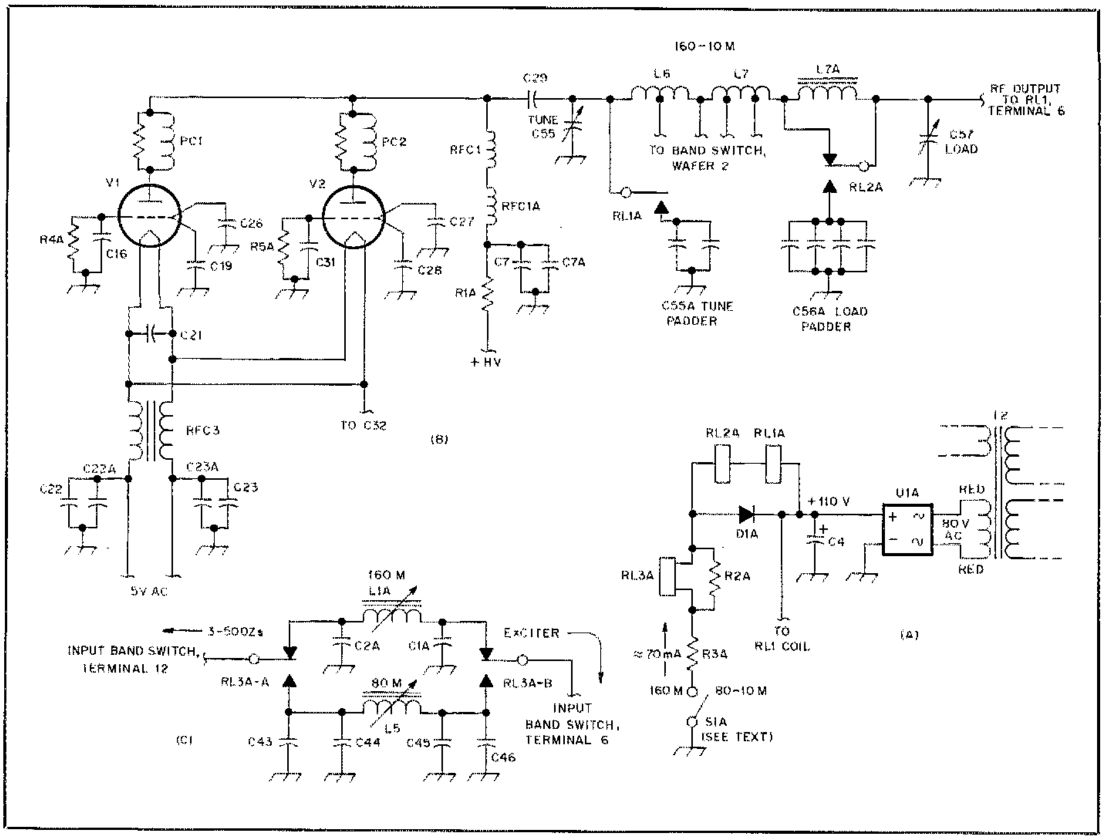


Fig 1—Schematic showing the changes necessary to put the Heath® SB-220 amplifier on 160 meters. (Components added for 160-meter operation are designation by the suffix *A*; components without the *A* suffix are original Heath parts. Component designators not in keeping with *QST* style are used for compatibility with designators on the SB-220 schematic.) Modified in this way, the SB-220 is switched to 160 meters by setting its BAND switch to 80 meters and selecting 160 M with S1A. Control circuitry for the added band-switching relays, and changes to the SB-220's relay power supply circuit, are shown at A. Modifications to the '220's filament, anode-supply and output circuitry are shown at B. C shows changes to the '220's input circuitry. R1A is included as an HV current limiter to protect amplifier components in case of VHF parasitic oscillation by the 3-500Zs. See text.

C1A—2700-pF, 500-V mica.
C2A—3000- to 3300-pF, 500-V mica.
C7A—4700-pF, 3-kV (or greater) disc ceramic.
C22A, C23A—0.02-µF (or greater), 1-kV disc ceramic.
C55A—Three 100-pF, or two 150-pF, 5-kV ceramic "doorknob" transmitting capacitors in parallel.
C56A—2000-pF, 2-kV mica; four 500-pF units (Heath part no. 20-711 suitable) in parallel.
D1A—200 (or greater) PIV, 1-A rectifier diode.
L1A—Slug-tuned, 4- to 6-µH coil wound with no. 24 (or heavier) enameled copper wire.
L7A—9 µH: 16 turns of no. 14 stranded, Teflon® -insulated wire on a T-225A-2 powdered-iron toroidal core. Cover the core with silicone-rubber or fiberglass tape before winding the coil. See text. (T-225A-2 cores are available from Amidon Associates, Palomar Engineers and RADIOKIT.)
R1A—10 Ω, 7 W, wirewound.
R2A—430 Ω, 2 W, metal film. See RL3A.
R3A—620 or 680 Ω, 4 W. Select for a current of approximately 70 mA through S1A.
R4A, R5A—24 to 30 Ω, ½ W. These resistors replace RFC4 and RFC5, respectively, and serve as fuses to protect the 3-500Zs against grid-to-filament shorts.
RFC1A—65 to 135 µH; see text.
RL1A, RL2A—Jennings RB1, Kilovac H-8 or similarly rated vacuum relays with 26-V coils. See text.
RL3A—Metal-can relay, 26-V coil, coil resistance about 700 Ω, 2-A contacts. If your relay's coil resistance differs greatly from 700 Ω, adjust the value of R3A to maintain the correct voltage drop across the coil. See R3A.
U1A—1-A, 200-PIV bridge rectifier.

100-pF, 5-kV, transmitting capacitors in parallel. The 100-pF capacitors are rated at 3.4 A each at 1 MHz; in parallel, the three have a total current rating of 12 to 15 A at 1.8 MHz—sufficient for the job.

The RF current ratings of transmitting ceramic capacitors vary with frequency. For example, a 500-pF, 5-kV Series 58 Centralab™ (now Jennings™ Series 58) capacitor is rated to handle 2.5 A at 10 MHz, but only 1.1 A at 1 MHz. At 1.8 MHz, this capacitor can probably handle around 1.5 A. Assuming that a 500-pF capacitor was called for in the first place, this unit won't cut it at C55A or C56A (the load padder) in Fig 1B. Investigation of the Jennings Series 58 range reveals that even the 1000-pF Series 58 entry is unsuitable for use at C56A: Its current rating is only 1.4 A at 1 MHz.

Relays: The current and the open-contact voltage ratings of the output-network switching relays, RL1A and RL2A, deserve special consideration because RF energy is much more capable of jumping across open switch contacts than 60-Hz energy. Breakdown voltage decreases with frequency: At

30 MHz, the breakdown voltage between two points separated by a given dielectric is roughly 60% of the 60-Hz value.

Conductor ratings: RF current travels on the surface of conductors, largely bypassing the conductive path below the conductor's skin. This is known as *skin effect*, and it becomes more pronounced as frequency increases. Because of skin effect, the effective RF resistance of a given conductor increases with frequency. As a result, the ac current capability of wire and contacts must be derated with frequency. (Example: No. 12 copper wire, which is rated to handle over 20 A continuously at 60 Hz, can handle only 5 A continuously at 30 MHz.).

RF-current-rated relays are normally derated to about 20 to 30% of their dc or 60-Hz current ratings for use at 30 MHz. Unlike RF voltage breakdown ratings—which are absolute and can't be pushed—the continuous-duty RF current ratings of wire and relay contacts can be exceeded in intermittent applications like CW and SSB. The result of this is a bit more conductor heating and a slight decrease in overall circuit efficiency.

Voltage ratings: The maximum RF peak voltage encountered by the output-network tuning capacitor in a *properly tuned* grounded-grid amplifier is approximately equal to the anode supply voltage minus about 200 V. In the SB-220, this is about 2.7 kV minus 200 V, or about 2.5 kV peak.[2]

Switching 2.5 kV is not difficult at 60 Hz. At 29 MHz, however, switching 2.5 kV is not so easy. Example: If a relay (RL1A) with a rating of 3 kV peak at 60 Hz were used to switch C55A (the tune padder), its *open contacts* would arc over during operation on the upper HF bands. Instead, a relay with a sufficient *RF* voltage rating must be used. The only practical relay for this difficult job is a *vacuum* relay that is (open-contact) rated for at least 2.5 kV peak *at 30 MHz*. (The Jennings RD5 and RB1, and the Kilovac® H-8, are suitable; many other vacuum relays are rated for 2.5 kV peak at 30 MHz. Those I've mentioned are more common at swap meets than other types, however.)

RL2A, the SPDT relay at the 50-Ω (low-voltage) end of the amplifier output network, switches the load padder (C56A) and the added output-network inductance (L7A). The maximum RF voltage at these points is less than 1.2 kV peak. An ordinary 15-A, open-frame relay can be used at RL2A if its open-contact air gap can withstand 2.5 kV dc on a breakdown-voltage tester.[3] Another Jennings RB1 or RJ1A (like that shown in Fig 2), or a Kilovac H-8 would be even better.

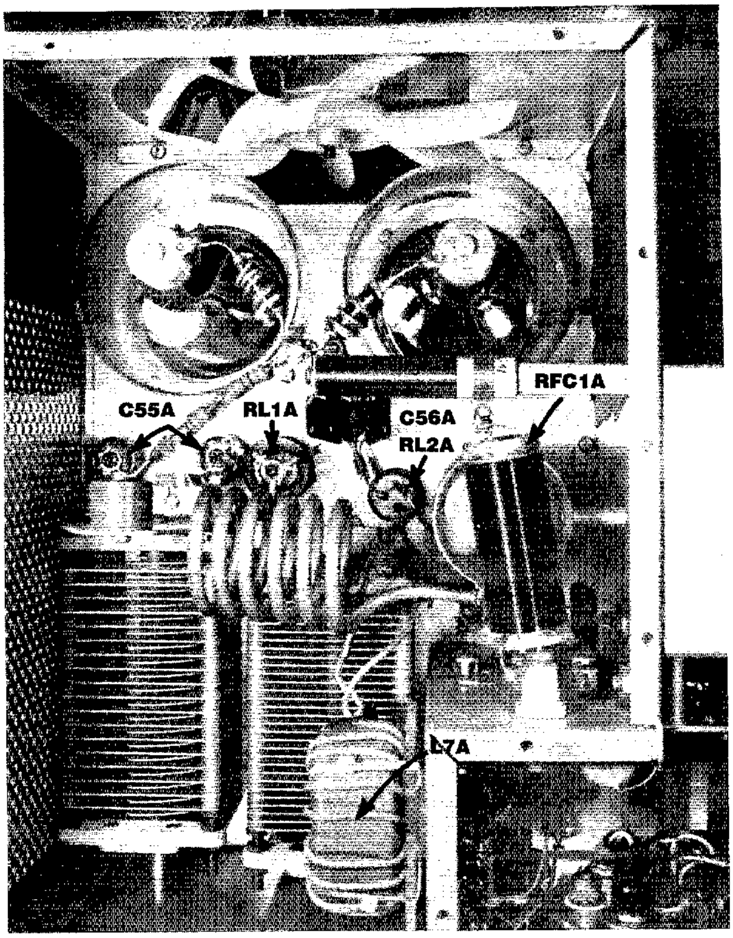


Fig 2—These components modify the output-network and anode portions of the SB-220 circuit for operation on 160 meters. The added anode RF choke (RFC1A) is left in the circuit on 160 through 10 meters; added output-network components C55A, C56A and L7A are switched into line on 160 by means of vacuum relays RL1A and RL2A. See text. (The resistors between the anode choke and the doorknob capacitor on the SB-220 TUNE capacitor [lower left] are not part of Heath's design. They were an intermediate—and unsuccessful—R and D step in suppressing VHF parasitics in this particular amplifier and are unrelated to the 160-meter modification process. The parasitic-suppression circuitry that *worked* is described in R. Measures, "Improved Anode Parasitic Suppression for Modern Amplifier Tubes," *QST*, Oct 1988, pp 36-38, 66 and 89.)

Powering the Relays

The rated coil current for a Jennings RB1 is 100 mA. If speed of relay closure is not a factor—as in this application—a lower actuating current may be used. The actual minimum pull-in current for an RB1 is about 50 mA. For reliable operation and maximum coil life, a coil current of approximately 70 mA is appropriate.

The stock, half-wave rectified, +110-V relay power supply in the SB-220 is adequate for the original current load (RL1 only) of about 25 mA. The additional current required by RL1A, RL2A and RL3A can be accommodated by modifying the SB-220's half-wave-rectified supply to a full-wave-bridge rectifier circuit. To do this, remove D16 and rewire the supply as shown in Fig 1A.

One Jennings RB3 DPDT relay can do the jobs of RL1A *and* RL2A, but the RB3's rated coil current (200 mA) is probably too much for T2's relay-supply secondary winding to handle. Thus, if you choose to use a single relay instead of RL1A and RL2A, you'll probably have to build in an 18- to 24-V supply to power it.

Filament Choke

Most of the articles about 160-meter amplifier modification that I've seen presume that a given amplifier's stock 80- to 10-meter filament RF choke must be replaced with a more inductive choke. On the contrary: *In most amplifiers—including the SB-220—the 80- to 10-meter filament choke can be used on 160.*

The SB-220 has a 9-μH filament choke. The reactance of this choke at 1.9 MHz is about $+j107\ \Omega$. If a reactance (at 1.9 MHz) of $-j107\ \Omega$ (an 800-pF capacitor is close enough) is connected in parallel with the 9-μH choke, the choke and capacitor resonate and act as a high impedance at 1.9 MHz. Resonated in this way, the original HF filament choke *can* do a good job on 160.

The impedance of a tuned circuit generally varies much more rapidly with frequency than the reactance of a choke (or capacitor) on its own, however. Because of this, the off-frequency impedance—at the 160-meter band edges—of a resonant filament-choke circuit deserves evaluation. The admittance of a 9-μH inductor in parallel with an 800-pF capacitor is about 1/900 S (siemens [previously called *mhos*]) at 1.8 MHz and 2 MHz. This admittance, equivalent to an impedance of about 900 Ω, is almost 14 times greater than that of the paralleled cathodes of the SB-220's two 3-500Zs (about 65 Ω [averaged over a full cycle of the input waveform]). Result: Resonating the SB-220's filament choke to 1.9 MHz causes the impedance of the 3-500Zs-and-filament-choke circuit to vary from just below 61 Ω at 1.8 and 2 MHz to about 65 Ω at 1.9 MHz. This modest impedance variation presents no problems.

Because the cold ends of the filament choke windings are grounded for RF by C22, C22A, C23 and C23A, the 800-pF resonating capacitance can be paralleled with the filament choke by connecting the capacitor between the 3-500Z cathodes and chassis. This is most easily done by adding 800 pF at the output of the amplifier's 160-meter input pi network. (The value given for C2A in the Fig 1 caption includes the 800 pF necessary to resonate the choke.) Because the input network is band switched, the filament choke resonates at 1.9 MHz only on 160 meters.

Getting Parts for 160-Meter Amplifier Modifications

Parts Suppliers

New vacuum relays and transmitting capacitors rated for RF current:

Surcom (Jennings relays)
2215 Faraday Ave, Suite A
Carlsbad, CA 92008
tel 619-438-4420

New vacuum relays:

Kilovac
550 Linden Ave
Carpinteria, CA 93013
tel 805-684-4560 (ask for Gail or the order desk)

New-surplus and used vacuum relays and transmitting capacitors rated for RF current:

Alan Emerald, K6GA
8956 Swallow Ave
Fountain Valley, CA 92708
tel 714-962-5940

Hiway Sales
305 Wisconsin Ave
Oceanside, CA 92054
tel 619-722-1175

Fair Radio Sales Co, Inc
Box 1105
1016 E Eureka St
Lima, OH 45802
tel 419-223-2196

Parts Costs and Tips

Vacuum relays average about $35 each at swap meets. New relays cost about $100 each. Test swap-meet relays—*before* purchasing them—with two seriesed 9-V batteries (to power the relay coil) and an ohmmeter (to make sure that the contacts open and close properly). I also strongly recommend that you test the open-circuit voltage capability of bargain relays *before purchase* with a current-limited HV breakdown tester. (The breakdown tester measures the integrity of the vacuum inside the relay. For information on how to construct such a device, see the article cited at note 3 of the main text.) If swap-meet vacuum testing is inconvenient, be sure to get the relay seller's call sign and vehicle license plate number—and a money-back guarantee—in case the vacuum proves to be bad.

Jennings 100-pF, 5-kV transmitting capacitors cost about $11 each new, and about $3 to $5 used.

The total parts cost of this project for a skilled scrounger is about $80. The cost of all-new parts is about $300.

Literature

For information on the availability of Varian EIMAC's *Care and Feeding of Power Grid Tubes*, call 415-592-1221, or write Varian EIMAC, 301 Industrial Way, San Carlos, CA 94070.

Tuned Input Circuit

Before the values of the components in the 160-meter input pi network can be calculated, a value of network Q must be chosen. For this purpose, Q is defined as the input resistance of the pi network divided by the reactance (in ohms) of the input capacitor, or $Q = R_{in} \div X_{Cin}$. If the Q chosen is too low, the bandwidth of the input network will be wide, but the SWR presented by the network to the exciter will not be especially good anywhere on the band. If the Q of the input circuit is too high, the SWR at the middle of the band will be low, but the SWR at the band edges will be too high. Because of this, a compromise Q must be chosen to balance bandwidth against minimum attainable SWR. According to the Varian EIMAC® book *Care and Feeding of Power Grid Tubes*, an input-circuit Q of about 2 should be used. The 80- through 10-meter input networks of the SB-220 exhibit a Q of only about 1. This results in an SWR that is acceptable for transceivers with vacuum-tube finals, but less than optimum for modern all-solid-state transceivers.

Plugging a Q value of 1.6 into the formulas in the Varian EIMAC book results in these calculated values: input capacitor (C1A), 2700 pF; L1A, 4 to 5 μH; output capacitor (C2A), about 2500 pF. (The C2A specification in the Fig 1 parts list is 3300 pF because the spec includes the 800 pF necessary to resonate the filament choke at 1.9 MHz.) C1A and C2A must possess a mica dielectric and be rated at 3.5 kV. Inductor L1A should be wound from no. 24 or larger insulated copper wire to keep the coil Q high; smaller-diameter wire would degrade the amplifier's input SWR. (L1A is wound on a slug-tuned form to allow some adjustment of the input SWR; see the next paragraph.)

Adjusting the amplifier input SWR: Do not try to minimize the input network SWR by varying the value of C1A (the input capacitor of the 160-meter pi network); doing so changes the network Q. Instead, adjust the network inductance. This adjustment mainly changes the network center frequency, however, and may not result in an acceptable minimum SWR. If this is the case, adjust the value of C2A *and* L1A until the proper impedance transformation ratio *and* minimum SWR are achieved.[4]

Anode Choke

Designing an anode choke for a single-frequency amplifier is easy. (For single-frequency operation, choke self-resonances—which are *unavoidable*—can be parked at frequencies sufficiently removed from the operating frequency to avoid frying the choke with the amplifier output.) When an amplifier is to be operated over a wide frequency range, however, anode-choke design is critical because the choke must (1) exhibit sufficient inductive reactance to keep it from dissipating too much power at the amplifier's lowest operating frequency and (2) *not* exhibit self-resonances at or near any of the amplifier operating frequencies. (The RF current responsible for destroying a choke that fails to satisfy either or both of these conditions flows through the choke and the HV-to-ground bypass capacitor [C7 and C7A in the modified SB-220].) Satisfying both conditions simultaneously is tricky: Adding turns to (increasing the inductance of) a choke that does not satisfy condition 1 increases the choke's distributed capacitance and the number (and position) of choke self-resonances below 30 MHz.[5] If one of these resonances occurs at an amplifier operating frequency, an unpleasant choke fire may result—and the choke may be "crispy-crittered."

The inductance of the SB-220's stock anode choke, RFC1, is 50 μH. Heath chose this value wisely: RFC1's lowest self-resonance occurs above 40 MHz—well above the operating frequency range of the amplifier. The reactance of this choke at 1.8 MHz is $+j565\ \Omega$. The ac anode voltage in the SB-220 is about 2.5 kV peak $\div \sqrt{2}$, or about *1768* V RMS. At this voltage, the RF current through RFC1 is 1768 ÷ 565, or 3.13 A! This substantial current would cause severe heating of the choke's no. 28 wire *and* the ceramic-dielectric HV bypass capacitors (C7 and C7A) at the cold end of the choke. Thus, another choke must be placed in series with, and at a right angle to, RFC1. The inductance of this choke (RFC1A) can be as little as 65 μH or as much as 135 μH. (Its inductance can be anything up to about 135 μH as long as a self-resonance cannot be found on frequencies within about 5% of the edges of any operating amateur band covered by the amplifier.[6])

A 65-μH choke can be made by filling about 2 inches of winding space on a 5/8-inch-diameter coil form with no. 27 high-temperature enameled copper wire.[7] The lowest self-resonance of such a choke occurs at about 35 MHz, so the choke should work well between 3.5 and 30 MHz while providing enough total inductance (RFC1 + RFC1A = 115 μH) to keep itself and bypass capacitors C7 and C7A from overheating at 1.8 MHz. A compact 65-μH choke can be made by filling about 1-9/16 inches of winding space on a 1-inch-diameter coil form with no. 27 wire. A suitable 135-μH choke can be made by filling 1-13/16 inches of winding space on a 1-inch-diam coil form with no. 27 high-temperature enameled copper wire. Such a choke is self-resonant at about 23 and 35 MHz, making it safe for use at 15, 12 and 10 meters.

To avoid destructive RF dielectric heating of the coil form, avoid form materials (such as nylon and PVC) that have high RF dissipation factors. Delrin® has an intermediate dissipation factor; polyethylene, TFE, and ABS (acrylonitrile butadiene styrene) and other styrenes, have low dissipation factors. Thin (0.02-inch)-wall G-10 or G-11 fiberglass tubing is excellent for this application because it is lightweight, RF- and heat-resistant, and very strong. (A choke constructed on fiberglass tubing is lightweight enough to be supported by the no. 18 solid wire I used to connect the choke into my amplifier.)

Wire gauges from no. 24 to 28 can be used for RFC1A if the winding space on the coil form is adjusted accordingly. After you build your choke, check its self-resonances as described in note 6. If necessary, remove turns to park the choke's self-resonances between Amateur Radio bands. (Achieving a particular choke inductance is far less critical than the position of the choke's self-resonances in the spectrum!) Give the finished choke a thin coating of polyurethane varnish to keep the winding from rattling with modulation.

General Construction Notes

Component placement is not critical when modifying an amplifier for use on 160 meters. The only guideline is to put each RF part reasonably close to the part of the circuit to which it is connected.

Use no. 14 or heavier wire for leads that carry RF circulating current in the amplifier output network. To minimize stress on the vacuum relays' metal-to-glass seals, install a flexible copper-ribbon section (about 1 inch long and 1/8 to 3/16 inch wide) between the relay RF terminals and the heavy wires that connect the relay contacts into the circuit.

Specifics on Modifying the SB-220

Figs 2 and 3 show how the 160-meter parts fit into an SB-220. Disconnect the doorknob capacitor (C6) at the base of RFC1. Remove RFC2 and replace it with RFC1A. Once this is done, C6 may be removed or reconnected in parallel with C7 and C7A for improved HV-lead bypassing.

If you use the compact 65-μH choke, you won't have to remove the SB-220's HV interlock switch to make room for RFC1A. If you use a larger choke for RFC1A, you'll have to remove the interlock to make room for the choke.[8]

The ceramic coil form used in the SB-220's stock anode choke (RFC1) cannot withstand the RF voltage that appears at its chassis end as a result of removing C6 and adding RFC1A. To solve this problem, replace the aluminum spacer under RFC1 with a no. 6-32 threaded ceramic pillar or the phenolic spacer from the SB-220's HV interlock. (You'll need to use washers with the phenolic spacer to make its length equal to that of the original aluminum spacer.)

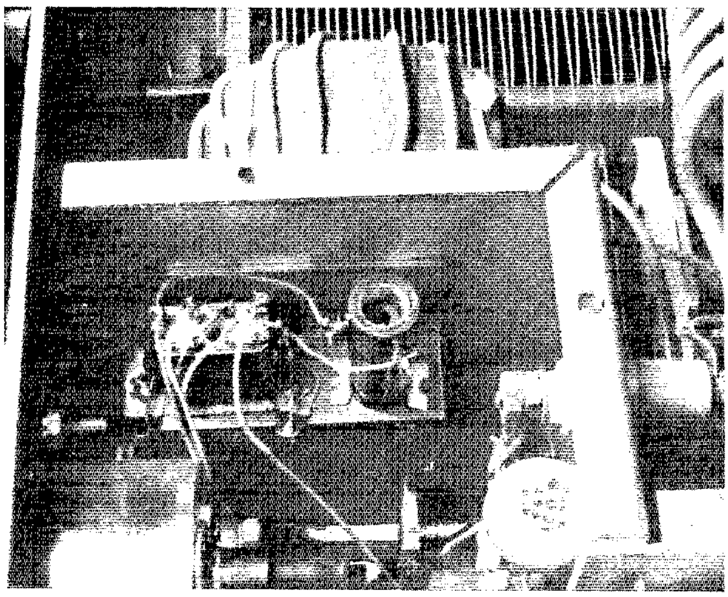


Fig 3—The additional components necessary to put the SB-220's input pi network on 160 are mounted near the input-network components for 80 through 10 meters. RL3A and L1A are mounted on the metal bracket at center.

The 160-meter tank circuit inductor (L7A) is wound on a T-225A-2 powdered-iron toroidal core. Cover the bare core with one overlapping layer of Plymouth Rubber Co silicone-rubber tape. If silicone-rubber tape is not available, use fiberglass tape. (*Don't* use vinyl tape.) Use Teflon-insulated wire for L7A; such wire is ideal for RF applications. Secure the ends of the winding with nylon cable ties. Also using cable ties, mount the completed inductor on a square of 1/8-inch-thick acrylic sheet. (Drill holes in the acrylic sheet to pass the ties.) Fig 2 illustrates this mounting method.

Conclusion

Putting an HF amplifier on 160 meters needn't be a hit-or-miss job. In this article, I've covered exactly what's involved in getting an SB-220 going on top band *and* covered the theory behind the modifications in sufficient detail to allow owners of other HF amplifiers to modify their gear for MF. If you would like discuss any part of this article with me, my telephone number is 805-482-3034.

More SB-220 improvements from Richard Measures—including better suppression of VHF parasitics, heat reduction, fan lubrication and how to keep your SB-220 from pitting the control-relay contacts in the transceiver that drives it—will appear in an upcoming Hints and Kinks column.

Notes

[1]Rich Measures' use of *HF* in this sentence is intentionally colloquial. *Of course* an HF amplifier doesn't cover 160 meters; 160 is an *MF* band, contemporary ad copy and transceiver-panel labels notwithstanding. If you need more output power than your "HF" transceiver may currently provide on 160, this article is for you: In it, AG6K shows you how to turn an HF amplifier into an *MF/HF* device. —*Ed.*

[2]When the peak anode current is at maximum and the instantaneous anode voltage is at minimum in a properly tuned amplifier, the anode voltage must be about 200 V more positive than the (grounded) grid in order to attract most of the electrons emitted by the cathode. If the output network is adjusted to load the amplifier tube(s) too lightly—which causes the instantaneous, minimum anode voltage to dip below about + 200—electrons that would normally flow from cathode to anode flow from cathode to grid instead. The result is excessive grid current and amplifier nonlinearity (a euphemism for *rotten splatter*).

[3]R. Measures, "High-Voltage Breakdown Tester," *QEX*, Aug 1988, pp 5-7.

[4]Altering a pi network's impedance-matching ratio involves adjusting the values of *two or more* of the network reactances. The network's impedance-transformation ratio cannot be altered by adjusting only one of its three reactive components.

[5]One popular variation on the add-turns-to-the-choke theme depends on a gap of about ¾ inch between the added turns and the main choke winding to decouple the inductors and avoid self-resonance problems. Unfortunately, a ¾-inch gap does not sufficiently reduce coupling between coils that share a common axis. *The best way to prevent inductive coupling between two or more unshielded solenoidal inductors is to place the inductors at right angles to each other.*

[6]The choke's self-resonant frequencies can be found by connecting the choke terminals together with a short clip lead, coupling a dip meter to either end of the choke and sweeping the choke's operating frequency range. Dips indicate self-resonances; these should be quite sharp and easy to find. If possible, check for resonances with the choke in its installed position; nearby metal objects—shield partitions and chassis walls—can cause self-resonances to shift. [Photographic evidence of this effect can be seen in Zack Lau, "More Choke Info," Technical Correspondence, *QST*, Jun 1988, p 51.—*Ed.*]

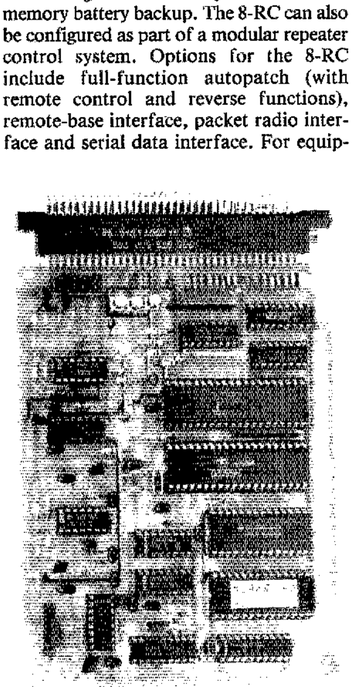
[7]This silicone-varnish-insulated wire is available from shops that rewind electric motors. It has much better RF and HV insulating qualities than any of the Formvar or nylon-clad wires.

[8]Readers may raise their eyebrows at my suggestion that the SB-220's HV interlock be removed and not reinstalled. In my opinion, this amplifier is not much safer with the HV interlock than without it. Even if the interlock is functioning properly—and with the amplifier plugged in and switched off—you can receive a fatal electric shock by touching any of several components under the amplifier chassis that are connected to the ac mains. Because this situation exists regardless of the presence or operability of the interlock, I had no qualms about removing my SB-220's interlock to make room for RFC1A. The choice is yours. (The *only* way to work on an amplifier safely is to *never* put your hands or a conductive tool inside an amplifier unless it is *unplugged from the ac mains* and its HV-supply capacitors are fully discharged. Don't let the presence of an interlock lull you into believing that a plugged-in amplifier is safe to work on!)

New Products

RF CONCEPTS 8-RC REPEATER CONTROLLER

☐ The 8-RC Repeater Controller is a multifunction device that can be configured as a stand-alone unit, or as part of a multifunction repeater system. Features include inputs for a control-link receiver, remote-base control and CTCSS-decoder. In addition, there are 8 (expandable to 40) auxiliary on/off outputs and alarm circuit controls for environmental conditions such as power failure or open doors. All controller program data is stored in EEPROM, eliminating the need for separate controller memory battery backup. The 8-RC can also be configured as part of a modular repeater control system. Options for the 8-RC include full-function autopatch (with remote control and reverse functions), remote-base interface, packet radio interface and serial data interface. For equipment availability and price information, contact RF Concepts, 2000 Humboldt St, Reno, NV 89509, tel 702-827-0133.—*Tom Francis, NM1Q*



QEX: THE ARRL EXPERIMENTERS' EXCHANGE AND AMSAT SATELLITE JOURNAL

The December issue of *QEX* includes:

• "CW and SSB Audio Filters Using 88-mH Inductors," by Ed Wetherhold, W3NQN. The passive LC audio filter is still preferred by many radio amateurs and professional filter designers. Here's how to apply LC-filter theory to the design and construction of inexpensive, high-performance, CW and SSB audio filters.

• "Path Selection," *Part 1*, by Dennis L. Haarsager, N7DH. Path selection is an important aspect of successful long-distance operation at wavelengths shorter than those propagated by the ionosphere. N7DH explains how to plan a DX-contact attempt over a non-line-of-sight path.

• >50, by Bill Olson, W3HQT. Reflector antennas, such as parabolic dishes and corner reflectors, are popular among VHF/UHF/SHF operators. This month's column is the first part of a series on reflector antennas, and covers basic parabolic-dish theory.

• Components, by Mark Forbes, KC9C. Mark talks about J. W. Miller and Coilcraft inductors; Inresco overcurrent protectors; the IBM® PS/2® Model 30 286 computer; NEC microwave prescalers; Polycore MMICs and RF power FETs; Micro Crystal crystals—and the Components reader survey is on!

• In Correspondence, Dom Mallozzi, N1DM, tells you how to obtain NTIS publications and reviews three of them he found of interest.

QEX is edited by Paul Rinaldo, W4RI, and is published monthly. The special subscription rate for ARRL/AMSAT members is $10 for 12 issues; for nonmembers, $20. There are additional postage surcharges for mailing outside the US; write to Headquarters for details.

Conversion Between Geodetic and Grid Locator Systems

This simple paper system lets you convert latitudes and longitudes to grid locators—and vice versa—*without* a computer or calculator. Give it a try on your next "gridpedition"!

By Edmund T. Tyson, N5JTY
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The grid locator system is widely used in Europe and North America for reporting station position during contacts at VHF and above.[1] One of the advantages of grid locators is that they describe positions in four or six characters—compared to the ten or fourteen characters necessary with the geodetic (latitude/longitude) system. A six-character grid locator describes a coarse position with its first two characters and, with successive characters, refines the position to an area 2.5′ of latitude × 5′ of longitude in size. This article describes a tabular method of converting between the grid locator and latitude/longitude systems.

Brief Anatomy of a Grid Locator

Of a full (six-character) grid locator, three characters (the first, third and fifth) specify longitude in steps of increasing precision; the remaining three characters (the second, fourth and sixth) specify latitude in steps of increasing precision. See Fig 1.

The first character (always a letter) of a grid locator specifies longitude in 20° increments, with the letter *A* corresponding to the interval 180° W to 160° W, the letter *B* corresponding to the interval 160° W to 140° W, and so on until the letter *R*, which covers 160° E to 180° E longitude.

The second character in a grid locator specifies latitude in 10° increments. For instance, the letter *A* covers the interval from 90° S to 80° S, *B* covers 80° S to 70° S, and so on until *R*, which specifies latitudes from

[1]In Europe, this system is usually referred to as the *Maidenhead locator system*.

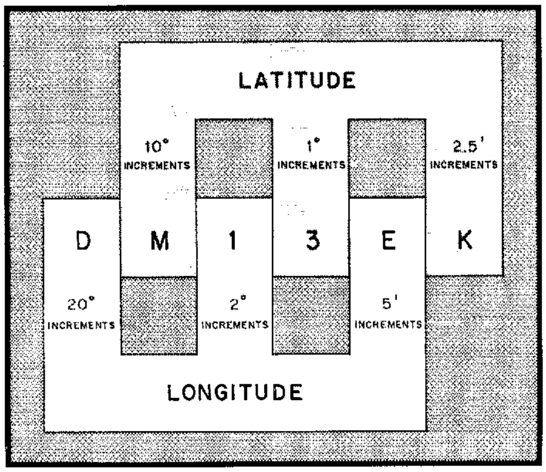


Fig 1—Anatomy of a grid locator. In its six-character form, the grid locator specifies positions on the earth to the nearest 5′ of longitude and 2.5′ of latitude. For many Amateur Radio purposes, however, only the first four grid characters (specifying positions—*grid squares*—to the nearest 2° of longitude and 1° of latitude) are used. See the text and Tables 1 through 6 for how to convert geodetic coordinates to grid locators and vice versa.

Table 1
1st Longitude Character

Degrees Longitude	Letter
−180	A
−160	B
−140	C
−120	D
−100	E
−80	F
−60	G
−40	H
−20	I
0	J
+20	K
+40	L
+60	M
+80	N
+100	O
+120	P
+140	Q
+160	R
+180	

Table 2
2nd Longitude Character

Degrees Longitude	Number	Degrees Longitude
−20	0	0
−18	1	+2
−16	2	+4
−14	3	+6
−12	4	+8
−10	5	+10
−8	6	+12
−6	7	+14
−4	8	+16
−2	9	+18
0		+20

Table 3
3rd Longitude Character

Minutes Longitude	Letter	Minutes Longitude
−120	A	0
−115	B	+5
−110	C	+10
−105	D	+15
−100	E	+20
−95	F	+25
−90	G	+30
−85	H	+35
−80	I	+40
−75	J	+45
−70	K	+50
−65	L	+55
−60	M	+60
−55	N	+65
−50	O	+70
−45	P	+75
−40	Q	+80
−35	R	+85
−30	S	+90
−25	T	+95
−20	U	+100
−15	V	+105
−10	W	+110
−5	X	+115
0		+120

Table 4
1st Latitude Character

Degrees Longitude	Letter
−90	
	A
−80	
	B
−70	
	C
−60	
	D
−50	
	E
−40	
	F
−30	
	G
−20	
	H
−10	
	I
0	
	J
+10	
	K
+20	
	L
+30	
	M
+40	
	N
+50	
	O
+60	
	P
+70	
	Q
+80	
	R
+90	

Table 5
2nd Latitude Character

Degrees Latitude	Number	Degrees Latitude
−10		+0
	0	
−9		+1
	1	
−8		+2
	2	
−7		+3
	3	
−6		+4
	4	
−5		+5
	5	
−4		+6
	6	
−3		+7
	7	
−2		+8
	8	
−1		+9
	9	
0		+10

Table 6
3rd Latitude Character

Minutes Latitude	Letter	Minutes Latitude
−60.0		0.0
	A	
−57.5		+2.5
	B	
−55.0		+5.0
	C	
−52.5		+7.5
	D	
−50.0		+10.0
	E	
−47.5		+12.5
	F	
−45.0		+15.0
	G	
−42.5		+17.5
	H	
−40.0		+20.0
	I	
−37.5		+22.5
	J	
−35.0		+25.0
	K	
−32.5		+27.5
	L	
−30.0		+30.0
	M	
−27.5		+32.5
	N	
−25.0		+35.0
	O	
−22.5		+37.5
	P	
−20.0		+40.0
	Q	
−17.5		+42.5
	R	
−15.0		+45.0
	S	
−12.5		+47.5
	T	
−10.0		+50.0
	U	
−7.5		+52.5
	V	
−5.0		+55.0
	W	
−2.5		+57.5
	X	
0.0		+60.0

Table 7
Sample Grid Locators

City	*Longitude*	*Latitude*	*Locator*
Munich	11° 36.5′ E	48° 8.8′ N	JN58TD
Montevideo	56° 12.7′ W	34° 54.6′ S	GF15VC
Washington, DC	77° 3.9′ W	38° 55.2′ N	FM18LW
Wellington	174° 44.7′ E	41° 17.0′ S	RE78IR

Remember: West longitudes and south latitudes are treated as *negative* values in the grid locator system; east longitudes and north latitudes are *positive*.

80° N to 90° N. West longitudes and south latitudes are treated as *negative* values in the grid locator system; east longitudes and north latitudes are *positive*.

The third and fourth characters are digits in the range 0 through 9. The third character divides longitude lunes into 2° increments; the fourth character divides latitude zones into 1° increments.

The last two characters (always letters) in a grid locator subdivide the 2° × 1° rectangles designated by the third and fourth characters into smaller rectangles that are 5 × 2.5 minutes of arc in size. The letters *A* through *X* are used to specify each coordinate of these 5′ × 2.5′ rectangles.

Conversion Tables

Tables 1 through 6, inclusive, can be used to convert latitude and longitude to grid locators, or grid locators to latitude and longitude.

Converting Latitude and Longitude to Grid Locators

Example: The location of an observatory at 105° 44.0′ W longitude and 32° 58.8′ N latitude can be readily converted to a grid locator. Find the longitude characters first. (Remember: West longitude is negative in the grid-locator system.) According to Table 1, the first grid character is *D* because the observatory's longitude is between −100° and −120°. Record the first character of the unknown locator, leaving space for the characters to come:

D_ _ _ _ _

(For values of longitude that are exact multiples of 20°, *work from zero* and choose the grid-locator letter *"above"* the correct exact longitude value. For examples: −120° longitude = C, not D; +20° longitude = K, not J. Apply this "use the higher letter or number" rule to Tables 1 through 6 whenever you must work with exact multiples of the longitude and latitude increments reflected in the tables.)

So far, we have accounted for exactly 100° of the observatory's longitude. Find the second longitude character by referring to Table 2 for the number corresponding to the longitude remainder, −5° 44.0′. Because −5° 44.0′ falls within the −4° to −6° range, that number is 7. We now have *two* characters of the grid locator:

D_7_ _ _

Now, we have accounted for exactly 104° of the observatory's −105° 44.0′ longitude. Use Table 3 to find the letter that corresponds to the remaining −1° 44.0′ of longitude. Expressed in minutes, −1° 44.0′ = −60′ + −44.0′, or −104.0′. This number falls within the −100′ to −105′ range, so the third longitude letter is *D*. Now we have all three longitude characters of the unknown grid locator:

D_7_D_

The three latitude characters come next. The observatory's latitude is 32° 58.8′ N. This is a *positive* latitude in the grid-locator system. According to Table 4, the first latitude character is *M* because the observatory's latitude is between +30° and +40°. We now have four grid characters:

DM7_D_

The most significant latitude character, M, accounts for exactly 30° of the observatory's latitude. Find the second latitude character by referring to Table 5 for the number corresponding to the latitude remainder, +2° 58.8′. Because +2° 58.8′ falls in the +2° to +3° range, that number is *2*. We now have *five* grid-locator characters:

DM72D_

So far, we have accounted for exactly 32° of the observatory's +32° 58.8′ latitude. Use Table 6 to find the letter corresponding to the remaining +58.8′ of latitude. Because +58.8′ falls within the +57.5′ to +60.0′ range, that letter is *X*. We now have the observatory's complete grid locator: DM72DX.

Converting Grid Locators to Latitude and Longitude

The conversion of grid locators to geodetic coordinates can be illustrated with the grid locator DM13EK. The geodetic coordinates we find will correspond to the *exact center* of the region specified by DM13EK. As before, it's useful to separate the grid locator into elements of longitude and latitude. Also as before, we'll do the longitude first:

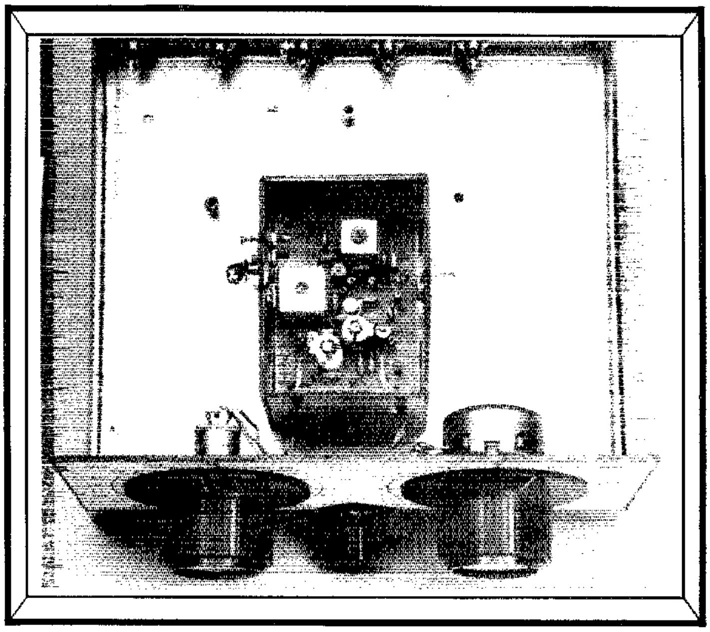
D = −100°
1 = −16°
E = −1° 35′
Round = −0° 2.5′

Sum = −117° 37.5′, or 117° 37.5′ W longitude

The rounding term is used to compute the longitude of the *center* of the specified region—a region 5′ × 2.5′ (longitude × latitude) in size because DM13EK is a six-character locator. We know that the longitudinal center of this region must lie somewhere along a line half—2.5′—of the region's longitudinal width (5′) from its

(continued on page 43)

A VFO with Bandspread and Bandset



Eliminate expensive vernier drives and dials with an old technique—bandspread and bandset tuning!

By Doug DeMaw, W1FB
ARRL Contributing Editor
PO Box 250
Luther, MI 49656

Are you old enough to recall those days when we amateurs had receivers that had two readout dials? One was a bandset dial (coarse tuning) and the other was for bandspread (fine tuning). When I compare that method to modern digital-readout techniques, I wonder how we managed to get on frequency; the resolution of the dials was primitive by today's standards! The bandset dial was calibrated in megahertz and the bandspread dial indicated kilohertz. The tuning increments for the bandspread dial were in 5- or 10-kHz steps, depending on the model of the receiver!

We may apply that old technique to modern circuits. Reasonable readout accuracy is possible with the method discussed in this article. The trick is to make both dials read kilohertz, rather than megahertz and kilohertz. The circuit described here is meant to be an inspiration toward a design of your own. It serves as a model for a starting point, with a circuit-board pattern offered if you wish to experiment. My circuit values are for use in a 6.572- to 6.872-MHz VFO. This VFO serves as the local oscillator for a homemade 80-meter CW receiver that uses a 3072-kHz IF and a crystal filter made from low-cost computer crystals. I plan to describe the entire receiver in a subsequent article.

Circuit Features

Please refer to Fig 1, which shows the circuit for my experimental VFO. You will note that I use electronic tuning. D2 and D3 are VVC (voltage variable capacitance) diodes. They are also called varactors or tuning diodes. As the reverse bias (positive voltage) is varied at the diode cathode, there is a significant change in the junction capacitance of the diode. This enables us to change the VFO frequency, as would be the situation if we replaced D2 and D3 with mechanical tuning capacitors. The advantage of using the diodes is that we can use standard carbon-composition controls (R2 and R7 of Fig 1) for tuning the VFO. This provides a compact VFO module, should that be our objective.

D2 functions as the bandset tuning diode, while D3 is used for the bandspread function. Each diode has a trimmer capacitor (C3 and C4) between it and L2. The trimmers are set to control the tuning range of each VVC diode.

All is not "milk and honey" when we use tuning diodes in VFOs. Although the diodes offer some advantages over air-variable capacitors, they are not as frequency stable as mechanical tuning devices. The more semiconductor junctions we add to an oscillator circuit, the greater the opportunity for frequency drift—particularly short-term drift (first five minutes of warm-up). This is because the transistor and diode junctions must come up to operating temperature as current flows through them. This involves both RF and direct currents. The stability of the VFO in Fig 1 is adequate for many amateur needs, such as simple receivers and signal generators. Short-term drift is on the order of 1.5 kHz from a cold start to the period when long-term drift commences. Long-term drift occurs for 15 or 20 minutes, and it amounts to a range of 200-300 Hz. Thereafter, the frequency creeps up and down over a range of 5-10 Hz at room temperature. In other words, the circuit in Fig 1 represents a good VFO, but not a spectacular one. It is on par with what I expected when using two VVC diodes.

Remainder of the VFO Circuit

Q1 of Fig 1 is a 2N4416 JFET. This device surpasses the performance of the generic MPF102 family of transistors. It has a better pinchoff characteristic than does the MPF102 and similar devices. This means that greater output is possible at a given operating voltage, compared to an MPF102. Oscillator feedback is by way of the Q1 source and L1. This link has ¼ the number of turns used on L2, which is pretty standard for a feedback winding. The two coils are wound on an Amidon L-57-6

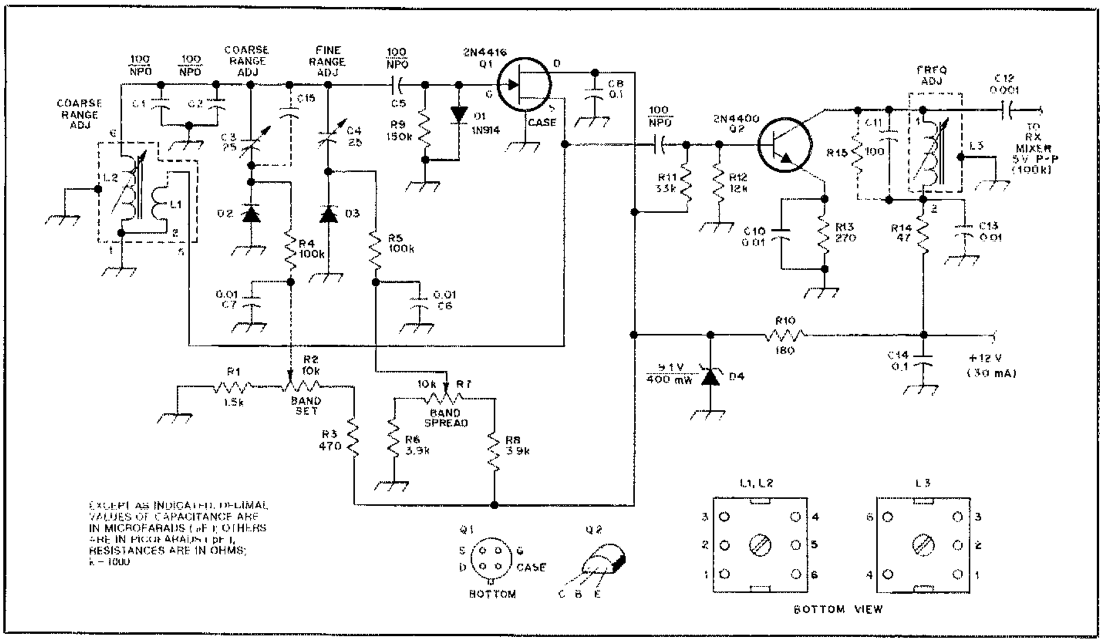


Fig 1—Schematic diagram of the VVC-tuned VFO. Fixed-value capacitors are disc ceramic, 50- or 100-V rating. Fixed-value resistors are ¼-W carbon composition. NPO notations are for temperature-stable disc capacitors (zero temperature coefficient).

C3, C5—25-pF NPO miniature ceramic trimmer or E. F. Johnson I-9-5 miniature air-variable trimmers.
C15—See text.
D1—Silicon switching diode, type 1N914 or equiv.
D2, D3—Motorola MV2109 tuning diode or equiv, 30-70 pF typical range. Available from All-Electronics Corp, Van Nuys, CA 91408.
D4—9.1-V, 400-mW Zener diode.
L1—4 turns of no. 30 enam or Litz wire over grounded end of L2. Use Amidon Assoc, Inc L-57-6 shielded assembly.
L2—16 turns of no. 30 enam or Litz wire on L-57-6 bobbin. Use Q-Dope to secure windings (see text).
L3—24 turns of no. 30 enam or Litz wire on the form of an Amidon Assoc L-43-2 shielded assembly. Turns must be scramble-wound to fit on form.
R2, R7—10-kΩ linear-taper carbon-composition control (see text).
R15—See text.

transformer assembly. The no. 6 (yellow) powdered-iron core material is best for VFO service. It is more temperature stable than the other core materials.

NPO temperature-stable capacitors (C1, C2, C5 and C9) are used to aid the stability. D1, from the Q1 gate to ground, stabilizes the bias on Q1 and limits the device transconductance on sine-wave peaks. This helps to keep the junction capacitance fairly constant—an aid to stability. A further enhancement to stability is provided by Zener diode D4. It regulates the operating voltage for D2, D3, Q1 and the base of Q2.

Buffer-amplifier Q2 is used to boost the RF output of the oscillator chain to 5 V P-P. The output is designed to look into a 100-kΩ load, which may be gate no. 2 of a dual-gate MOSFET mixer. R15 may be added (3.3 kΩ to 10 kΩ) across L3 (dashed lines in Fig 1) to broaden the response of L2. This will reduce the RF output somewhat.

You may use a lower value of capacitance at C9 if you require lower output from Q2. The smaller the C9 value, the greater the overall VFO stability. In a like manner, the lower the C5 value, the better the stability. C5 needs to be of a large enough value to allow Q1 to oscillate. The Q of the oscillator tank and the specific transconductance of Q1 are determining factors when selecting the C5 value in a VFO of this general type. C5 values as low as 5 pF are usable, especially when L2 has a high value of Q (100 or greater).

Circuit Variations

If you desire greater frequency stability than I mentioned earlier, replace D2 and D3 with small air-variable capacitors. You may use a 100-pF unit in place of D2. The bandspread tuning can then be done with a 15- or 20-pF variable. This calls for the deletion of the VVC diode components, R1 through R8, plus C6 and C7, and of course, D2 and D3.

C15 of Fig 1 is shown in dashed lines. You may add a capacitor at this circuit point if you wish to increase the tuning range of the bandset control. Experiment with the C15 value to obtain the range you need.

Construction in General

Use a single-sided PC board for this project. Double-sided board material increases the VFO drift, owing to the formation of unwanted low-stability capacitance between the PC foil and the ground-plane side of the board. Try to use high quality glass-epoxy board material. Phenolic PC boards are not suitable for VFOs.

I enclosed my VFO in a homemade box, as shown in the title photo. The box is made from pieces of PC board that have been soldered together. The cover, removed for the photograph, is a U-shaped piece of aluminum. The cover is affixed to the box by means of two no. 4-40 screws. I soldered two 4-40 × ¼-inch nuts on the inside of the box to accommodate the two screws. I used two surplus Teflon push-in feed-through terminals to route the +12 V to the circuit, and to bring the RF output from

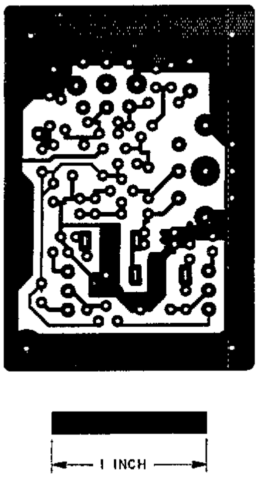


Fig 2—Circuit-board etching pattern for the VVC VFO. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil.

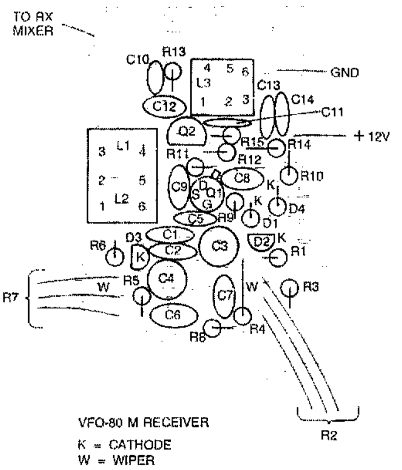


Fig 3—Parts-placement guide for the VFO, not to scale. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. In the interest of stability, do not use double-sided board material and a ground plane. Component outlines are not necessarily representative of the shapes of the actual parts used.

the box. Two no. 6 spade bolts secure the VFO box to the mainframe assembly that will later contain the remainder of my 80-meter receiver. The hookup-wire cables for tuning controls R2 and R7 are brought from the VFO box through ¼-inch holes in the box wall. The VFO module measures (HWD) 2 × 2 × 2½ inches.

A scale etching pattern for the VFO PC board is provided in Fig 2. A parts-placement guide is shown in Fig 3.[1]

The dial-calibration plate for my VFO is homemade, visible on edge in the title-page photograph. I drew the circles with a ballpoint pen and compass. I use knobs with large skirts (2 inches OD), bought at a flea market. If you can't locate a pair of large knobs with skirts, you may use standard-size knobs and metal or plastic dial skirts with them. The skirts may be attached to the knobs by means of epoxy cement or small screws.

After I made the dial plate I photocopied it. The copy was used for dial calibration with a pencil. I measured the VFO output with a frequency counter. My VFO is set for 50 kHz of tuning range with the bandset control. The bandspread covers only 10 kHz. Midrange on the bandspread control is marked zero. To the left of zero I calibrated this dial with minus kHz marks. Plus-kHz marks are to the right of zero. After plotting the calibration scales I made marks between the two rings of each dial face, then typed the frequencies alongside the marks. Rubber cement is used to affix the dial plate to the front panel.

Try to obtain commercial-grade controls for R2 and R7 of Fig 1, such as Allen-Bradley units. They will last longer than imported controls, and will be less prone to resistive instability from shock and vibration. Check the surplus catalogs for these controls.

Checkout and Operation

You will need to adjust the slug in L2, along with the settings for C3 and C4. First, determine how much frequency range you want to cover with the bandset control. Adjust C3 and L2 so R2 provides the desired range. Next, adjust C4 to yield 10 kHz of tuning range for R7. This will cause some interaction with the settings of C3 and L2. Repeat those adjustments to obtain the desired tuning range for R2.

Next, terminate C12 with a 100-kΩ resistor. Connect a scope or RF probe from the output side of C12 to ground. Adjust the slug in L3 for maximum RF output voltage.

L1 and L2 should be coated with GC polystyrene Q-Dope after they are wound on the L-57-6 bobbin. Allow at least 48 hours for the coil to dry before you check the stability of your VFO. Q-Dope is available by mail from Small Parts Center.[2] Do not attempt drift tests if you have recently soldered connections on the VFO PC board. Allow an hour after all soldering is completed before you commence your drift run. Keep the module away from desk or bench lamps and enclose the VFO PC board in its box to prevent air currents from reaching the critical components. Terminate the VFO output with a 100-kΩ resistor and attach a frequency counter to the VFO output through a 27- or 33-pF capacitor. Apply the VFO operating voltage and log the initial frequency. Monitor the frequency change until the drift is only 1 or 2 Hz per count. Observe the frequency change until it stabilizes. This will be noted when the frequency shifts up and down by a few hertz in a random manner. Dial calibration (discussed earlier) should be done *after* the short-term drift has occurred. This should take place within five minutes after turn-on.

Closing Comments

I want to stress that this is an "idea" article rather than a project for duplication. The main thought here is that you can capitalize on the old technique of using a bandset and bandspread setup in order to avoid the high cost of vernier mechanisms. Tuning diodes are discussed in the interest of equipment miniaturization and reduced cost.

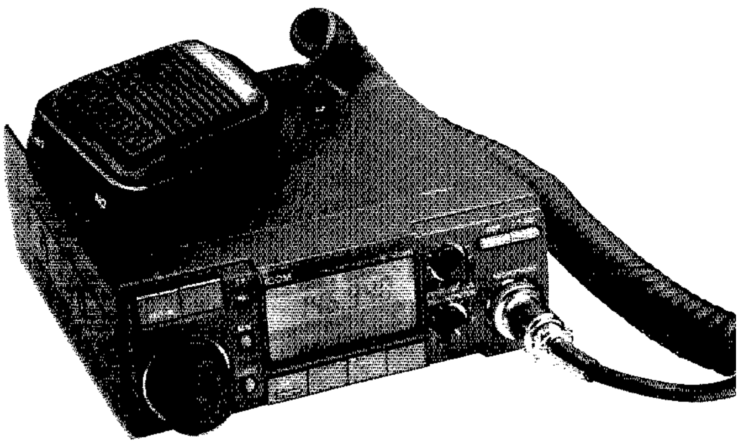
This VFO is not recommended for use with transmitters unless one or more additional stages of buffering are used. A single buffer-amplifier does not provide the load isolation that is necessary between the VFO and a transmitter. It is adequate, however, for connection to a mixer that presents a relatively constant load impedance.

You should have no difficulty in tailoring this circuit to other frequencies. All that is necessary is to change the inductance of L2 and L3, along with appropriate modifications for the values of C1, C2, C5, C9 and C11. I'm sure you will have fun experimenting with this circuit, and you can learn by doing!

[1]Far Circuits (N9ATW), 18N640 Field Court, Dundee, IL 60118; tel 312-426-2431 evenings.
[2]Small Parts Center, 6818 Meese Drive, Lansing, MI 48911; tel 517-882-6447. Catalog available. QST

ICOM IC-228H 2-Meter FM Transceiver

Reviewed by Rick Palm, K1CE



You would think that after tens of years in business, and producing countless models, ICOM would have the production of high-quality 2-meter rigs down to a T. Well, you're right—they do. The IC-228H continues a long tradition of excellence in 2-meter FM rigs. I know—I've owned or operated most of them. My classic six-year old IC-25A is still ticking, even after being brutalized by two years of 24-hour-per-day use with my packet-radio bulletin-board system. So, there's one item you can count on—reliability.

There are others, beginning with user friendliness. All IC-228H functions are front-panel controlled, and yes, you can play with them safely while driving. To test this, I used the '228 while driving through the downtown Hartford "mixmaster"—the intersection of two interstate highways rated in the top five most hazardous in the nation. In rush-hour traffic, I successfully selected one of four frequency display backlighting levels and entered into memory two repeater channels with irregular split—all without incident! I even made an autopatch telephone call without hitting anything—powerful testimony to the rig's ergonomics, considering that many other hapless drivers (with both hands on the wheel) enter the mixmaster, never to be seen or heard from again!

Front Panel

The front panel is utilitarian, but attractive. One large tuning knob takes care of memory and frequency selection. The buttons are easy to use while driving. Special mention goes to the power/volume control—pushing it toggles between power off and on, but the volume stays the same. The controls have an avionics-quality feel. Nice!

The very first thing I look for in a 2-meter FM transceiver is frequency display readability. Can the frequency be read easily? In inky blackness? In direct sunlight? With the IC-228H, the answer is *yes*. The frequency display is incorporated in an LCD that occupies almost a third of the front panel. The frequency display characters are oversized black numbers on a yellow background that stand out in the

Table 1

ICOM IC-228H 2-meter FM Transceiver, Serial no. 671-001094

Manufacturer's Claimed Specifications	***Measured in ARRL Lab***
Frequency coverage: receiver, 138.0 to 174.0 MHz; transmitter, 140.0 to 150.0 MHz. Specifications apply from 144 to 148 MHz only.	As specified.
Mode of operation: FM.	As specified.
Frequency display: Not specified.	6-digit LCD, black digits with amber background.
Frequency resolution: 5 kHz.	As specified.
Power requirements: 13.8 V dc (±15%) at 9.5 A max on transmit and 800 mA on receive.	13.8 V dc at 8.0 A on transmit high power) and 3.0 A (low power), and 630 mA on receive.
Transmitter	*Transmitter Dynamic Testing*
Power output: Low, 5 W; high, 45 W.	Low, 5.1 W; high, 43 W at 146 MHz.
Spurious signal and harmonic suppression: Better than 60 dB.	See Fig 1.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: Better than 0.18 μV for 12 dB SINAD.	0.16 μV for 12 dB SINAD. 0.28 μV for 20 dB quieting.
Squelch sensitivity: Not specified.	0.05 μV min, 0.27 μV max.
Receiver audio output: More than 2.4 W at 10% distortion (THD) with an 8-Ω load.	3.13 W at 10% THD with an 8-Ω load.
Color: Black.	
Size (height, width, depth): 1.97 × 5.5 × 6.25 inches.	
Weight: 2.45 lbs.	

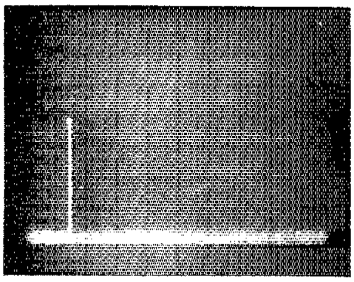


Fig 1—Worst-case spectral display of the ICOM IC-228H. Horizontal divisions are each 100 MHz; vertical divisions are each 10 dB. Output power is approximately 43 W at 146 MHz. The fundamental has been reduced approximately 31 dB by means of notch cavities to prevent analyzer overload. All harmonics and spurious emissions are at least 70 dB below peak fundamental output. The IC-228H complies with current FCC specifications for spectral purity.

most intense glare of the sun. At night, excellent backlighting highlights the display characters. Four levels of display backlighting—dim to bright—are available. So, when you're with your spouse, you can "set the mood" as you would with your dimmer-controlled dining room chandelier! Seriously, adjustable backlighting is a nice feature, and I used it a lot.

In addition to operating frequency, the LCD shows more than a dozen other operating parameters. Displayed parameters include selection of duplex operation (+ or − offset), VFO or memory operation, memory channel in use and selection of low (5 W) transmit power. Also shown are received-signal strength and relative RF-power output.

Other Features

Audio quality, both received and sent, is excellent. Full, deep, loud received audio is a key factor in enjoying QSOs in my noisy truck. Transmitter audio reports were good. The microphone didn't pick up ambient noise in my vehicle.

I hate things that beep at me. The IC-228H beeps when you touch just about any control. Fortunately, it's possible to turn the beep function off so you can enjoy blissful operation without the obnoxious beeps. Nice! (The way things are going, next year's models will have synthesized voice advisories like "you're 5 kHz off frequency," or "illegal to order pizza via autopatch, patch disconnected.")

Memory programming is a breeze: weird offsets, ups and downs—no problem. Priority and calling features allow you to listen on one frequency while spot-checking (every five seconds) another for calls. A touch of the CALL button brings you immediately to your favorite repeater. Tuning steps are easily programmed from 1 MHz down to 5 kHz, a useful feature when tuning large chunks of band space (the receiver covers 138-174 MHz).

If you're looking for someone to talk to on a lonely stretch of interstate, or if you want to mind somebody else's business in the public safety band, then scanning is essential. With the '228H, you can scan the entire band or selected frequencies within boundaries you set. You can scan just the memories, too. Memory skip allows you to skip selected channels.

Here are some other IC-228H features.

- The microphone has a 16-digit keypad, as well as UP/DN buttons for memory or frequency selection and scanning start/stop.
- If you press the MONITOR button, the squelch opens and you hear the input frequency of the repeater you're using so you can determine if your contact is within simplex range.
- The transmitter's 45-W output is handy if you're mobiling in some repeater's fringe, or in a mountainous area.
- The rig is durable. It survived bumps, jolts, grinds, beer and pizza spills, in my dilapidated old pick-up truck.
- IC-228H is small. This is a big plus for owners of small cars; the '228H can be mounted just about anywhere. But, be sure to leave room for air circulation around the radio: At full power, the deep heat sink on the back of the chassis gets hot!

Summary

There's no sense in hiding it: The IC-228H is expensive! More than $500 is a lot of money to pay for a 2-meter radio. But, it's no more expensive than other comparably equipped Japanese rigs. The yen is strong, and prices are high. If you're in the market for a new 2-meter mobile rig, and ready to plunk down big bucks, take a look at many models and brands, bells and whistles, and choose carefully. After having used this rig for four months, I'll bet my emergency brake release warning beeper that the IC-228H will be among your finalists.

Price class: $540. Manufacturer: ICOM America, Inc, 2380-116th Av NE, Bellevue, WA 98004, tel 206-454-7619.

AUSTIN CUSTOM ANTENNA'S METROPOLITAN TRIBAND VHF/UHF ANTENNA

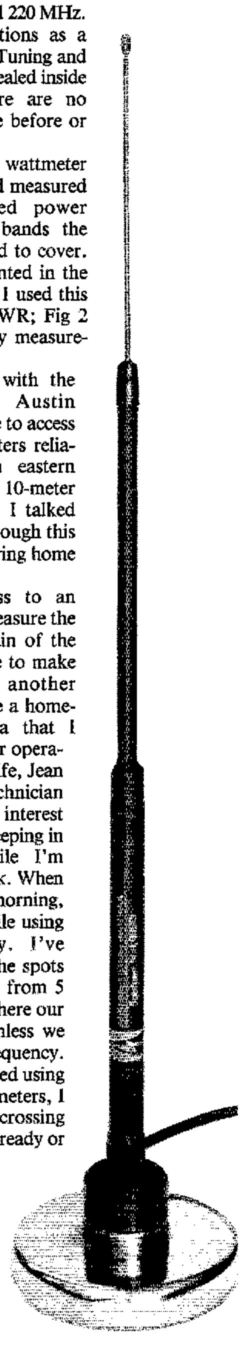
Reviewed by Larry Wolfgang, WA3VIL

As I prepared to install the ICOM IC-900 multiband radio in my car to do a Product Review[1], I realized that I did not have an antenna for 220 MHz. One of my favorite 2-meter repeaters in the Hartford area is linked with a 440-MHz repeater. Both repeaters use antennas from Austin Custom Antenna. In fact, a member of the repeater group had often told me about the performance of Austin antennas; it sounded almost too good to be true!

Several of the regulars on these repeaters were also using Austin mobile antennas, and one of them had recently installed a multiband antenna for use with a 144- and 440-MHz dual-band radio. About this same time, I saw some information about an Austin mobile antenna that covers 144, 220 and 440 MHz. So when I began to think about an antenna to go with the IC-900, I naturally wondered about reviewing the Metropolitan, as this triband antenna is called.

The 18-7/8-inch-long Metropolitan antenna consists of three sections (see the accompanying photo). The bottom section is 6¾ inches long and just over ½ inch thick. The middle section is also 6¾ inches long, but only about 5/16 inch thick. These two sections are rigid, and they are covered with a heavy layer of material that appears to be heat-shrinkable tubing. The top section is a 5-3/8 inch long steel whip. The bottom antenna section features a length of 3/8-inch threaded rod, so it can be attached to just about any standard mobile antenna mount. I used the review antenna with an optional Austin magnetic mount that includes a length of coaxial cable and a very powerful magnet.

The Metropolitan operates as a ¼-wavelength vertical on 144 and 220 MHz. On 440 MHz, it functions as a ¾-wavelength antenna. Tuning and matching networks are sealed inside the antenna, and there are no adjustments to be made before or after installation.



I borrowed an RF wattmeter from the ARRL lab and measured forward and reflected power throughout the three bands the Metropolitan is designed to cover. (The antenna was mounted in the center of my car roof.) I used this data to calculate the SWR; Fig 2 shows the results of my measurements.

I was very pleased with the operation. Of the Austin Metropolitan. I was able to access several 220-MHz repeaters reliably, including one in eastern Connecticut that has a 10-meter link. On one occasion, I talked with a ham in Texas through this repeater while I was driving home from work.

I didn't have access to an antenna test range to measure the radiation pattern or gain of the antenna, but I was able to make a comparison with another 2-meter antenna. I have a homemade on-glass antenna that I normally use for 2-meter operation from my car. My wife, Jean (WB3IOS), has a Technician license. Most of Jean's interest in ham radio involves keeping in contact with me while I'm driving to and from work. When I leave for work in the morning, we often chat for a while using a simplex frequency. I've become familiar with the spots where I have to switch from 5 watts to 25 watts and where our conversation is over unless we change to a repeater frequency.

The first day that I tried using the Metropolitan on 2 meters, I suddenly found myself crossing the "conversation over, ready or not" line and wondering how much farther I would still be able to talk with Jean. When she mentioned that I was getting pretty noisy, I was about to sign clear until I real-

[1]L. Wolfgang, "ICOM IC-900 Multiband VHF/UHF FM Mobile Transceiver," *QST*, Dec 1988, pp 37-40.

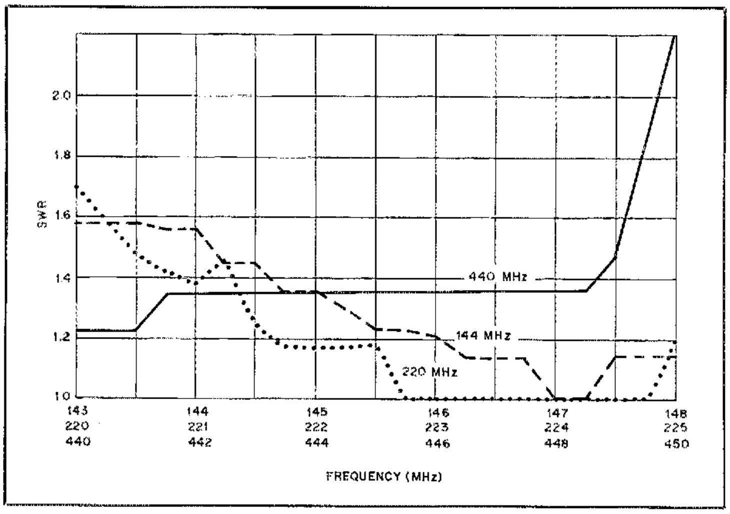


Fig 2—Graph of the measured SWR with the Austin Custom Antenna's Metropolitan Triband Antenna over the 144, 220 and 440-MHz bands. The antenna is usable over a wide range, including MARS frequencies between 143 and 144 MHz.

ized that I was still using low power! I switched to high power and was able to continue the conversation until I went over a hill that would block my signal no matter how much power I was using. We repeated that exercise for several days and then I switched back to the on-glass antenna. Sure enough, we lost contact at the old spot again. I don't know how much gain the Metropolitan has, but it works better than anything else I've used on my car.

The Metropolitan has been on my car continuously for several months. The antenna itself is in excellent condition. It has collected a bit of dirt and a few bugs between washings, but otherwise shows no negative effects from the weather. The heat-shrinkable tubing that covers the bottom two sections of the antenna is an effective seal against moisture. The magnetic mount, however, is beginning to show some signs of weathering. Some rust is starting to show through the chrome on the top of the magnet. That surprises me.

To use this one antenna on two or three bands with the IC-900, you need a duplexer (or triplexer), since each band module has its own antenna connector. Some other dual-band radios have a built-in duplexer so they only have one antenna connector. The Metropolitan antenna is ideally suited for use with that type of radio. If you are looking for mobile antennas to cover the 144, 220 and 440-MHz bands, this one antenna may be just what you need.

Price class: Metropolitan triband antenna, $40; magnetic mount, $22.50. Manufacturer: Austin Custom Antenna, PO Box 357, Sandown, NH 03873, tel 603-887-2926.

SOLICITATION FOR PRODUCT REVIEW EQUIPMENT BIDS

[In order to present the most objective reviews, ARRL purchases equipment "off-the-shelf" from Amateur Radio dealers. ARRL receives no remuneration for items presented in the Product Review or New Products columns. —Ed]

The following ARRL-purchased Product Review equipment is for sale to the highest bidder. Prices quoted are minimum acceptable bids and reflect a discount from the purchase price.

Sealed bids must be submitted by mail and be postmarked on or before January 27, 1989. Bids postmarked after the closing date will not be considered. Bids will be opened seven days after the closing postmark date. In the case of equal high bids, the high bid bearing the earliest postmark will be declared the successful bidder.

Please clearly identify the item you wish to bid on, using the manufacturer's name, model number, or other identification number if specified. Each item requires a separate bid and envelope. Shipping charges will be paid by the successful bidder, FOB Newington. The successful bidder will be advised by mail of the successful bid. No other notifications will be made, and no information will be given by telephone to anyone regarding final price or identity of the successful bidder.

Please send your bids to Kathy McGrath, Product Bids, ARRL, 225 Main St, Newington, CT 06111.

ICOM IC-900 VHF/UHF FM transceiver, serial no. 654-001349, with UX-29A 2-meter band unit and UX-39A 220-MHz band unit (sold as a package only; see Product Review, December 1988 *QST*). Minimum bid, $673.

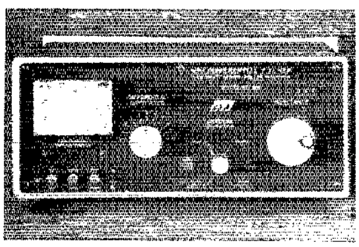
Yaesu FT-212RH 2-meter FM transceiver, serial no. 7N050451 (see Product Review, December 1988 *QST*). Minimum bid, $264.

Yaesu FT-712RH 70-cm FM transceiver, serial no. 8C050021 (see Product Review, December 1988 *QST*). Minimum bid, $290.

New Products

MFJ-986 DIFFERENTIAL-T ANTENNA TUNER

□ MFJ Enterprises of Starkville, Mississippi, has introduced the MFJ-986, a 3-kW roller inductor differential-T antenna tuner. The MFJ-986 tuner employs a single differential capacitor in place of two variable capacitors, simplifying the antenna matching process. Other features of the MFJ-986 include an illuminated, two-color, peak or average cross-needle SWR/wattmeter, three-digit inductor position readout, and six-position antenna switch. The MFJ-986 is housed in a 10 ¾ × 4 ½ × 15-inch black aluminum cabinet. Price class: $239. For more information, contact MFJ Enterprises, 921 Louisville Rd, Starkville, MS 39759. —*Tom Francis, NM1Q*



MORE ON RESONANT SPEAKERS

☐ I read with interest the article by Wally Millard, K4JVT, concerning the construction of a resonant speaker for CW.[1] Using the editor's note that accompanied Wally's article, I decided on a four-inch-long piece of PVC that has an ID of 42 mm (1-5/8 inches). I mounted a 2-inch-diam speaker (Radio Shack® 40-245) to one end of the tube with electrical tape as suggested by K4JVT.

In order to test the resonance of the system, my son wrote a program in Microsoft® BASIC 3.0 for the Macintosh computer. This program allows me to modify and display the frequency of the tones produced at the speaker port. Using the Macintosh to drive the speaker system, a noticeable increase in volume was apparent at 870 Hz.

With some further experimentation, I found that an even stronger peak occurred—at a frequency somewhat lower than that of the open-ended tube—when the tube is placed open end down on a hard surface with a small space between the tube and supporting surface. Currently, I am supporting the tube on three pennies (Fig 1). This provides maximum output at 670 Hz—approximately 200 Hz lower than the "wide open" tube.

This project is very easy to construct, and is certainly worth the few dollars of investment needed for the parts. Any CW enthusiast should enjoy the result. —*Richard Clemens, KB8AOB, 103 Barbour St, Buckhannon, WV 26201*

AK7M: There isn't space in Hints and Kinks to publish the Clemens resonant-speaker program, but Richard Clemens has graciously agreed to make a source code listing available for a no. 10 SASE carrying 25 cents postage. "Or," Richard adds, "if interested readers are willing to send a formatted Macintosh disk and return postage, I would be happy to copy the software to their disk. [ARRL and *QST* in no way warrant this offer.—*AK7M]* Two items should be noted: (1) My son, Michael Clemens, is the author of the software (he adds his blessing to the project) and (2) the software has been placed on CompuServe™ and is currently available for downloading."

[1]W. Millard, "A Resonant Speaker for CW," Hints and Kinks, *QST*, Dec 1987, p 43.

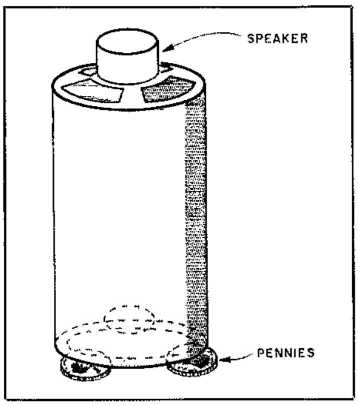


Fig 1—Richard Clemens increased the sharpness of his resonant speaker's peak by upending the tube and supporting the tube on three pennies. This also decreases the assembly's resonant frequency somewhat; see text.

NOTES ON RESONANT SPEAKERS FOR ENHANCED CW RECEPTION

☐ Resonant columns are somewhat like antennas: Short, fat pipes are low-Q, like cage or cone antennas; long, thin pipes are high-Q resonators. (Trying to use a resonant column as a sound generator can give you an idea of the importance of "acoustical Q" in a resonator: Blowing across a pop bottle produces a fairly well-defined tone with many overtones, like a flute. Producing any sort of tone with a pop *can* is difficult.)

A fat tube with a speaker in the end is not exactly a closed pipe, so formulas that attempt to characterize a speaker-tube assembly as such will fail. Instead of altering the length-to-diameter ratio with a plug, using *a smaller-diameter pipe* should give a sharper resonance. (Consider the length-to-diameter ratio of organ pipes as a good starting point; their proportions are similar to those of a pencil.)

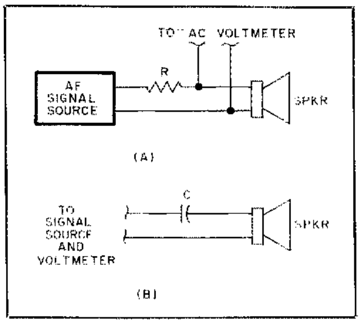


Fig 2—A setup for determining speaker resonance is shown at A. R (5 to 10 Ω) may be necessary for isolation between the audio source and tuned speaker. Speaker resonance is indicated by a voltmeter peak. Jim Weiss suggests enhancing the speaker's free-air resonance by means of a series capacitor or capacitors (B); if you do this, use your receiver or transceiver as an audio source to ensure that the capacitance selected allows for the effects of the rig's audio-output circuitry.

The 440-Hz peak Wally Millard heard may have been the speaker's free-air resonance (as modified by the presence of the resonant tube), which can be determined with the setup shown in Fig 2A. Matching the pipe length to the speaker's resonance will improve performance. A capacitor can be added to series-resonate the speaker inductance for an even sharper response (Fig 2B). This requires cut and try; use nonpolarized capacitors, paralleling capacitors of different values as needed.

For optimum results with a resonant speaker, especially at slower code speeds, I suggest using a tiny speaker resonating at 300 to 400 Hz (tune the speaker with a capacitor to accentuate the speaker's natural resonance). Once the speaker has been tuned, find the pipe length that matches the speaker's resonance and mount the speaker to the pipe. The speaker's free-air resonance shifts when the speaker is coupled to the pipe, so some fine tuning of the speaker tuning capacitors will probably be required. (Adjustment of the pipe length may also be necessary, so make the pipe longer than necessary to start with.)

I suggest using resonant speakers at pitches between 300 and 400 Hz because the ear is logarithmic in sensing volume and pitch. QRM at 700 Hz is about a whole step removed from a desired signal at 800 Hz, but almost *half an octave* removed at signal and QRM pitches of 300 and 200 Hz, respectively. Thus, lower received-signal pitches generally allow the ear to do a better job of distinguishing adjacent signals from one another.

By the way, graphic equalizers can also be used for tailoring audio response. Boosting a desired pitch and attenuating all other frequencies produces a well-defined passband. A stereo equalizer with both sections connected in series should provide more than adequate audio selectivity for general communication purposes.—*Jim Weiss, W9ZMV, c/o WTAQ, La Grange, IL 60525*

AMPLIFIER TR RELAY SWITCHING INVERSION

☐ Because I burned out a relay contact in my Drake TR-5 transceiver by switching the antenna relay in my Heath® SB-200 amplifier, James Hebert's January 1988 article on a solid-state antenna-relay switch caught my attention.[2] I wanted to use

[2]J. Hebert, "Using the SB-220 Amplifier with Solid-State Transceivers," Hints and Kinks, *QST*, Jan 1988, page 45.

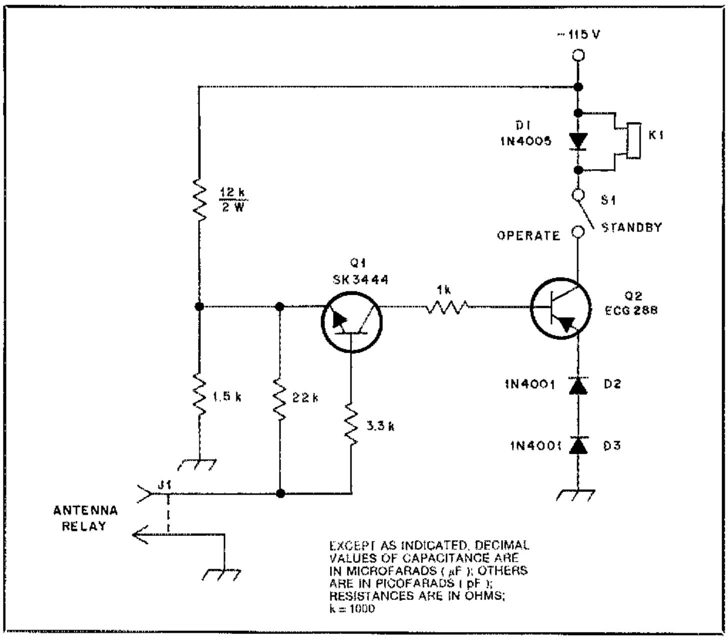


Fig 3—Wilbur Fulton modified the K8SS antenna-relay control circuit for use with the SB-200's negative antenna-relay supply as shown here. J1 and K1 are SB-200 parts; D1 is a 1-A, 600-PIV diode; D2 and D3 are 1-A, 50-PIV diodes and S1 is an SPST toggle. Resistors are ¼-W, carbon-film units unless designated otherwise.

James' circuit, but the SB-200's antenna relay operates at *negative* 115 V dc instead of the +125 V used in the SB-220. With a few modifications, the circuit can key the SB-200 relay:

1) Substitute an SK3444 (PNP) for Q1.
2) Substitute an ECG288 (PNP) for Q2.
3) Reverse the polarity of D1-D3.

Fig 3 shows the revised circuit. The relay in my TR-5 now switches only 10 V at 0.8 mA.—*Wilbur S. Fulton, W2SE, Box 681, 7 Lakes, West End, NC 27376*

BETTER SSB FOR THE COLLINS R-390A RECEIVER

☐ The Collins R-390A is a great receiver except for its poor performance on SSB. The primary reason for this fault is an improper signal versus BFO level in the detector stage; with the BFO as weak as it is, the '390A's AGC range is insufficient to ensure undistorted reception of strong SSB signals. The addition of a single 33-kΩ resistor between the anode of the AGC rectifier tube (pin 6 or 7 of V510) and the grid of the AGC time constant tube (pin 7 of V511) gives the AGC a helping hand, producing excellent SSB quality.

You can test this modification without removing the R-390A's IF subchassis as follows: Extend the leads of a 33-kΩ, ½-watt resistor by soldering a length of solid, insulated hook-up wire to each resistor pigtail. Wrap the resistor and its leads with insulating tape. Next, strip both of the extended resistor leads for ½ inch. Remove tube V510 from the R-390A IF subchassis and tightly wrap the bare end of one resistor lead around pin 6 or 7 at the tube base. Reinstall the tube, being careful that the twisted resistor wire remains insulated from the other tube pins and shield base when the tube is seated. Connect the other resistor lead to pin 7 of V511 in the same manner. Excellent SSB performance should be noticed, with no adverse affects on AGC time constant.

A more permanent modification would involve placing the 33-kΩ resistor in parallel with the series combination of resistors R556 and R557 inside the IF subchassis. —*Ken Johnson, N5US, PO Box 10063, Austin, TX 78766*

GENERIC FILM FOR THE FILM-AND-PHOTOCOPIER PC-BOARD METHOD

☐ In his article on PC-board fabrication,[3] Doug DeMaw mentions Meadowlake Tec 200 film, a commercial product useful in making photocopier-transferred PC-board patterns. I've had good results replacing Tec 200 film with 10-mil Mylar® film. Such film is often available from paper suppliers or transformer manufacturing companies.—*Peter Robson, 18 Washington Tr, Hopatcong, NJ 07843*

[3] D. DeMaw, "Homemade Circuit Boards—Don't Fear Them!," *QST*, Aug 1987, pp 14-16 and 23.

RFI-PROOFING A PHONOGRAPH TURNTABLE

☐ I recently discovered that my wife's hi-fi setup (a Hitachi turntable and a Sherwood receiver) did *not* like me operating on 15-meter CW at 100 W output: Every time I tapped my key, a sound akin to a bass drum emanated from the speakers.

The first thing I checked was whether or not the speaker leads were acting as antennas and feeding RF into the receiver. I verified that the RFI was *not* entering the receiver via this route by disconnecting the speakers and listening to the stereo receiver with a pair of headphones. The interference persisted.

Working through the rest of the system interconnections in a systematic way, I discovered that the most significant interference reduction occurred when the phonograph input cables (shielded cables equipped with phono plugs) were disconnected from the back of the stereo set. This, of course, pointed to the record player as the primary culprit in my RFI problem.

I removed the bottom cover of the phonograph. At the exit point of the two phono cables, inside the turntable itself, I installed ferrite beads and 0.001-µF bypass capacitors as shown in Fig 4.

As a further measure, I took the precaution of bypassing the ac-power-cord wires to ground with two more 0.001-µF disc-ceramic bypass capacitors. Then I reassembled the phonograph.

To choke common-mode RF currents on the shields of the phono input cables, I wound both cables several times through a large ferrite toroid (the core of a discarded TV deflection-yoke coil). This concluded my modification of the record player.

Because many TVI/RFI solutions come about only with application of *several* cures in combination, I also replaced the "zip cord" stereo speaker leads with foil-shielded wire. Again using ferrite beads and 0.001-µF capacitors, I bypassed the speaker

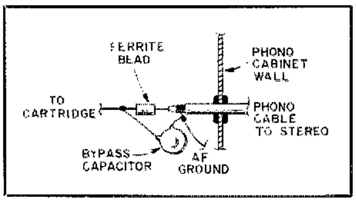


Fig 4—Battling a case of "hi-fi-I," Edward P. Swynar installed two RF-filter components at the phonograph end of each phono input lead as shown here for one cable. See text.

leads at the stereo-receiver speaker terminals. As a further precaution, I installed a good-quality high-pass filter at the receiver's FM-antenna terminals. Finally, I wrapped the receiver's ac-line cord around a 7-inch-long ferrite rod, securing the turns to the rod with electrician's tape. (This choke, I felt, would minimize common-mode conduction of RF up the line-cord wires.)

The result of all these maneuvers? My wife and I are friends again—and the RFI has gone for a hike!—*Edward Peter Swynar, VE3CUI, 48 Evergreen Dr, Whitby, ON L1N 6N6*

AK7M: For golden-eared audiophiles who cringe at the thought of bypassing high-impedance phono inputs (Z = 50 kΩ for many magnetic cartridges) with 0.001-µF capacitors (X = 10.6 kΩ at 15 kHz, the upper limit of the Record Industry Association of America's standard phono equalization curve), I suggest replacing the ferrite beads and 0.001-µF capacitors in VE3CUI's phono-cable filters with 1-mH chokes and 100-pF disc-ceramic capacitors, respectively. At 3.5 MHz, 100 pF looks like 455 Ω and 1 mH looks like 22 kΩ; such a filter should be reasonably effective in suppressing HF interference. At 15 kHz, 100 pF looks like 106 kΩ and 1 mH looks like 94 Ω—reactances that should have a minimal effect when used in parallel and series, respectively, with a 50-kΩ audio circuit. Beware of one potential snag when using solenoidal chokes in this application, through: They *may* introduce hum into the phono circuit in the presence of strong mains-ac fields.

CURING AIR-CLEANER INTERFERENCE

□ My Heathkit® GDS-1297 electrostatic air cleaner worked fine as assembled, with the exception that it caused a loud frying noise in nearby MF and HF receivers, and snow on a TV in the same room. The unit's power supply—approximately 6 kV—is clean. Only when the air-filter cell was connected to the supply did the noise appear. My cure? A simple T-section filter consisting of two 1-MΩ resistors and a 500-pF, 7.5-kV capacitor to ground between the power supply and the air-filter cell (see Fig 5). This filter reduced the noise to an acceptable level.—*John L. Morris, W6YAR, 14427 Allingham Ave, Norwalk, CA 90650*

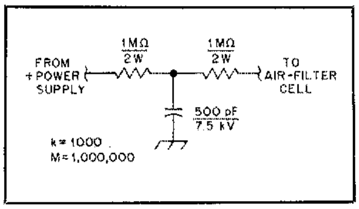


Fig 5—John Morris cleaned up air-cleaner interference with this simple T-section filter. See text.

STOP THAT DRILL

□ To avoid overdrilling holes in sheet metal, find a piece of metal tubing about ¼ inch shorter than the bit. Slip the tubing over the bit before drilling. The tubing limits the bit's travel and keeps the bit from damaging components behind the drilled surface. A stack of rubber grommets works well, too.—*Frank A. Reed, Jr, W6PWQ/7, PO Box 275, Langlois, OR 97450*

CONTROL EXTENSIONS FOR THE ICOM IC-735 TRANSCEIVER

□ I'm sure there must be other fat-fingered hams out there who are proud but uncomfortable owners of IC-735s: proud because they own a '735, and uncomfortable when trying to use the tiny slide controls under the rig's front-panel trapdoor. The door can be removed easily: Just flip it to the horizontal position and pull.

Here's how I extended the IC-735's slide controls for easier operation. (These instructions are for one control.) Cut a bobby pin so that its loop end is about ¾ inch long (Fig 6A). Slip small-diameter heat-shrink tubing over the pin ends as shown in Fig 6B. Shrink the tubing. Next, use a small screwdriver to spread the bobby-pin ends and slip the modified pin over one of the IC-735's slide controls. Push the control extender into place until it protrudes for 5/16 inch or so.

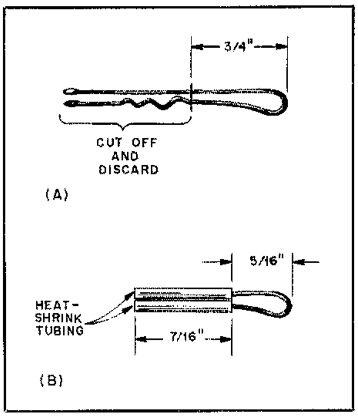


Fig 6—Larry Murdoch increases the "grab-ability" of his IC-735's slide controls with bobby pins modified as shown here.

This idea works well for me; I put these extenders on the IC-735 slide controls I use most: RF POWER, VOX DELAY, and MIC GAIN. Yes, they are removable!—*Larry D. Murdoch, K6AAW, 14370 Brian Rd, Red Bluff, CA 96080*

HEAD-OPERATED TUNING FOR FREQUENCY-SLEWABLE TRANSCEIVERS

□ While renovating an old pair of boom-mic-equipped headphones, the idea occurred to me of controlling some of my new transceiver's functions at the headset. Many newer transceivers offer scan tuning that can be operated by UP and DOWN buttons on a microphone. I developed the scheme of using two mercury switches glued to each other at angles (Fig 7). By mounting this arrangement inside the headset, I reasoned, frequency control could be accomplished by simply tilting the head left for DOWN and right for UP. I tried the idea, and it works! With a little practice, I could fine-tune my transceiver with quick nods to either side.

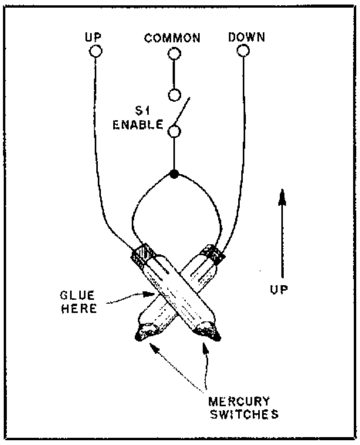


Fig 7—Bob Nagy's head-operated tuning scheme uses two mercury switches as UP and DOWN frequency-slewing controls. Mounted in a headset, they allow hands-off frequency excursions with rigs that include this feature. See text.

This little modification has applications for handicapped hams, of course, but it's a neat idea for anybody's shack. Be sure to include a switch (S1) to turn the circuit on and off, though: If you forget that the head-operated tuning is operative, you may think other stations are drifting every time you scratch your head!—*Bob Nagy, WA2TMD, 3303 Larry Ln, Austin, TX 78722*

FIXES FOR 3-400Z AND 3-500Z TUBES

□ In investigating a filament failure in my home-brew push-pull 3-500Z 40-meter amplifier, I found something that I had never seen before. All wiring, the filament transformer and tube sockets were working correctly, but the series connected filaments of the tube would not light. I pulled the amplifier out of the relay rack and examined the circuitry. It was easy to find which tube was at fault: Twisting one tube lightly in its socket caused both tubes to light. Examination of the tube base showed slight signs of heating on pin 1. (I just couldn't believe that a 3-500Z's filaments might burn out after only 3½ years of use!) Using a soldering iron, I melted the solder on pin 1 of this tube and an air bubble appeared—an indication that the pin had been improperly soldered to begin with. I resoldered the pin and everything worked fine. The other filament pin of the faulty tube was soldered properly, as were those of the other 3-500Z.

REMOVING GRID-TO-FILAMENT SHORTS IN 3-400Zs AND 3-500Zs

Since they were introduced in the 1960s, 3-400Z and 3-500Z vacuum tubes—particularly early versions—have been plagued with grid-to-filament shorts. In my opinion, this usually results from inadequate ventilation of the tubes, or from the improper operating conditions that can occur when 3-400Zs are replaced with 3-500Zs without adjusting the bias on the newer tubes.[4] (I did the latter myself on an early version of the original Henry 2K amplifier and experienced nothing but grid-to-filament shorts—until I rebuilt the transmitter and changed the bias, that is!)

If the tubes are not severely damaged, grid-to-filament shorts can be removed by connecting 120 V ac (in series with a 120-V, 500-W incandescent lamp for current limiting) between pin 1 or 5 (filament) and pin 2, 3 or 4 (grid) of the tube base. Gently tap the tube with a soft piece of wood or similar material. This should clear the grid-to-filament short and restore the tube to useful service. *Wear eye protection* and take care not to contact the ac mains while doing this—and be careful not to break the tube!

Experience has shown me that removing grid-to-filament shorts with this technique eventually deteriorates the grid, the result of which is the flow of plate current even with the associated amplifier in standby. I don't consider this current to be a problem as long as it remains below 50 mA—I've been operating a pair of original carbon-plate 3-500Zs (purchased in the mid 1960s) in this way for over ten years! In standby, they draw about 45 mA. "Zapping" the grid-to-filament short circuits out of these tubes did not affect their output-power capability.

If your tubes are still under warranty and seem to harbor grid-to-filament shorts, contact the tube manufacturer instead of trying my zapping technique. If the tubes' warranty has expired, though, give my idea a try; you may be pleased with the results. —*John O. Norback, W6KFV, ARRL Assistant Technical Coordinator, 133 Pino Solo Ct, Nipomo, CA 93444*

[4] A recent *QST* article suggests another possibility: that grid-to-filament shorts in these tubes can occur as a result of strong VHF parasitic oscilliations. See R. Measures, "Improved Anode Parasitic Suppression for Modern Amplifier Tubes," *QST*, Oct 1988, pp 36-38, 66 and 89. —*Ed.*

TOOTHPASTE AS A POLISHING AGENT

□ After accidentally scratching the digital readout on my Kenwood TR-2600A hand-held transceiver, I wondered if the scratch could be removed. On a hunch, I discovered that the readout face could be polished to its original smoothness with toothpaste—by briskly rubbing a small amount of paste over the scratched area with tissue paper. Since then, I've found that this method works well on many soft plastics.—*Ronald E. Wright, N9ADJ, 612 Forest Ave, Alton, IL 62002*

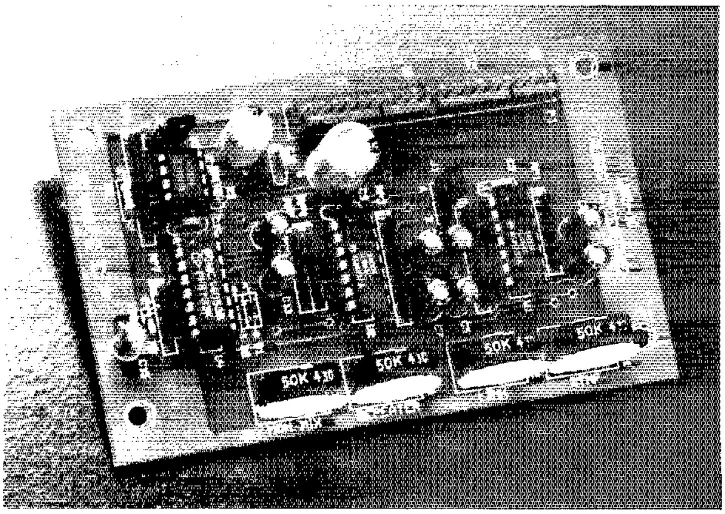
New Products

KANTRONICS PRESS COMMUNICATIONS BOOKS

□ Kantronics Press, a subsidiary of Kantronics Company, Inc, is introducing a series of pocket-sized books suitable for Amateur Radio operators. Book titles include *Introduction to Packet Radio, Packet Command Handbook, Advanced Packet, The Hamfest Book, Beginning Packet* and *Communication Codes Handbook.* The retail price for each book is $2.95 plus $1 for shipping and handling. Foreign orders incur additional costs. All of these are available from Kantronics Company, Inc, 1202 E 23rd St, Lawrence, KS 66046, tel 913-842-7745.—*Tom Francis, NM1Q*

UAI-10 UNIVERSAL AUDIO INTERFACE

□ The UAI-10, designed and built by Creative Control Products, is a repeater and link audio mixer featuring DTMF mute, DTMF output and monitor and mixing controls. This mixer will interface a repeater receiver, transmitter and link radio to any stand-alone repeater controller. Price class: $44. For more information, contact Creative Control Products, 3185 Bunting Ave, Grand Junction, CO 81504, tel 303-434-9405.—*Tom Francis, NM1Q*



Technical Correspondence

Conducted By Paul K. Pagel, N1FB
Associate Technical Editor

The publishers of *QST* assume no responsibility for statements made herein by correspondents.

BIASING BIPOLAR RF TRANSISTORS

☐ Bipolar RF transistor biasing circuits are usually misunderstood. Often, for the sake of convenience, the current-shunt diodes connected in parallel with the transistor base are incorrectly placed far from the transistor being biased. This effectively defeats the intended purpose of the diode: *to provide thermal compensation of the bias supply current.* In other words, if the diode doesn't get hot when the transistor does, the circuit won't work well.

The basic concept behind simple diode biasing is to feed the base of the transistor and the diode from a current source as shown in Fig 1A. The current source is often approximated with a large-value resistor (R1) hooked to the supply voltage. When a diode or transistor junction gets hot, its voltage drop for a given amount of current decreases. If D1 is omitted, decreased voltage drop across Q1's base-emitter junction results in increased base and collector current flow through Q1. This leads to a phenomenon known as thermal runaway.

The heated diode steals current from the transistor's base, preventing the transistor from drawing more current. For proper operation, select a diode having thermal characteristics that match those of the transistor with which it is to be used. Here's how: With a properly selected diode, the base bias current level will drop to normal when RF drive is removed. With no RF drive, the bias level should be relatively constant and exhibit little, if any, increase over time. Self-biasing problems caused by rectification of the driving RF signal do not appear to be a problem with current-source biasing using active current sources. As shown in Fig 1B, the LM317 adjustable regulator is easily configured as a current source.

It is possible to bias a bipolar transistor with a *thermally compensated* voltage source, as used in the 140-W amplifier built by Helge Granberg, K7ES, and described in *The 1987 ARRL Handbook*.The negative feedback is accomplished by means of a diode that is thermally coupled to the transistors. However, this circuit does not support the incorrect assertion that one can bias a transistor with a 0.7 V source—that rarely works without feedback.

Unfortunately for builders used to dealing with vacuum tubes and FETs, bipolar transistors aren't as easily modeled as voltage-controlled devices because they are *current*-controlled devices.—*Zack Lau, KH6CP, ARRL Lab Engineer*

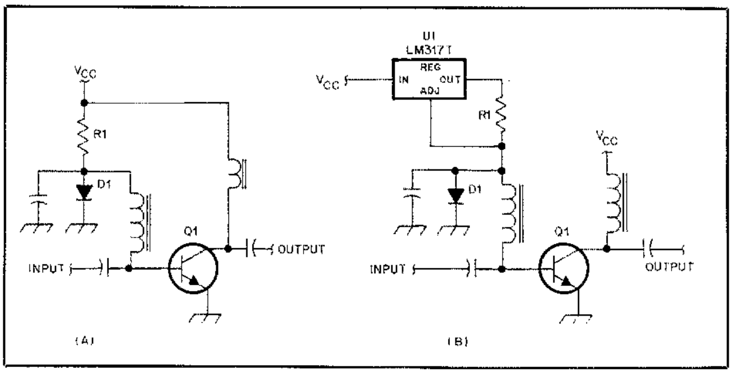


Fig 1—Two methods of biasing bipolar transistors with dc shunt diodes. See text for details.

GROUNDING TECHNIQUES

☐ The US Army Signal Corps recently reported on the results of improved grounding techniques for mobile field tactical radio stations.[1] These mobile stations are usually installed in trucks, and use vertical antennas. The ground system consists of a cable connected to a copper rod driven several feet into the earth. The typical ground resistance and RF impedance obtained, therefore, are often not optimal.

In order to improve the effective ground, field tests were made employing a number of ground rods mechanically connected in *parallel* around the mobile radio station. The ground rods were driven into the earth at various depths, and the resultant ground resistance and RF impedance measurements were recorded. Then the tests were repeated with ground rods mechanically connected in *series* and driven to different depths in the earth.

Analysis of the recorded data and the field radio transmission tests indicated that the use of four *series-connected* ground rods, driven only a foot or two into the earth, provided the most efficient ground system. These improved field grounding techniques should be applicable to Amateur Radio stations, particularly during Field Day operations.—*Lt Col AUS (ret) David Talley, W2PF, Suite 1533-S, 10275 Collins Ave, Bal Harbour, FL 33154*

[1]*Signal*, Mar 1988, pp 79-80.

"SUPER DUMMY" RESISTOR CONSIDERATIONS

☐ If you're thinking of constructing the Super Dummy,[2] you should be aware of some subtle differences between Carborundum's 889SP and 889AS resistors.[3] They both look the same, but the SP series is rated to 350 °C, and the AS series is rated to only 230 °C. More significant, though, is the performance of these resistors when immersed in cooling fluids. To quote the Carborundum catalog:

> *Fluids*
>
> The power-handling capability of the resistors may also be increased by immersion in (cooling) fluids. Mineral oils, fluorocarbons, and silicones are often used. Many fluids will be limited in application by their own maximum temperature, not by the maximum temperature of the resistor.
>
> *Type SP*
>
> These (cooling) fluids have no known effect upon type SP resistors except that they increase the ability of the resistors to dissipate power. They do not increase the ability of the resistors to handle high voltages.
>
> *Type AS*
>
> *Unless the resistors are protected by a coating that the fluid cannot permeate,* [italics added] such as an epoxy, these fluids cause the

[2]See *The 1988 ARRL Handbook*, pp 34-22 to 34-23.

[3]The SP series resistors are available from RADIOKIT, PO Box 973, Pelham, NH 03076, tel 603-635-2235.

resistance of Type AS resistors to *increase* [italics added]. With some silicones, this increase is as little as 10%; with some mineral oils, this can be as much as 100%. Generally, the resistance will rise as the fluid permeates the resistor body, and it will finally stabilize. . .

—*Dick Jansson, WD4FAB, ARRL TA, 1130 Willowbrook Trail, Maitland, FL 32751*

CYCLON-BATTERY DISCHARGE WARNING

☐ Sealed rechargeable lead-acid batteries bearing the trade name Cyclon (made by Gates Energy Products) have appeared at local hamfests and at other sources. The ones seen most often are rated at 2.5 Ah, and are the same size as a D cell, although they are rated at 2 V each. One of the cautions printed on the battery label says to avoid shorting—*this warning should be followed scrupulously!*

The Cyclon cells have, according to the manufacturer's data sheet, a low internal impedance and are capable of high discharge rates. The X cell can put out 200 A, the J cell, 250 A, and the BC cell is capable of delivering up to 600 A. Even the lowly D cell is capable of delivering (for a short time) over 100 A!

A local ham accidentally shorted a battery pack made up of four series-connected Cyclon D cells. The connecting wires were melted, and the cells spit out drops of molten metal and were destroyed.

Anyone using the Gates Cyclon cells should be aware of their tremendous short-circuit-current capability. Make sure the cells are fused as closely as practical to the battery terminals, and use care in installation.—*Michael A. Czuhajewski, WA8MCQ, Box 232, Jessup MD 20794*

Note: All correspondence addressed to this column should bear the name, call sign and complete address of the sender. Please include a daytime telephone number at which you may be reached if necessary.

Feedback

☐ Please refer to "Build A Dummy Dipole!," *QST*, April 1985, p 52. There is an error in Equation 3. The proper form of this equation is:

$$C = \frac{1}{(2\pi f_0)^2 L}$$

(Tnx to Fred Grant, AA4NG.)

☐ In my article, "A Dipper Amplifier for Impedance Bridges," *QST*, Sep 1988, pp 24-25, I suggested that T1 should have a 25-turn primary and 9-turn secondary for use at 1.8 MHz. This was a calculation based on performance at 3.5 MHz. At 1.8 MHz, however, this number of turns provides insufficient inductance and results in a maximum reading of only 5 μA on the bridge meter.

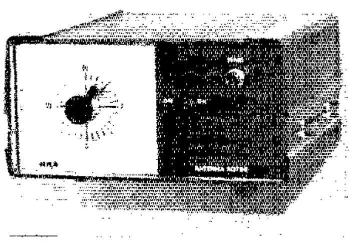
With the following modifications, a full-scale meter reading can be obtained from 1.8 MHz to 45 MHz when the bridge is looking at a 50-Ω resistive load and is set to maximum impedance. Use an FT-37-43 core for T1. Place 20 turns on the primary and 7 turns on the secondary. Increase the number of turns in the pick-up coil (L1) from 1½ to 2½.

As described in the article, the bridge works fine over the 3-60 MHz range. I apologize for the error and hope it did not inconvenience anyone.—*Andrew S. Griffith, W4ULD, 203 Lord Granville Dr, Rt 2, Morehead City, NC 28557*

New Products

ROTATOR-CONTROL UNIT FOR VISUALLY IMPAIRED HAMS

☐ Norm's Rotor Service, of Rockville, Maryland, is producing the HAM-SP rotator control for visually impaired hams. The HAM-SP controller works with the following rotators: TR-44 (series 3), CD-44 and -45-II, HAM-M series 3, 4 and 5, HAM-II, HAM-III, HAM-IV and Tailtwister. The controller will also work (after wiring modifications) with the following rotators: TR-44 (series 1 and 2), HAM-M (series 1 and 2). In all rotators used with the HAM-SP, the 500-Ω position-feedback potentiometer must be replaced with a 1-kΩ unit.



Operational functions of the HAM-SP are marked on the front panel in Braille and with panel labels. Operation of the HAM-SP is simple: twist the direction dial to the desired heading, push the start button, and listen for the rotation-indicator tone (2900 Hz, ±500 Hz). The control takes care of extracting the brake wedge, turning the rotator to the desired heading, and reinserting the brake wedge after a five-second delay. Price: $249. Available from Norm's Rotor Service, 677 Southlawn Ln, Rockville, MD 20850, tel 301-340-0520.—*Rus Healy, NJ2L*

How to Contribute to the W1AW Renovation Drive

• **By Mail:** Address all contributions to W1AW Fund Drive, 225 Main St, Newington CT 06111. Please make your check or money order payable to W1AW Renovation Fund.

• **By Phone:** For your convenience, credit-card contributions can be made by calling Jennifer at ARRL HQ, tel 203-666-1541, between 8 AM and 4 PM Eastern Time, weekdays.

All contributions are tax deductible to the extent allowed by law, as ARRL is a 501(c)(3) tax-exempt organization. Does your employer have a match-contribution program? Some major employers will match your contribution.

Recognition

Contributors to the W1AW Fund Drive will be recognized as follows:

- *W1AW Kilowatt Club:* Those contributing $1000 or more.
- *Hiram Percy Maxim Club:* Contributions of $500-$999
- *W1AW Century Club:* Contributions of $100-$499
- *W1AW Booster Club:* Contributions of up to $100

All contributors will receive a handsome certificate, suitable for framing. Members of the *Hiram Percy Maxim* and *Kilowatt Clubs* will, in addition, have their name and call sign inscribed on a special plaque that will be on permanent display in the renovated W1AW Building. Members of the *Kilowatt Club* will receive a specially inscribed personalized plaque, which you'll be proud to display in your ham shack. In addition, special recognition will be given to those who donate substantially more than $1000.

New Books

THE "GROUNDS" FOR LIGHTNING AND EMP PROTECTION

By Roger R. Block. Published by Polyphaser Corp, 1425 Industrial Wy, Gardnerville, NV 89410-1237. 1987 edition. Soft cover, 8½ × 11 inches, 108 pages, $19.95.

Reviewed by Doug DeMaw, W1FB

If books with nontechnical language appeal to you, this may be a volume to add to your reference library. *The "Grounds" for Lightning and EMP Protection* contains a minimum number of formulas so that "a maximum number of people can understand and install good protection/ground systems for protecting communications equipment against all active pulses." This statement is found in the book's introduction, and it appears to me that the author has lived up to his pledge.

The text of the book was prepared in camera-ready form with a word processor. This is similar to the format of *W1FB's QRP Notebook* and *W1FB's Antenna Notebook.* The print is bold and clear, and the text is justified. Line drawings are provided where necessary. They are easy to read and are labeled adequately.

The chapter titles are: Current Distribution; UFER Grounds; Low Inductance Ground Rods and Connections; Guy Anchor Grounding; Ground Impedance; Inside Hut Grounding and Shielding; Protecting Remote Equipment from Power Source Surges; Tower-Top and High Rise Radio Equipment; Exploding the Myths about Lightning Protection; Protecting Equipment from EMP Damage; The Dynamic Testing of Grounds; A General Review of Standard; Radius of Protection and Side-Mounted Antennas; Security Cameras; CATV; Telephone Central Offices and Computers; Ethernet Protection Method; TVRO Systems; Utility Pole Supports; Towers on Buildings.

This book also contains an epilogue, a bibliography and two appendixes. The chapters are short and to the point, which makes for comfortable reading. For instance, in chapter 7, the following quote shows this book's clarity in style: "Four-layer semiconductor protection devices are not limited to power-line applications. They also may be used on telephone or control lines. Sometimes they are used alone, sometimes in complex combinations (hybrids)." Another excerpt provides an example of the easy reading I find in this book: "In some installations, the tower-hut distance can be a 'pretty far piece.' Ground rods are needed. But how deeply they are driven into the earth, how far apart they are placed and how they are connected together is very important."

This book should be a useful reference in a radio-club library. Those who operate and maintain repeaters, especially, should find this book helpful, owing to the lofty heights where most repeaters are situated. But even the amateur with ordinary equipment and modest antennas can benefit from the sound advice given in this volume. I'm sure that this book will be of value to members of the industrial fraternity also. I consider it recommended reading for all who need to protect electronic equipment from lightning and EMP damage.

Conversion Between Geodetic and Grid Locator Systems

(continued from page 30)

eastern and western edges, so the longitude rounding term is 2.5′. (The rounding term must carry the same sign as that of other coordinate digits [negative rounding terms for negative longitudes and latitudes, positive rounding terms for positive longitudes and latitudes.]) Next, we'll calculate the *latitude* specified by DM13EK:

M = +30°
3 = +3°
K = +0° 25′
Round = +0° 1.25′

Sum = +33° 26.25′, or 33° 26.25′ N latitude

For six-character locators, the latitude rounding term is 1.25′ because the region designated by a six-character locator is 2.5′ wide in latitude. Again, the rounding term must carry the same sign as that of the other coordinate digits.

For *four*-character (grid-square) locators, the rounding terms are 1° (longitude) and 30′ (latitude) because grid squares are 2° × 1° (longitude × latitude) in size. As before, the grid-square rounding terms must carry the same sign as that of the other digits in their respective coordinates.

For more examples of grid locators, see Table 7. Use the coordinates and grid locators shown there as a basis for practice in converting geodetic coordinates to grid locators, and vice versa.

The *Rand-McNally Road Atlas* can be used for estimating station locations by interpolating between the geodetic coordinates marked on the edges of the atlas' state maps. For the highest precision, use US Geological Survey quad sheets that cover your areas of interest.

Summary

Tables 1 through 6, inclusive, provide a field-transportable method of converting between the geodetic and grid-locator systems. For Field Day exercises and VHF/UHF contests, the tables provide a means of cross-checking station coordinates when the station computer has been left at home.

References

J. Lindholm, "VHF/UHF Century Club Awards," *QST*, Jan 1983, pp 49-51.

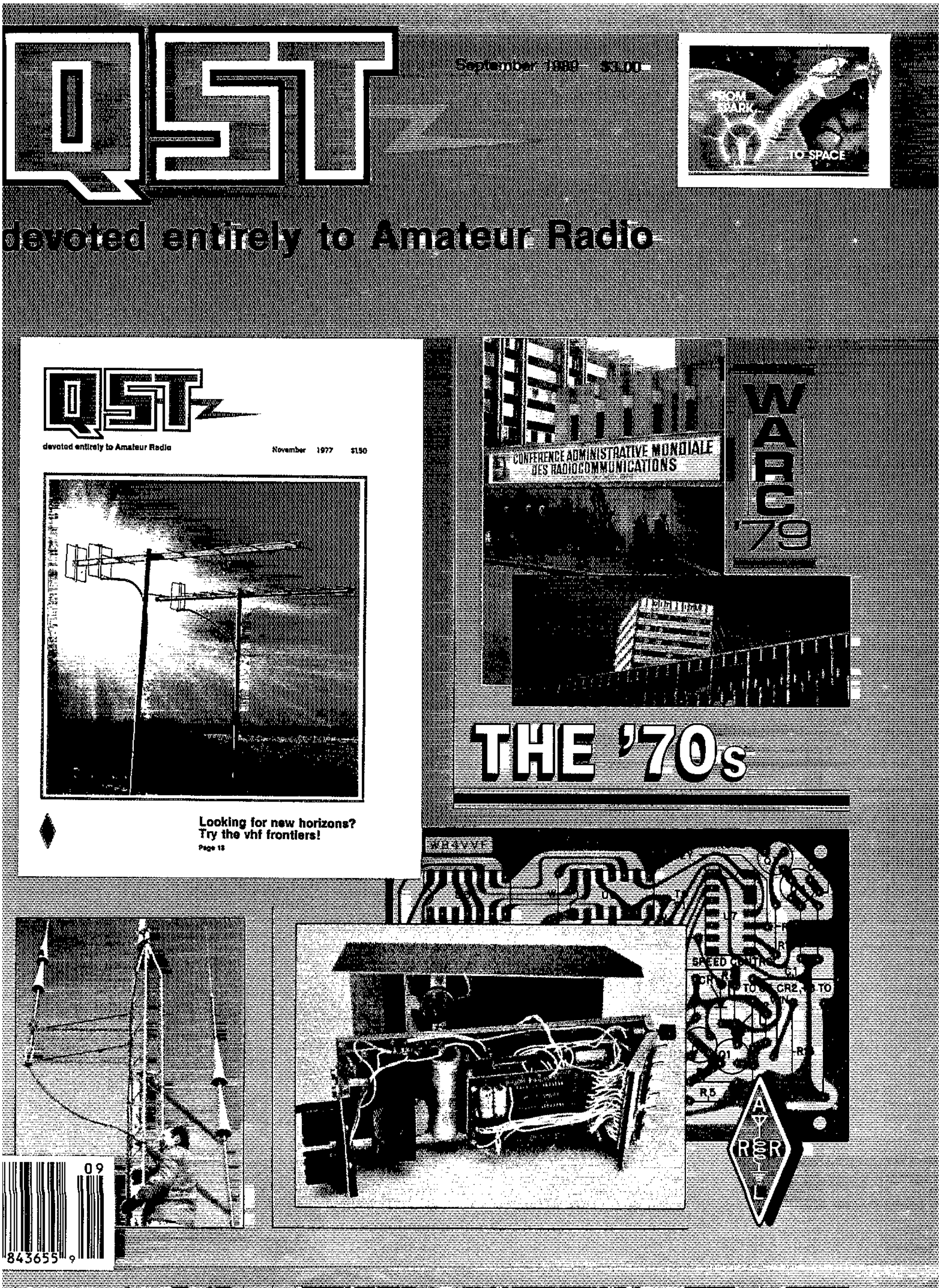
W. Overbeck, "A Universal Grid-Locator Program for Your Personal Computer," *QST*, Dec 1986, pp 30-31.

Edmund T. Tyson became interested in Amateur Radio in the early 1940s. Entering military service in 1944, he worked in various career fields involving electronics. Assigned to Wright Field in 1953, Ed worked on airborne TV systems for reconnaissance. In 1957, he was assigned as project engineer to establish and operate an observatory for tracking and photographing satellites. Retiring after 33 years of military and civilian service, Ed has been involved in designing and building electronic and computer equipment for astronomical applications. He is currently involved in relocating a 48-inch telescope from New Mexico to California. He was licensed as a Technician in 1986 and upgraded to Advanced Class in 1988.

New Products

VEHICULAR CALL-SIGN DISPLAYS

☐ Sign On, of Merrick, New York, makes vehicular call-sign displays in two varieties: a magnetic vinyl sign for metal vehicle panels, and a suction-cup mounted version for inside-window mounting. The flexible, plastic 2- × 8-inch in-window signs are available in white lettering on black, blue or red backgrounds. Magnetic signs, also 2 × 8 inches, are available in black, blue or red lettering on a white background. Price: $8.50 per sign, postpaid; volume discounts are available. For more information, contact Sign On, Dept PT, 1923 Edward Ln, Merrick, NY 11566.—*Rus Healy, NJ2L*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OUR COVER

During the seventies, amateurs gained three new HF bands—thanks to the efforts of the IARU team at the World Administrative Radio Conference in Geneva. *QST* went to a new size, thousands of WB4VVF "Accu-keyers" and "Accu-memories" were built, and the *ARRL Repeater Directory* grew to over 5000 listings by the end of the decade.

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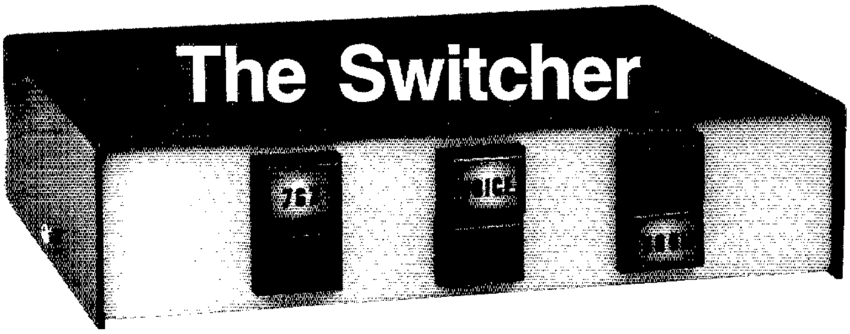


This versatile station accessory makes switching rigs, mikes and modes as simple as pushing a button!

By Raymond P. Bintliff, K1YDG
2 Powder Horn Ln
Acton, MA 01720

Getting new ham equipment is fun, but additional gear usually makes for a more complicated shack. If you acquire a boom mike/headset for contesting or DXing, for example, but prefer to use your desk mike for less-intense activities, changing mikes can be a nuisance. *Frequent* mike changes may even wear or damage your transceiver's mike connector! Adding a second MF/HF transceiver adds further complications, such as different mike-connector pinouts, and the need to move your headset from one rig to the other. And then there's digital operation: Adding RTTY or packet radio can *really* increase the complexity of a station!

This article describes the Switcher, an accessory that can centralize and simplify interconnection and selection of a variety of station equipment. Although I designed the Switcher for my particular collection of gear, you can adapt its circuit to your needs.

What the Switcher Switches

As described here, the Switcher allows quick selection between (1) two transceivers (in my station, a Yaesu FT-767GX and a Kenwood TS-940S); (2) voice or digital operation; and (3) a desk microphone and separate headset or a boom mike/headset. Fig 1 shows this switching in simplified form, and the title photo shows the Switcher's front-panel layout.

Illuminated, push-button switches select the Switcher's functions. Pressing 767, for instance, selects the FT-767GX mike and PTT inputs and headphone output; pressing 940 selects the TS-940S. Assuming that the FT-767GX has been selected, pressing the VOICE or DIGI switches connects the '767GX's mike and PTT inputs to the Switcher's mike-selection circuitry (VOICE) or to the station TNC (DIGI). Selecting the Voice mode allows the further selection of desk and boom mikes by means of DESK and BOOM buttons. These buttons also direct the transceiver's headphone output to the appropriate headset—a pair of headphones in the Desk mode, and the boom-mike headset in the Boom mode. As configured for my station, the Switcher's default modes are 767, Voice and Desk.

Relays handle the Switcher's audio and control-line switching; the front-panel push buttons control the relays.[1] Figs 2 and 3 show the complete schematic of the Switcher. Switching between the 767 and 940 modes is accomplished by K1, K2 and K3. The inactive transceiver's mike, ground and PTT lines are disconnected from the Switcher to prevent accidental operation of the inactive transceiver if its mike PTT switch is pressed. K1 and K2 switch the audio-in and PTT lines; K3 switches the audio-out line.

K4 and K5 handle switching between the Voice and Digital modes. Because the TS-940S supports direct frequency-shift keying (FSK), my version of the Switcher does not perform voice/digital switching of the TS-940S mike line. Instead, my TS-940's FSK input is connected directly to the TNC's FSK output. Voice/digital mike-line switching is necessary with the FT-767GX, however, because *audio* frequency-shift-keying (AFSK) must be applied to the '767 for digital operation. For digital operation with the FT-767GX, then, the Switcher (1) disconnects the Switcher's mike line from the '767GX and (2) connects the TNC's audio output to the FT-767GX's mike input. The TNC-audio-output line floats in all other Switcher modes.

To better isolate the Switcher's voice/digital switching, the TNC-Switcher ground connection is opened in the Voice mode. Also in the Voice mode, the TNC-audio input is grounded and the TNC-to-Switcher PTT line is opened. K6 and K7 switch between desk and boom mikes.

In addition to the audio and control-line switching described above, the Switcher lights the push buttons of selected functions and dims or extinguishes those associated with unselected functions. For example, selecting the Switcher's Voice mode fully lights the VOICE lamp and dims the DIGI lamp.[2] In the Digital mode, the DESK and BOOM lamps are turned off.

The Switcher requires 12-V-dc, floating-

Fig 1—In its basic form, the Switcher allows push-button selection between (1) two transceivers; (2) voice or digital operation and (3) a desk microphone and separate headset or a boom mike/headset. Relays handle the actual switching of audio and control lines; see text.

[1]Notes appear on p 21.

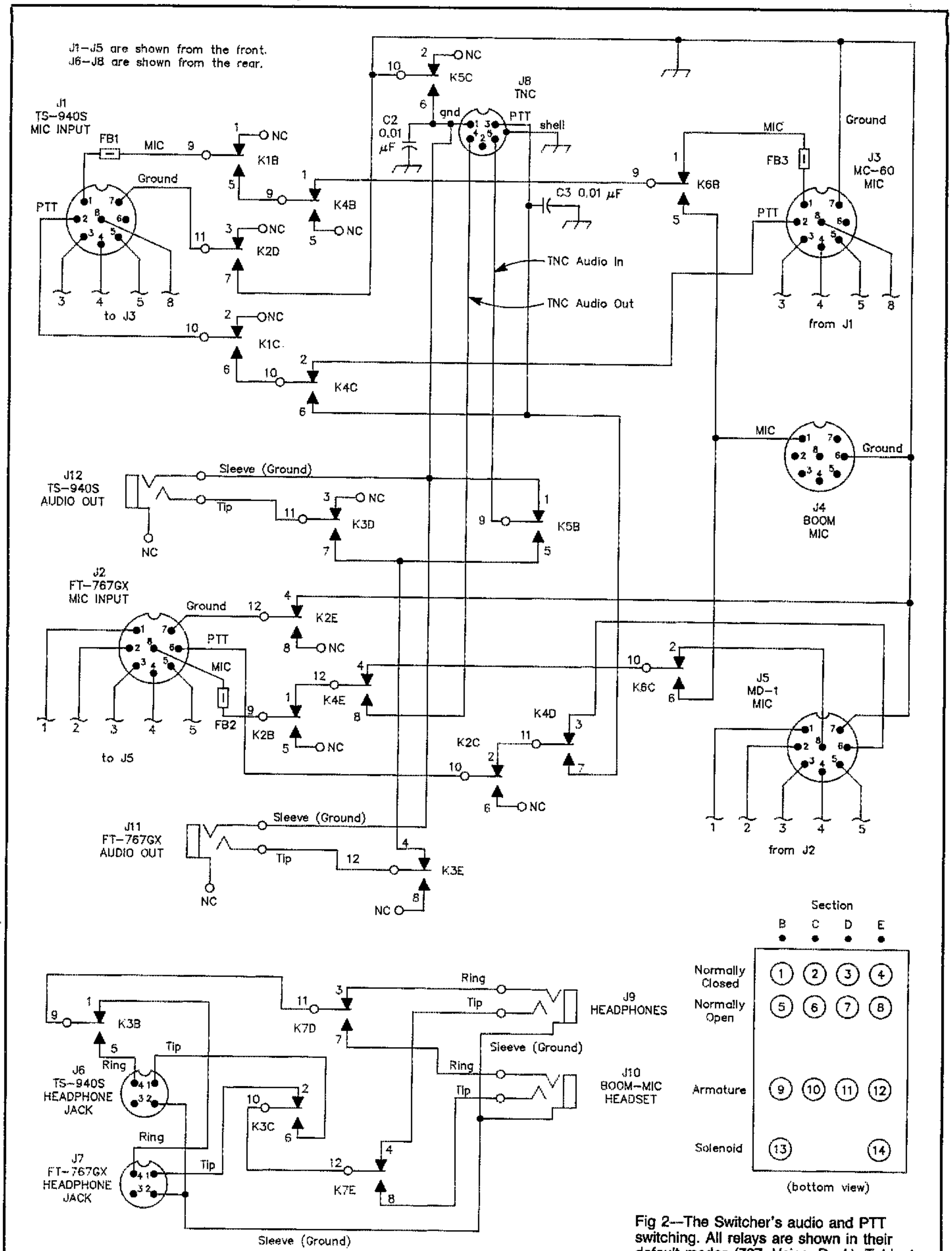


Fig 2—The Switcher's audio and PTT switching. All relays are shown in their default modes (767, Voice, Desk). Table 1 lists the parts used in this circuit.

negative power. (A grounded power supply introduces hum into the switched audio circuits and should not be used.) The maximum current drain, 650 mA, occurs when the Switcher is in the 940, Voice and Boom modes.

Constructing the Switcher

Radio Shack® carries all Switcher components except FB1-3 and the eight-pin, chassis-mount, male mike jacks (J1-J5).[3] I built my Switcher into a Ten-Tec TG 28 aluminum cabinet (approximately 2 × 8.25 × 6 inches [HWD] in size). Figs 4 and 5 show the Switcher's connector layout and internal wiring. I mounted K1 through K7 directly to the cabinet with double-stick foam tape. The sidebar, "Modifying the Push-Button Switches for Momentary Operation," tells how to modify the push-on, push-on switches (S1-S6) for use in the Switcher.

To avoid ground loops,[4] I insulated all connector ground lines (except for those of mike connectors J3, J4 and J5) from the Switcher chassis. I insulated J9 and J10 from the chassis with nonconductive (fiber) shoulder washers, and used four-pin connectors at J6 and J7 to keep the transceiver-headphone-output commons separate from the Switcher chassis. (You can use phone jacks at J6 and J7 if you insulate them from the chassis with nonconductive shoulder washers.)

Ground the bus that connects pin 7 of J3, pin 6 of J4 and pin 7 of J5 to the Switcher chassis at one point only. (J8's ground terminal is a convenient point for this.) Be sure that the positive *and* negative sides of the Switcher's 12-V dc supply float above ground outside the Switcher, and that the supply negative connects to the Switcher chassis *only* at the common ground point described above. Hum or feedback

Table 1

Switcher Parts List

C1—4700-µF, 35-V electrolytic (RS 272-1022).
C2-C4—0.01-µF, 500-V disc ceramic (RS 272-131).
FB1-3—FB73-101 (Amidon, RADIOKIT) or FB-7-73 (Palomar) ferrite bead.
K1-K7—4PDT, 12-V dc relay (RS 275-214).
J1-J5—Eight-pin male mike jack, chassis mount (see text and Note 3).
J6, J7—Four-pin male mike jack, chassis mount (RS 274-002).
J8—Five-pin female DIN connector, chassis mount (RS 274-005).
J9, J10—Three-conductor, open-circuit, ¼-inch phone jack (RS 274-312).
J11, J12—Three-conductor, open-circuit, 1/8-inch phone jack (RS 274-249).
J13—Dc power connector (RS 274-1565).
S1-S6—Illuminated push-on, push-off SPDT NO/NC switch (RS 275-678), modified for momentary operation as described in the sidebar, "Modifying the Push-Button Switches for Momentary Operation."
R1-R6—150-Ω, ¼-W, carbon-film resistor (RS 271-1312).

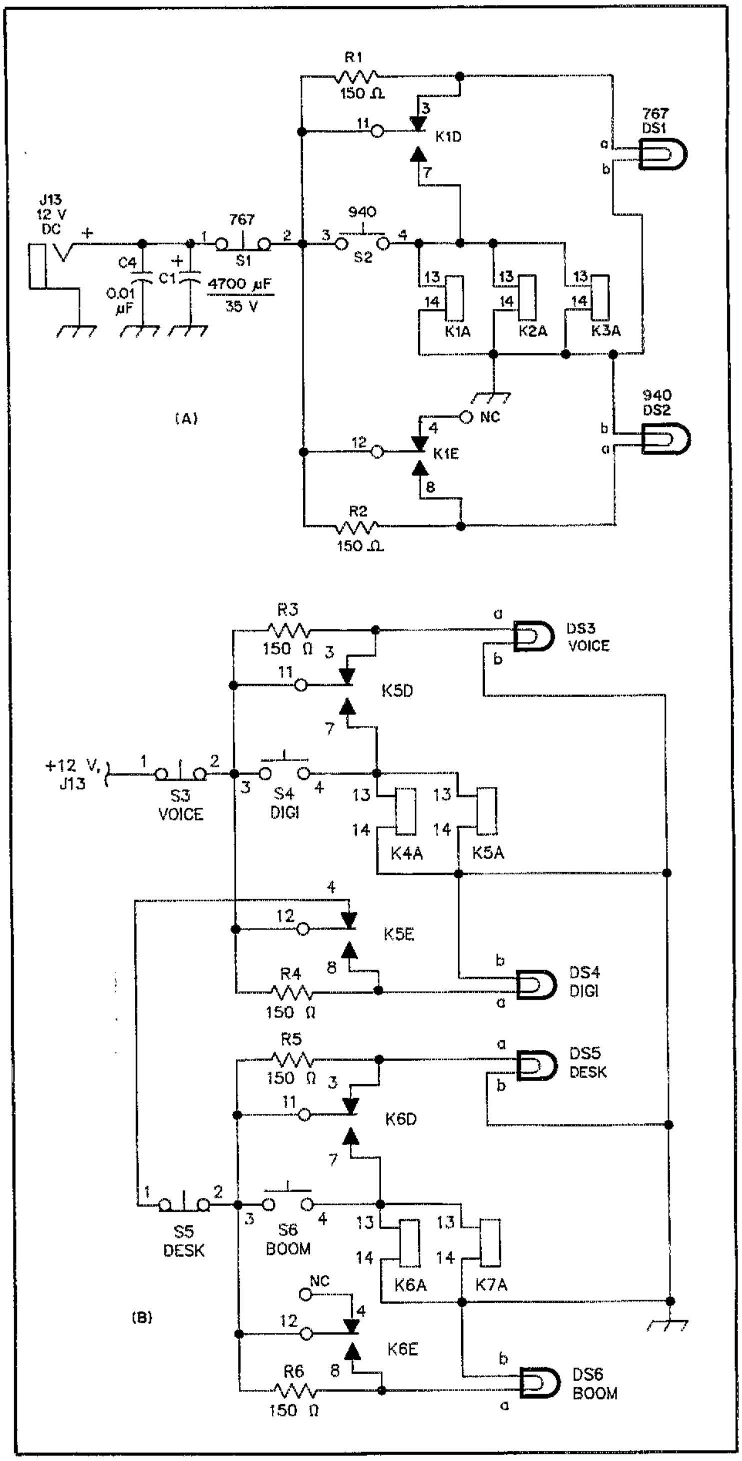


Fig 3—At A, relay and lamp switching for the Switcher's 767 and 940 modes; at B, relay and lamp switching for the Voice, Digital, Desk and Boom modes. Table 1 lists the parts used in these circuits; the inset in the lower right-hand corner of Fig 2 shows the relays' pinout.

Modifying the Push-Button Switches for Momentary Operation

The Switcher uses push-on, push-off switches (S1 through S6) that must be modified for momentary action. The modification procedure is as follows:

1. Set the switch to its "out" position.
2. Remove the switch's red lens and white-plastic light diffuser.
3. Using a small screwdriver, pry out and remove the rectangular, white-plastic lamp holder from the black-plastic shell. (Be careful not to bend the two silver coil springs. These springs provide the electrical connection between the lamp assembly and the base of the switch assembly.)
4. The black-plastic shell contains a detent spring, one end of which is inserted in a small brass eyelet located on the flat side of the shell. Remove and discard the spring.
5. Remove the self-adhesive label from the black-plastic shell. Retain the label so you can replace it later. (The three access holes visible with the label removed will be used to guide the coil springs into place during replacement of the white-plastic lamp holder.)
6. Carefully insert the lamp holder into the black-plastic shell. Note that the flat sides of the shell and the lamp holder must be aligned.
7. Guide the coil springs over the plastic pins in the base of the shell, taking care not to bend the springs. When the coil springs are properly engaged, press the lamp holder until it snaps in place.
8. Test for correct lamp operation by applying 12 V dc to solder lugs a and b. If the lamp tests good, replace the label you removed in Step 5.
9. Replace the switch's white-plastic light diffuser and colored lens. (Two lenses, one red and one green, are furnished with the switch. Use the color of your choice.) When replacing the light diffuser, be sure to correctly position its indexing tab in the lamp holder. Once you've done this, you've successfully converted a push-on, push-off switch to momentary operation.

I elected to use the illuminated switches specified in the parts list because their white-plastic light diffusers can be marked to identify the switches' functions. Dry-transfer lettering works well for this. (I used C-Thru Graphics' "Futura Demi-Bold 24pt" to label the Switcher shown in the photographs.) Many stationery stores carry dry-transfer lettering in various styles.—*K1YDG*

problems may occur if you don't take these precautions.

Other Design Possibilities

Because I use a separate coaxial switch for RF switching, my version of the Switcher does not switch the transceivers' RF-output lines. Additional relay switching can be incorporated to do this, and to permit the use of one microphone with both transceivers.

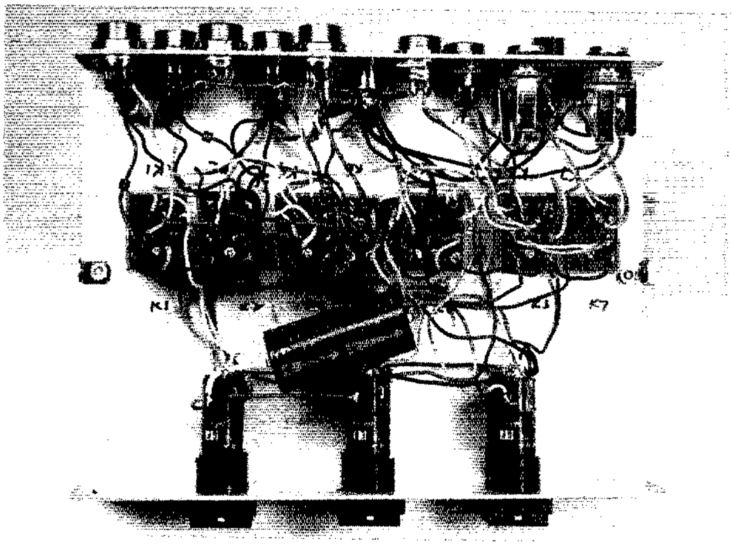


Fig 4—The Switcher's wiring emphasizes short interconnections. From left to right, the relays are K1, K2, K4, K6, K5, K3 and K7. The sidebar, "Modifying the Push-Button Switches for Momentary Operation," tells how to modify and label the Switcher's push buttons.

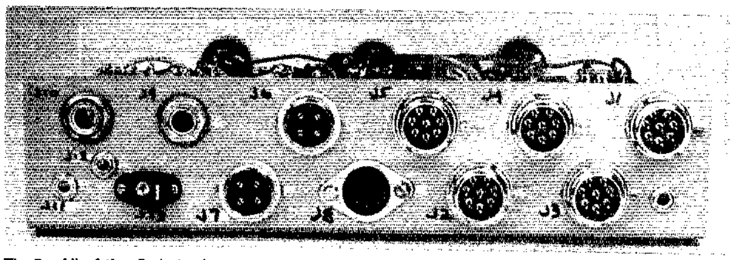


Fig 5—All of the Switcher's connectors mount on the rear cabinet panel. See text for how to wire the connectors to avoid ground loops. The phone jack at lower right is unused.

In my version of the Switcher, however, I chose to simplify the mike switching circuitry, and to retain the up/down tuning capability the MD-1 and MC-60 microphones provide when used with their respective transceivers.

Summary

I've used the Switcher for over a year at my station, and it has proven to be a reliable and easy-to-use accessory. Although it's hardly state-of-the-art, the Switcher is easy to build and uses readily available parts. I encourage you to adapt it to suit your requirements.

Ray Bintliff was first licensed in 1957 as W2HTL, and presently holds an Extra Class license. He held engineering and management positions at RCA until his retirement in 1983. In addition to home-brewing small projects, Ray enjoys chasing DX—and has, on occasion, been known to catch some!

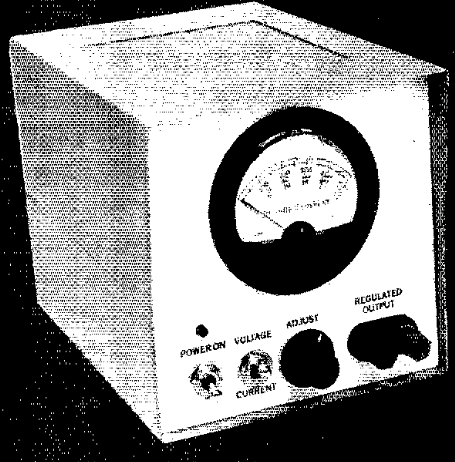
Notes

[1]A mode-by-mode listing of the function of each section of the Switcher's relays is available for a business-size SASE from Switcher Relay Listing, Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111.

[2]This dimming feature is useful under low-ambient-light conditions, in which the buttons of unselected functions might otherwise be invisible. If this feature doesn't interest you, you can eliminate it and use the lamp-dimming relay contacts for other purposes.

[3]Amateur Electronic Supply lists suitable connectors in its spring 1989 catalog. Other Amateur Radio equipment dealers likely carry such connectors as well.—*Ed.*

[4]A *ground loop* is a common path along which two or more points intended to be at the same ground potential are actually at *different* potentials. Ground loops are undesirable because the unintended inter-circuit coupling they support can cause hum, noise, feedback and data errors.—*Ed.*



A 1.25- to 25-V, 2.5-A Regulated Power Supply

Let's discuss the practical aspects of a test-bench power supply that's easy to build and get working. Most of the parts are available as surplus.

By Doug DeMaw, W1FB
ARRL Contributing Editor
PO Box 250
Luther, MI 49656

I needed a regulated 24-V power supply for development work with power FETs, but my lab supply could not deliver the current required because it provides a maximum of only 1.5 A. My work called for a current range from 2 to 2.5 A. Although I found a number of surplus fixed-voltage power supplies offered at modest prices, they were not variable-voltage units, and they qualified for the "boat anchor" weight class! I chose a typical amateur solution: build the power supply and make it compact.

This article covers the essentials of a simple power supply that you can duplicate in a few evenings. It can be expanded easily to deliver greater output current. The heart of this power supply is contained on a PC board that is available from FAR Circuits.[1] In fact, most components are available from mail-order houses.

Circuit Details

Fig 1 shows the circuit for my supply. The components marked with a double asterisk are external to the PC board. I recommend that you read the *ARRL Handbook* (1989 or other recent editions) for an explanation of how regulated power supplies operate. See pages 27-12 and 27-13 for a design description of a similar power-supply circuit.

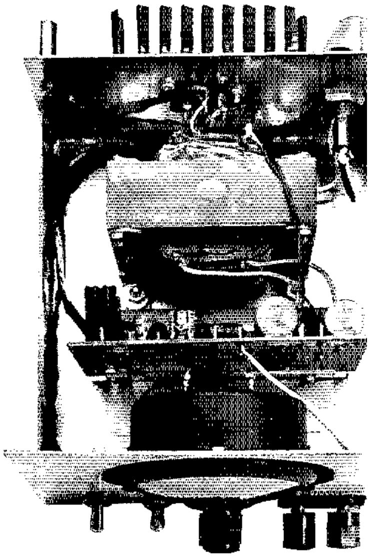
T1 is chosen for the voltage and current you require. You can use a 24-V transformer if you can work with a voltage range of 1.25 to 24. Select a transformer that can deliver 0.5 A or greater current than the maximum direct current you need. Likewise, use rectifier diodes that are rated for substantially more direct current than the supply will deliver. The PIV rating should be at least twice the secondary voltage of T1. U1 is a rectifier module that contains four 6-A, 200-PIV diodes in a full-wave bridge hookup. U1 is mounted on a small heat sink. I used a Thermalloy 6118B that is sold by BCD Electro.[2] The heat sink helps to keep the diodes from overheating when heavy current is flowing.

DS1 is a red LED that serves as the POWER ON indicator. You can replace the LED with a 28-V pilot lamp. If so, eliminate R10. By placing the LED or lamp in this part of the circuit, you will always know if the fuse, T1 and U1 are functional.

R1, R2 and R7 can be wound from no. 28 enamel wire on insulated forms, such as the body of a 10-kΩ, 1-W carbon resistor. You will need an accurate way to measure the wire resistance if you do this. These resistors are available from Mouser Electronics.[3]

U2 is a 1.25 to 30-V, 1.5-A three-terminal positive regulator. This device is also mounted on a small heat sink. I used a Thermalloy no. 6098 that I obtained from All Electronics Corp.[4] You can build your own heat sinks from 16-gauge aluminum or brass. Form U-shaped channels that are approximately 1-1/2 inches square by 5/8 inch high.

Q1 is a PNP (TO-204 case) power transistor. I recommend a Radio Shack® MJ2955 or RCA SK3335 transistor. These have a 150-W rating. The emitter and base pins are bypassed to ground at the pins by means of C7 and C8 in Fig 1. This is a preventive measure against instability, owing to the long leads between Q1 and the PC board. You can parallel two or more pass transistors to increase the output current of the supply. Each pass transistor provides an output-current increase of approximately four times that of U2. The single device at Q1 in Fig 1 ensures an out-



Internal view of the assembled power supply. The chassis and panels are made from single-sided PC board. The circuit board is mounted vertically to conserve space.

[1]Notes appear on page 25.

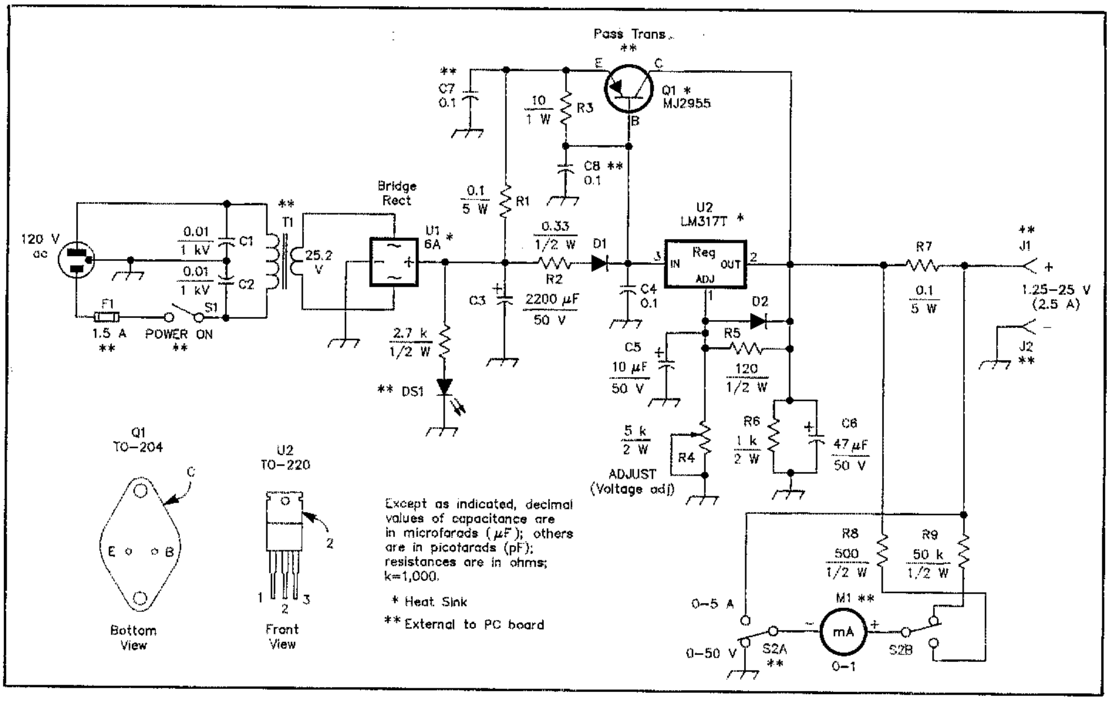


Fig 1—Schematic diagram of the 1.25- to 25-V regulated power supply. Capacitors are disc ceramic except for those with polarity marked, which are electrolytic. See text for data concerning heat sinks for Q1, U2 and U3.

D1, D2—1-A, 100-PIV rectifier diode.
DS1—Red LED.
F1—1.5-A, 3AG fuse in chassis-mount holder.
J1, J2—Standard five-way binding post, one red, one black.
M1—Milliammeter, 0-1 mA dc (see Notes 5 and 9).
Q1—NPN power transistor MJ2955 (Radio Shack) or equiv device with a +70-V, 10-A, 150-W rating in a TO-204 case.
R1, R2, R7—5-W wire-wound resistor. See Notes 3 and 4 for source. Or, use 17 inches of no. 28 enam wire, single-layer wound, on a 10-kΩ, 1-W carbon-composition resistor for R1 and R7. For R2, use 36 inches of no. 30 enam wire on a 10-kΩ, 1-W carbon-composition resistor (scramble wound).
R4—Panel-mount, 5-kΩ, 2-W or 5-W potentiometer, carbon or wire wound (see Note 8).
R8, R9—See text.
S1—SPST toggle switch.
S2—DPDT toggle or rotary wafer switch.
T1—25.2-V, 2.75-A power transformer (see text).
U1—6-A, 200 PIV bridge rectifier with heat sink. See text.
U2—LM317T +1.25- to 30-V, 1.5-A TO-220 regulator. Use an LM317HVK (TO-204 case) for dc output voltage greater than 40. See text.

put current of 5 to 6 A if the transistor has a large enough heat sink to remain at a safe operating temperature. If you use additional pass transistors, you will need to replace T1 with a heftier transformer.

Output voltage and current monitoring is done with a 0-1 mA meter (M1). I used a surplus meter I had available, hence the additional scales on the meter face. A suitable 2¼- × 2-inch meter can be purchased from Dick Smith Electronics.[5] The voltage drop across R7 indicates the current being taken by the load. R8 allows M1 to read 0.5 V full scale, which corresponds to 5 A of current through R7. R9 permits the meter to read 50 V full scale. Try to use 1% resistors for R7, R8 and R9 for best meter accuracy. I used two 1-kΩ, ¼-W resistors (5% tolerance) in parallel for R8 and two 100-kΩ, ¼-W resistors in parallel at R9. R7 in my unit is a 3% resistor. The accuracy of the readings is satisfactory for my work.

You can lift J2 above chassis ground if you want to extract negative voltages from the power supply. A third binding post can be added (common to the chassis) for connection to J1 or J2, depending on the desired polarity. If this is done it will be necessary to bring all of the negative circuit leads to a bus that connects to J2, except for C1, C2, C7 and C8.

Construction Notes

The photograph shows the interior of my power supply. I used an old cabinet that a welder friend had made for me some 25 years ago. The chassis and panels are made from single-sided PC-board material (metal side in). The mating surfaces are soldered together. I used gray automotive primer as the undercoating for the cabinet, then sprayed it with clear lacquer. The panel has gray primer for the undercoating and white spray enamel as the finish coat. Clear lacquer was sprayed over the white panel after the decals were added. The cabinet dimensions are (HWD) 6 × 6 × 8 inches.

You can see in the photograph that the PC board is mounted vertically to save space. It is held in place by an L-shaped aluminum bracket. Q1 and its heat sink are attached to the rear outer wall of the chassis assembly. My heat sink is a surplus extruded type, measuring 3½ × 3¾ × 1 inch. I do not recommend a Q1 heat sink that is smaller than 13 square inches by 1 inch thick. Larger heat sinks will provide added Q1 protection. A hefty heat sink is available from Dick Smith Electronics (no. DS-H3471).[6] The photograph shows a thick heat sink with fingers. It was replaced by a heavier, extruded unit of the type just mentioned, owing to excessive Q1 heat during high-current periods. John Meshna Jr, Inc lists a dual TO-3 (TO-204) heat sink (no. SP-58A-28) that is suitable for one or two pass transistors.[7]

You may find that R4 and R6 are difficult to locate. Wire-wound or high-wattage carbon potentiometers are scarce items on the surplus market. I was able to find a 2-W

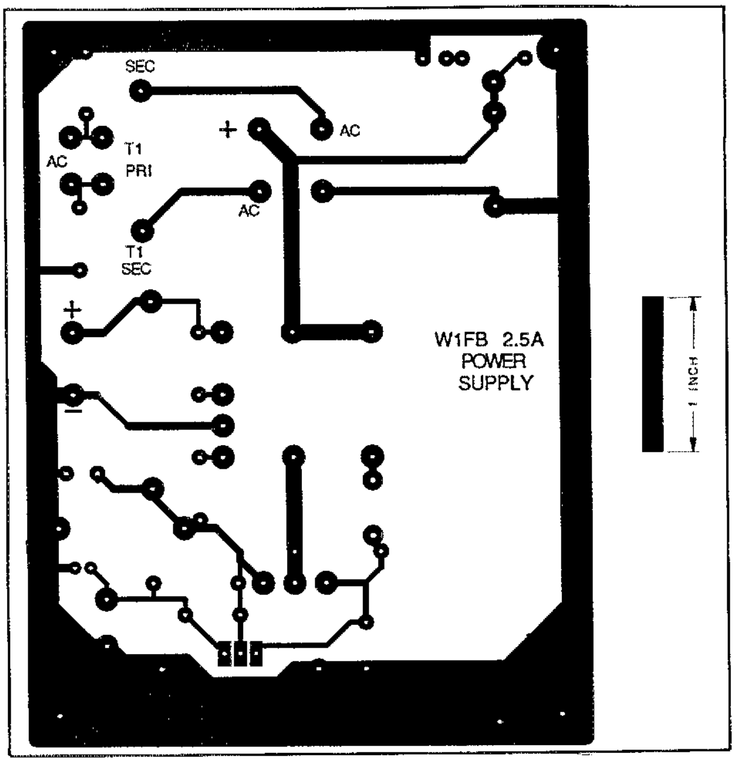


Fig 2—Circuit-board etching pattern for the power supply. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper.

(5-kΩ) control in the Jameco catalog (no. CMU-5021).[8] It is a chore to locate 2-W carbon resistors. If you can't find the proper unit for R6 of Fig 1, you can parallel two 2.2-kΩ, 1-W resistors.

As mentioned earlier, most of the parts for this project can be purchased by mail. The LM317T, for example, is available from the suppliers listed in Notes 2, 4 and 5. U1 can be purchased from BCD Electro (see Note 2) or from Mouser Electronics (no. 33BR062—see Note 3). C3 can also be obtained from Mouser (no. 20NR905). I purchased T1 from Electronic Surplus, Inc (no. 767B11).[9] If you desire an output voltage greater than 25, you can buy a 32-V, 3.5-A transformer from Fair Radio Sales (no. X5157308).[10] The increased dc voltage (46 V maximum) will require that you replace U2 of Fig 1 with an LM317HVK, which is supplied in a TO-204 case. The use of this IC requires a modification of the PC board in Fig 2.

You can buy a modestly priced 0-1 mA dc meter from Fair Radio Sales, which offers a 3½-inch round unit that has a 0-50 scale (ideal for this project). The cost is $5 at this writing.

Be sure to use a thin layer of heat-sink compound or silicone grease between Q1, U1 and U2 and their respective heat sinks. Affix the three devices firmly (but not excessively tight) to the heat sinks. Too much tension causes stress that can damage the semiconductors.

Use 16- or 18-gauge insulated hookup wire between the T1 secondary and the PC board, and likewise between J1 and the PC board. This will minimize unwanted voltage drops through these wires. Also, use insulating hardware to isolate Q1 and U2 from their heat sinks, unless the sinks are "floated" above chassis ground. Radio Shack has insulating kits (no. 276-1371 for Q1 and 276-1373 for U2).

A scale PC-board etching pattern is shown in Fig 2. A parts-placement guide is provided in Fig 3 (see Note 1).

Summary

Many hams have told me they don't build equipment because "It's impossible to find the parts." Perhaps the references

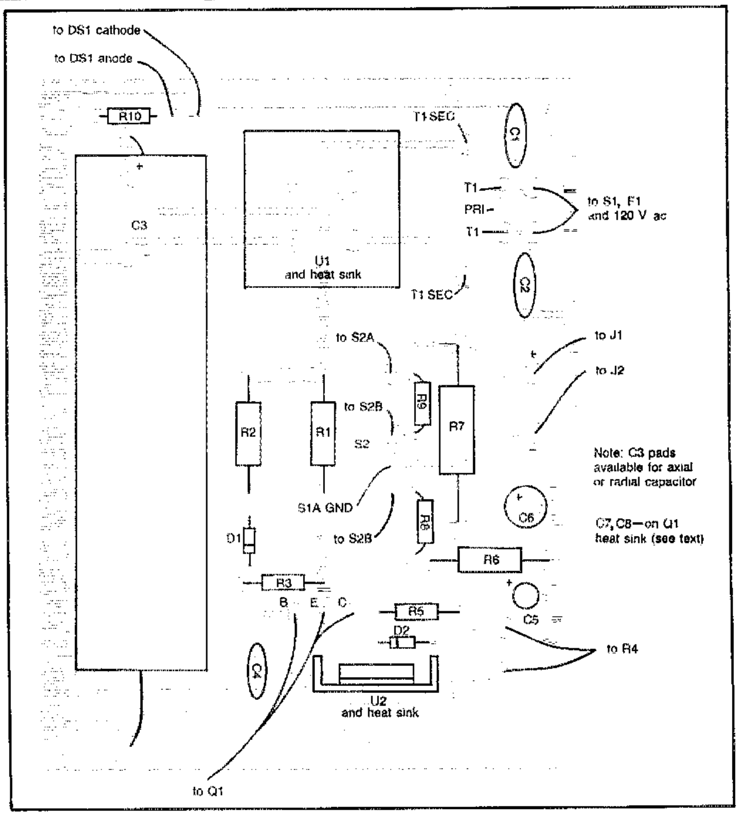


Fig 3—Parts-placement guide for the circuit board, not to scale. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. Component outlines are not necessarily representative of the shapes of the actual parts used.

in this article will make your job easier—and they should also be useful when searching for parts to use in other projects.

The maximum recommended load current versus output voltage for the circuit in Fig 1 is 500 mA (1.5 V), 750 mA (6 V), 1 A (9 V), 1.5 A (12 V), 1.75 A (18 V), 2 A (20 V) and 2.5 A (25 V). These figures are for steady-state load current. For intermittent loads, such as for CW and SSB transmitters, the current maximums can be increased 25 to 30 percent, assuming a typical duty cycle during transmit.

This power supply is certainly suitable for uses other than a test-bench unit. It can be used to operate a low-power VHF transceiver or homemade QRP gear, or as a battery charger. Good luck and have fun!

Notes

[1]FAR Circuits, 18N640 Field Ct, Dundee, IL 60118, tel 312-426-2431, evenings. Price: $8.50 (includes shipping to US addresses).

[2]PO Box 830119, Richardson, TX 75083-0119, tel 214-343-1770 (catalog available).

[3]Mouser Electronics, PO Box 699, Mansfield, TX 76063, tel 800-346-6873 (catalog available).

[4]All Electronics Corp, PO Box 567, Van Nuys, CA 91408, tel 800-826-5432 (catalog available).

[5]Dick Smith Electronics, PO Box 468, Greenwood, IN 46142, tel 317-888-7265 (catalog available).

[6]See Note 5.

[7]19 Allerton St, Lynn, MA 01904, tel 617-595-2275 (catalog available).

[8]Jameco® Electronics, 1355 Shoreway Rd, Belmont, CA 94002, tel 415-592-8121 (catalog available).

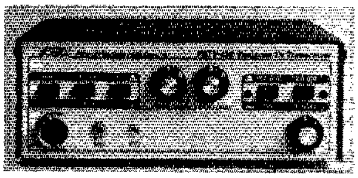
[9]Electronic Surplus, Inc (formerly R&D Electronics), 1224 Prospect Ave, Cleveland, OH 44115, tel 216-621-1052.

[10]Fair Radio Sales Co, PO Box 1105, 1016 Eureka St, Lima, OH 45802, tel 419-227-6573 (catalog available).

New Products

430-MHz FAST-SCAN-TELEVISION TRANSCEIVER

☐ Advanced Electronic Applications has introduced the FSTV-430, a fast-scan TV transceiver that provides all the necessary FSTV functions, except those provided by a video camera or video-cassette player.



The FSTV-430's transmitter-output power is 1 watt. AEA has also introduced a 16-element 430-MHz Yagi antenna, model 430-16, for use with the FSTV-430.

Price class: FSTV-430, $440; 430-16 Yagi, $120. Manufacturer: AEA, Inc, PO Box C-2160, Lynwood, WA 98036, tel 206-775-7373.—*Rus Healy, NJ2L*

CATS ROTATOR-PRESET CONTROLLER

☐ Craig's Antenna and Tower Service (CATS) has introduced a rotator-preset controller designed for installation in any Hy-Gain rotator manufactured since 1974. The Positioner-1 provides a single preset rotator heading and incorporates CATS' Brak-D-Lay 7-second delayed-brake-actuation controller, which is also available separately. Price: Positioner-1, $75. For more information, contact Craig Henderson, N8DJB, CATS, 7368 SR 105, Pemberville, OH 43450, tel 419-352-4465.—*Rus Healy, NJ2L*

PREAMPLIFIER-DESIGN SOFTWARE

☐ SoftWare Innovations For Technology Enterprises® (SWIFT) has introduced *Amplifier Simulation Program* (ASP) 1.00, a preamplifier-design and -modeling package for IBM® PC and compatible computers. ASP calculates amplifier noise figure and gain, and includes documentation covering the noise-figure equations used by the program, matching techniques and other design hints.

Computer-system requirements include an IBM PC, XT, AT or compatible computer with at least 360 kbytes of RAM and monochrome or CGA-compatible video. A printer and a math coprocessor are optional. Price: $54.95 plus $2.50 shipping and handling (to US addresses). For more information, contact Charles Reichert, KD9JQ, 955 Concord Ln, Hoffman Estates, IL 60195.—*Rus Healy, NJ2L*

Strays

"HOW TO TEACH" VIDEOS

☐ ARRL HQ is looking for videotapes on "how to teach." We'd like to train new instructors or help the experienced ones brush up on new teaching methods. If you know of any public-domain or try-before-you-buy tapes that cover teaching techniques and how to make interesting presentations, please contact the ARRL Educational Activities Branch.

LIFE MEMBERSHIP INFORMATION

☐ The Life Membership is the League is currently $625 in the US and $900 elsewhere. There is a quarterly payment plan, where a Member makes an initial payment of $79 and seven more payments of $78 over a two-year period. Outside the US, the payments are $112.50. Immediate family members of a paid-in-full Life Member can sign up for family Life Membership with a one-time payment of $50. The $50 payment also applies to unsighted individuals. The fee for persons age 65 is $500 in the US. Please contact the Circulation Department for a formal Life Membership application. Write to Rose Cavanaugh, ARRL, 225 Main St, Newington, CT 06111.

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- Charles W. Denk, W8LUH, Harbert, Michigan
- George J Apfel, W2GHV, Park Ridge, New Jersey
- C. E. Cottrell, W4GPL, Madeira Beach, Florida
- Robert E. Blair, K5AY, Richardson, Texas
- Lenore K. Jensen, W6NAZ, Sherman Oaks, California

The Care and Feeding of an Amateur's Favorite Antenna Support–the Tree

If your tree-supported antenna fell down, you'd care. Did you ever think about caring for the tree that holds up your antenna?

By Doug Brede, W3AS
116 Ridgewood Dr
Post Falls, ID 83854

For most hams, trees are favorite antenna supports. Many radio amateurs begin their operating careers by hanging the far end of a wire up in the family's shade tree. On Field Day, resourceful hams find a hundred and one ways to get an aerial into the air; many (if not most) of these methods involve using trees as supports or aids.

During my 20 years as a radio amateur, I've used tree-supported wire antennas almost exclusively. Some of those antennas lasted several years; most didn't. Over the years, by trial and error—and because of my trade association with arborists and horticulturists—I've gained an understanding of what can (and can't) be expected of trees as antenna supports.

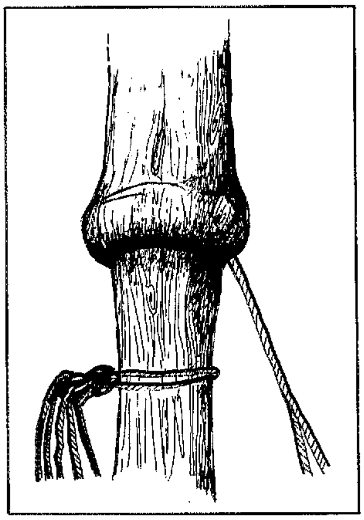


Fig 1—Attaching ropes or wires to trees can sometimes lead to major problems for the tree. Wrapping a rope around a limb or trunk and leaving it unattended will suffocate the tree and cause a distortion of growth or the death of the limb.

There are right and wrong ways to attach and maintain your tree-mounted skyhooks over the long haul. In this article, I'll share with you some pointers from two noted horticulturists who talk about attaching wires to trees. Safety is also discussed—your safety during antenna installation, and the safety of the tree.

Trees Are Alive

Few antenna supports can be classified as life forms. Trees are an exception. Tree experts usually cringe when someone brings up the idea of attaching a wire to a tree—especially when connecting a chunk of wire to its midriff (see Figs 1 and 2). The experts know that trees are made up of three basic layers: the bark, the living sapwood, and the nonliving heartwood. The bark protects the sapwood from injury. The sapwood contains the "skin and blood vessels" of the tree. If the sterile barrier between the bark and the sapwood is broken, infection can set in. Infection, if unchecked, can kill even a mighty oak within a year.

Trees have the same basic problems with infection as we humans do. If a tree gets a cut or gash, infection from bacteria and fungi is bound to set in. But there's one important difference between trees and humans: "Tree wounds don't heal," says noted tree expert Dr Alex L. Shigo. "People heal; when you are wounded, you have forces that fight off the infection. Trees don't have these forces to fight off infection, and *every wound* will become infected."

Shigo, author of the book, *Tree Biology and Tree Care*[1] notes that trees lack an immune system that fights off infection from wounds that occur from the actions of a careless climber or the attachment of an antenna-support eyebolt. Trees treat their wounds by walling off the infected area and isolating it from the living part of the tree. "If you cut open a tree that's 2000 years old, you'll see every injury in that tree that occurred over its lifetime," says Shigo.

Whenever you wound a tree, you weaken the tree in that spot. The walled-off wood around the wound lacks the strength of healthy wood. When attaching an antenna to a tree, it's important to traumatize the tree as little as possible. This will ensure a strong, enduring connection.

Most people believe that tree paint or shellac is the best way to treat a tree wound. "Not so," says Shigo. "Wound dressing paints just protect the microorganisms." Scientific research with tree-wound preparations have failed to show *any* benefit to the tree.

Making the Attachment

Although it's relatively easy to get a wire up into a tree, it's certainly more difficult to keep it there for the long term. Usually,

Fig 2—Over the years, this tree has grown around the cable of a roadside barrier. Dave Newkirk, AK7M, spotted this tree in Glastonbury, Connecticut. *(photo KC1MP)*

[1] A. Shigo, *Tree Biology and Tree Care*, (Shigo and Trees, Assoc, 2nd ed. 1989) 4 Denbow Rd, Durham, NH 03824; $52 plus shipping and handling. A companion to this book, an expanded glossary of 239 tree terms, is priced at $13. The shipping and handling charge for any single book is $3. For any combination of books ordered, the shipping and handling charge is $3 for the first book and $1 for each additional book.

Some Questions and Answers about Tree Antennas

Q: *A CBer in my neighborhood cut the top out of his pine tree and stuck a ground plane antenna up in it. Is this an acceptable way to mount an antenna?*

A: Definitely not. Not only is this a hazardous way to mount an antenna, it essentially ends the useful life of the tree. Topping of trees is strongly discouraged by professional arborists. Because topping removes the growing point of the tree, the tree recovers from the damage by sprouting numerous lateral buds around the top, which soon overrun the antenna.

Q: *I've heard that if you fertilize a tree, your antenna will grow higher each year. True?*

A: False. Although fertilizing is a desirable way to keep your tree healthy, it does not raise the height of your attached antenna one inch. Trees grow by extension of the apex. A wire attached to the trunk at 30 feet will still be at 30 feet 10 years later. By the way, when you fertilize your tree, use regular garden fertilizer distributed around the drip line of the tree. The fancy tree spikes you see advertised are unnecessary because most tree feeder roots are near the surface.

Q: *Is there any way to slow down the growth of a tree, so that it doesn't interfere with my antenna?*

A: Some home-and-garden stores now stock growth regulators for trees. These products can be injected into the tree, dropped on the soil surrounding the tree, or sprayed on the leaves (follow label directions). Tree professionals can also perform this service. These growth regulators are used by some utility companies to reduce the need for tree trimming near power lines.

Q: *Are certain types of trees better wire-antenna supports than others? What about hardwoods versus softwoods?*

A: There's little difference between hard- and softwoods in their ability to hold up antennas. Conifers, because of their shape, are nearly ideal antenna supports. Avoid the use of red oaks and silver maples if possible, because they tend to rot easily if wounded. Avoid using poplars, too. In spite of their height and rapid growth, their branches are brittle and break easily.

Q: *If I damage a tree during antenna installation, what should I do? Is tree replacement expensive?*

A: If the damage is minor, your best bet is to do nothing. If it's a broken limb, saw the limb off cleanly, perpendicular to the axis of the branch. Never saw off a branch flush with the surface of the trunk, as this allows decay to set into the trunk. Using tree paint for injury repair is unnecessary (see text). In case of major tree damage, consult a trained arborist.

The answer to the second question is: Yes, tree replacement is expensive. The International Society of Arboriculture publishes a formula for calculating replacement cost of shade trees of various sizes. This pamphlet can be obtained from many tree services and libraries. Here's one point to ponder: A large, stately shade tree can add several thousand dollars in value to the property on which it sits.

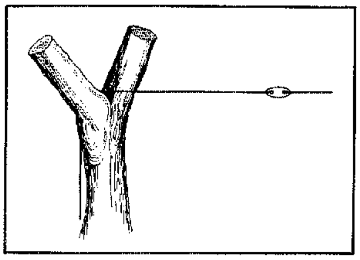


Fig 3—Most hams install tree-mounted antennas by throwing a line over a branch crotch. This should be used only as a temporary installation, because abrasion of the rope and tree results. Over time, girdling may occur leading to the loss of one or more of the branches.

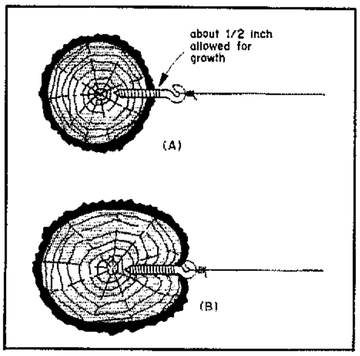


Fig 4—The best way to secure a wire to a tree is with an eyescrew mounted into the wood (A). As the tree grows and expands, however, the eyescrew will become embedded (B) and must be removed and replaced.

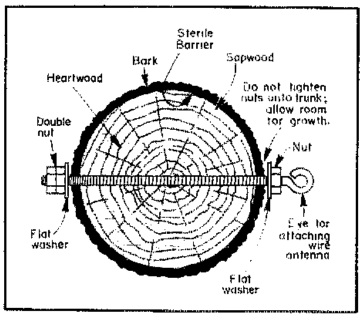


Fig 5—For heavy antenna loads, an eyebolt passed through the trunk or limb will support more weight than an eyescrew. Allow about ½ inch of play between the bolt and trunk or limb. Don't tighten the bolt completely; this allows for tree growth.

annual (sometimes weekly) restringing is needed. It seems that trees "instinctively know" just when to drop a wire to the ground: during midwinter when the snow is high and the skip is long, or in the middle of a heated contest!

The bow-and-arrow method has become a standard of the wire-in-the-tree crew. But many other methods, slingshots, for example—even attaching a string to a golf ball and whacking it with a sand wedge—are common.

One of the easiest and most common ways to connect a wire to a tree is to throw a rope over a branch crotch (see Fig 3) and tie off the loose end. This is the main method used in temporary (such as Field Day) installations. "Doing this probably won't hurt the tree if it's done as a temporary thing," says Washington State University horticulturist Ray Maleike. But with any of these simple antenna-stringing methods, some problems for the tree (and the antenna) may develop later.

"First of all, you're not stabilizing the antenna very well with this type of setup. The other thing is that people have a tendency to forget the antenna's there. As the tree grows—as it increases in diameter—you can girdle the tree. If you've got this girdling rope or wire up there, you can actually kill that portion of the tree above the wire."

Another no-no when attaching an antenna to a tree is wrapping a wire around the trunk. This strangles the veins in the sapwood the same way a noose around your neck would strangle you. "It's important not to wrap anything around the trunk," says Maleike.

Many commercial nurserymen wrap stabilizing ropes around newly transplanted saplings to keep them from falling over. Recently, however, this practice has been questioned because of the restrictions these ropes place on the growth of the tree. People forget about these ropes; some remain on

Practical Tree Biology Tips

Excerpted from *A New Tree Biology*,† by Alex Shigo, PhD

- Tree wood is not dead. There are more living cells than dead cells in sapwood.
- Tree wounds will become infected. Trees cannot restore, regenerate, or repair injured wood.
- Branches are attached to trunks by a series of collars; branch collars over trunk collars.
- Branch removal that injures or removes the collar will destroy a tree's defense system.
- Trees have five major growth periods during each growing season: (1) onset of growth, (2) leaf formation, (3) wood and inner bark formation, (4) storage, and (5) dormancy.
- Fertilize injured or stressed trees during growth periods (3) and (4).
- Trees get food (sugar) by trapping the energy of the sun.
- Trees get water and elements essential for growth from the soil.
- Substances for tree defense come mostly from stored energy reserves.
- Healthy trees have living cells with high amounts of energy reserves.
- When defense is low, opportunistic diseases attack.
- Because it grows big and fast does not always mean that a tree is healthy.
- If possible, cut tree limbs only when they're dormant or after leaf formation.
- There is no data to show that wound dressings stop rot.
- Tree topping is a crime against nature!
- Read and learn about trees.

†A. Shigo, *A New Tree Biology* (Shigo and Trees, Assoc, 1989), 4 Denbow Rd, Durham, NH 03824; $21 plus $3 shipping and handling (see note 1).

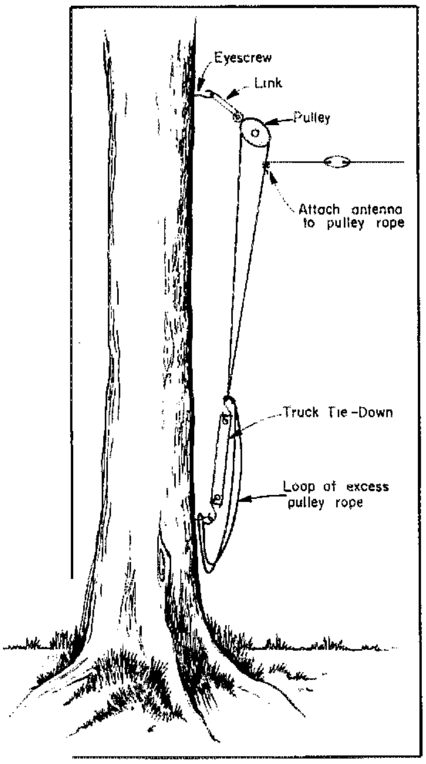


Fig 6—By using a pulley, raising and lowering the antenna for repairs can be done without the need to climb the tree. Flexible truck tie-downs can be used to apply tension to the antenna. (Early editions of *The ARRL Antenna Book* show a weight used to provide the required tension. A weight swinging from a tree can be hazardous.) Loop the excess pulley rope to a second eyescrew, in case the tie-down fails.

trees for years after transplanting.

Encasing the stabilizing (or antenna) wire in rubber or plastic hose is not the answer either. "Wire wrapped in hose is just as injurious to the tree as the bare wire itself," says Shigo. "If you remember your basic physics, you're applying the same number of pounds of force to the tree with or without the hose." Shigo recommends that if you must wrap something around the trunk of a tree, use a wide fabric strap to do the job.

Two methods have emerged among leading horticulturists as the preferred way to attach a wire to a tree. For light antenna loads (eg, the end of a dipole), a threaded eyescrew (Fig 4) is the method of choice. Simply drill a hole into the tree about 1/16 inch smaller than the screw diameter, then twist in the eyescrew. Be sure to select a cadmium-plated eyescrew threaded for use in wood. A thread length of 2 or 3 inches should secure most antennas. Allow about ½ inch of space between the trunk and the eye; this allows for outward growth of the tree with time.

For stouter antennas, such as multielement wire beams, another method for securing wires to trees is recommended. This procedure involves using an eyebolt longer than the tree diameter, drilling clear through the tree and securing the eyebolt on either side of the tree with round washers and nuts (see Fig 5).

Fig 7—A professional arborist uses a safety belt and rope when climbing trees. Hams should take similar safety precautions. *(A. Douglas Brede, W3AS photo)*

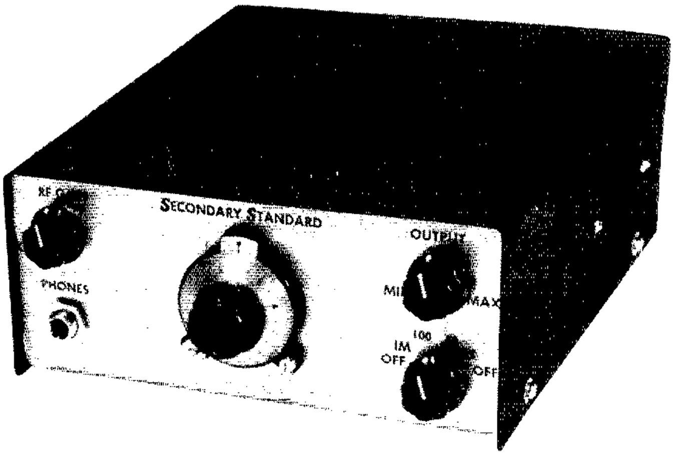
Drilling a hole through a tree causes much less trauma to the tree than wrapping something around it. Much of the core of a tree is dead tissue, used mainly for physical support. Although there will be some wounding of the tree at the site of the bolt or screw, such wounding will be far less than that which occurs from wrapping a wire around the trunk.

Over time, either type of eyescrew connection will have to be replaced. "If these fasteners are left on the tree for a long time, the fastener will eventually become embedded in the tree," says Maleike. "You're going to have to pull these fasteners out and replace them every now and then." Maleike recommends replacement of tree eyescrews every 5 to 8 years as the tree matures. Commercial arborists use *drive fasteners* for securing wires to trees; drive fasteners are similar to eyescrews. "These fasteners keep the wire away from the tree, allowing the tree to grow out to it," says Maleike. Drive fasteners are used for securing lightning rods and their accompanying wires to trees. The use of drive fasteners is common in the Midwest, where lightning strikes to trees are common. You may have to shop around to find drive fasteners—try calling tree-care services in your area.

It's easier to periodically service a tree-supported antenna if a pulley is used (see Fig 6). Raising and lowering the antenna for repairs can be done without the need to climb

(continued on page 40)

A Simple Secondary Frequency Standard



This simple weekend project nets you an accurate frequency standard and a dedicated WWV receiver.

By James G. Lee, W6VAT
Box 357
Cupertino, CA 95015

One FCC requirement that has not changed in this era of deregulation is your need to observe the frequency limits of each amateur band and the limits of the subbands for your license class. Today's transceivers have built-in calibrators, but these calibrators have limitations: Some are awkward to use, and all need to be checked periodically against an accurate frequency standard, such as WWV.

The US National Institute of Standards and Technology (formerly National Bureau of Standards) stations WWV and WWVH transmit accurate frequency and time signals on 2.5, 5, 10, 15 and 20 MHz. Using an atomic standard as the primary reference, these signals have an accuracy of 1 part in 10^{11} —1 Hz in 100 GHz. We hams don't need this level of accuracy, but we can approach 1 part in 10^7 (1 Hz in 10 MHz) without undue strain on technology or budget. The secondary frequency standard[1] described here provides such accuracy inexpensively and gives you a receiver for WWV time checks and propagation information as well.

The Circuit

My standard uses the Neophyte receiver described by John Dillon, WA3RNC, in February 1988 *QST*,[2] along with some common ICs for marker generation. Fig 1 shows a block diagram of the standard. I recommend that you refer to Dillon's article; it contains a lot of detail about the receiver that won't be repeated here.

The Neophyte, a direct-conversion (D-C) receiver, was originally designed for 80- and 40-meter operation. I've converted it to a 10-MHz WWV receiver by adding a 10-MHz CMOS local oscillator (LO) and retuning its front end. The 10-MHz oscillator is also divided by the TTL string to give 1-MHz, 100-kHz, 50-kHz and 25-kHz markers.

D-C receivers have been popular over the years, and rightly so. Sometimes referred to as "zero-IF" receivers, they use an LO signal at (or, for CW, very close to) the received-signal frequency. Although normally used for CW and SSB reception, D-C receivers can copy AM signals when they are tuned to exact zero beat with the signal carrier.

The standard uses analog and digital circuits, and the two must be interconnected. The 10-MHz LO circuit is the best place to do this. Initially, I tried crystal-controlling the Neophyte LO, but the LO output was insufficient to drive the marker-generator TTL string. I tried several simple LO amplifiers with mixed success. Realizing that the interface circuitry was more complicated than it needed to be, I decided to drive the Neophyte with an external LO.

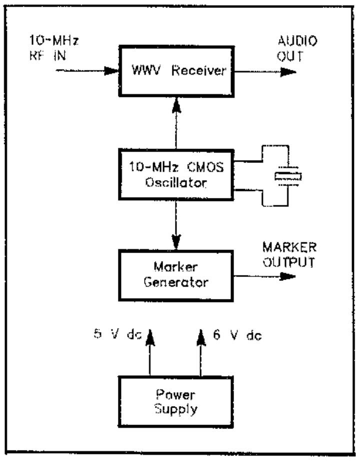


Fig 1—Block diagram of the Simple Secondary Frequency Standard.

The external LO used in this application must meet several requirements. It must be lightly loaded for good stability, consume little power, be capable of providing 200 to 300 mV of drive to the Neophyte, and yet still be able to drive a TTL load. A single CMOS chip—the CD4049A—provides all these requirements with a minimum of parts. The CD4049A, a hex inverter/buffer, makes an excellent oscillator, can drive two standard TTL loads, consumes little power and is inexpensive.

Fig 2 is a schematic of the Neophyte, its new LO and the marker generator. Although standard (74 series) TTL chips (U4, U5 and U6) are used for the marker generator in the unit shown, the 74LS series can be used if desired. U4 and U5 provide two cascaded divide-by-10 ratios to divide the 10-MHz signal to 1 MHz and 100 kHz. U6, a 7474 dual-D flip-flop, divides the 100-kHz signal to 50 and 25 kHz.

The power supply is straightforward, but you might look askance at the use of a bridge rectifier when a simple half-wave rectifier might do. The bridge used is not costly, and it helps reduce power-supply hum, a potential bugaboo in D-C receivers.

Voltage is regulated by U8, a 78M06 3-terminal, 6-V regulator. If you can't find a 78M06 (TO-5 version), you can use a standard 7806 or a TO-220-cased 78M06, or even an adjustable regulator set to 6 V. Check your wiring; pinouts vary among the different devices. Use a heat sink on U8: It gets quite warm when standard TTL chips are used for U4-U6. D2, a 6.8-V Zener diode, is optional. U3 can safely

[1]Notes appear on p 33.

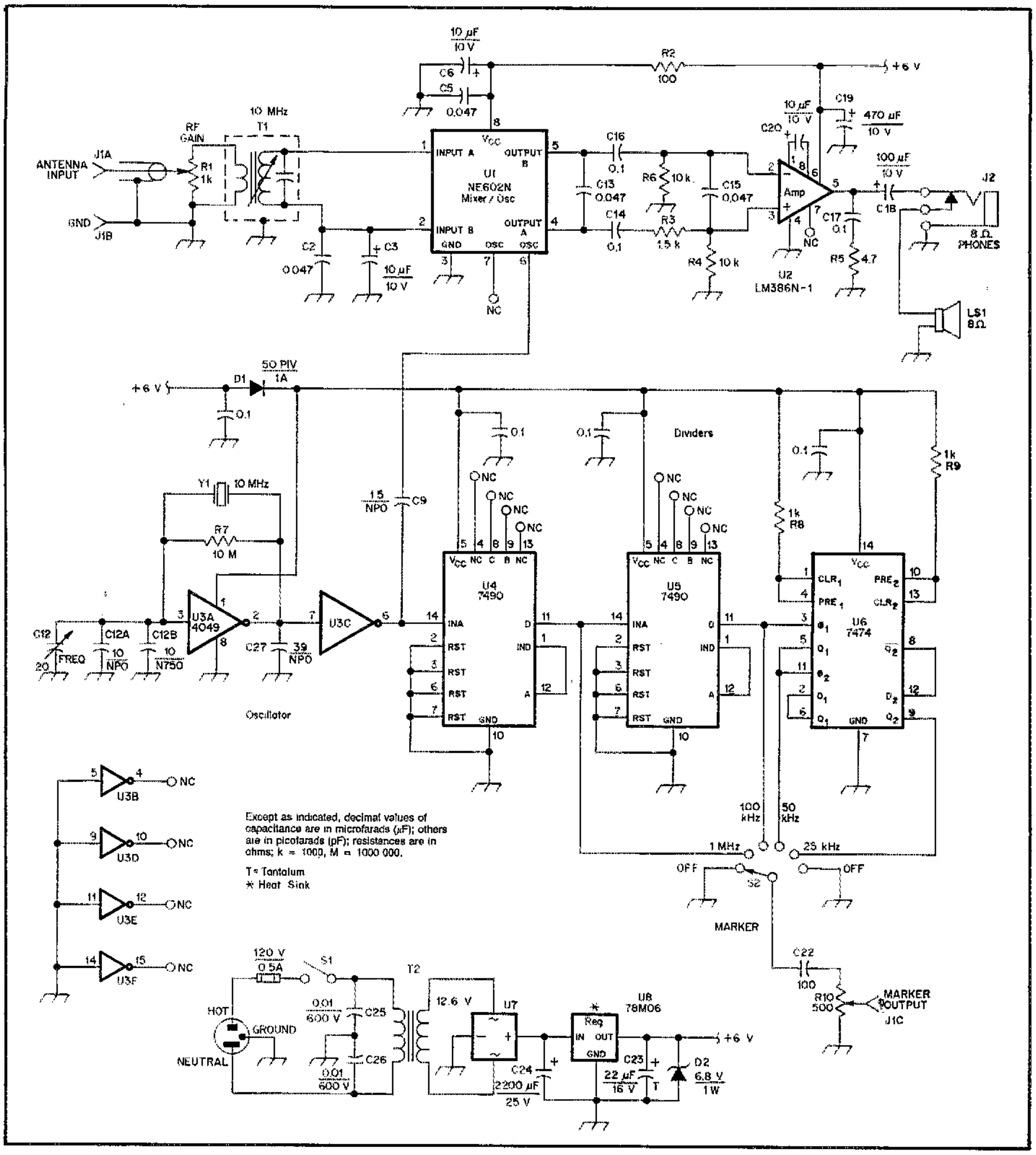


Fig 2—Schematic of the Simple Secondary Frequency Standard. Unless otherwise noted, capacitors are 50-V monolithic or disc-ceramic units. Polarized capacitors are electrolytic. Fixed resistors are ¼-W carbon-film units unless noted.

C2, C5, C13, C15—0.047-µF polyester or ceramic (0.01 µF also suitable for C2 and C5).
C12—20-pF variable capacitor (RADIOKIT 193-0006-001) in parallel with two ceramic capacitors (C12A and C12B). See text.
C14, C16, C17—0.1-µF polyester film or ceramic.
J1—Three-position terminal strip (Radio Shack® 274-620).
J2—Phone jack, ¼-inch, closed-circuit (RS 274-255).
LS1—8-Ω speaker, 2¼-inch diameter (Mouser 25SP024 or equiv).
R1—1-kΩ audio-taper potentiometer with switch.
S1—SPST switch (part of R1).
S2—Single-pole, 6-position rotary switch, nonshorting (one section of RS 275-1386).
T1—10.7-MHz IF transformer, 7:1 turns ratio, green core (Mouser 421F123).
T2—12.6-V, 300-mA power transformer (RS 273-1385 or equivalent).
U1—Signetics SA/NE602N mixer/oscillator IC.
U2—National Semiconductor LM386N-1 audio amplifier.
U3—CD4049A hex inverter/buffer.
U4, U5—7490 or 74LS90 decade counter.
U6—7474 or 74LS74 dual-D flip-flop.
U7—1-A, 50-PIV bridge rectifier.
U8—78M06 6-V, 0.5-A regulator (see text).
Y1—10.0-MHz crystal, 0.001% or better tolerance, HC-18/U holder.

Miscellaneous Parts

Cabinet: Aluminum with steel cover, 2¾ × 6¼ × 7¼ inches (HWD) (Mouser 40UB104, Jameco® B2744 or equiv).
Miniature test points (optional—see text; Mouser ME151-200 series).
Reduction-drive dial, 1½-inch diam (Mouser 45KN100 or equiv).

withstand full power-supply voltage, but U2 and U4-U6 have maximum voltage ratings of 9- and 7-V dc, respectively. D2 is cheap insurance in case of a blown regulator.

Building the Standard

The Neophyte PC board is used as is.[3] I've deleted parts, changed some parts values and made wiring changes. The new parts-placement guide is shown in Fig 3. C1, C4A, C4B, C7, C8, C10, C11 and T2 are deleted. C9 is changed to 1.5 pF and installed where C10 was. W1, a jumper, is installed at C9's former location. D1 is moved to the digital board. Another jumper, W2, is installed where D1 used to be. C12, the Neophyte tuning control, is replaced by a 20-pF variable capacitor in parallel with two temperature-compensating ceramic capacitors (see the sidebar, "Temperature Compensation"). C12, FREQ, is used to shift the crystal frequency to zero beat with WWV.

The Neophyte is powered by 6 V dc. U3-U6 operate at 5 V dc by virtue of the drop across D1. The speaker and headphone audio outputs are retained.

Buy a good-quality crystal for Y1. Avoid cheap microprocessor crystals, no matter how tempting their price might be. Y1 should have a frequency tolerance of 0.001% or better (±100 Hz at 10 MHz). A crystal with a tolerance of 0.0005% is not that much more expensive. The average microprocessor crystal has a tolerance of only 0.01%—1 kHz at 10 MHz—and some I checked were much worse. Crystal manufacturers such as JAN and International will sell single crystals to amateurs (see Table 1).

I recommend Molex® pins or small sockets for mounting the ICs. If you use Molex pins, first cut them to length, leave the bridging strips attached until you are ready to install the chips. Install the rest of the components on the Neophyte board beginning with T1, the resistors, ceramic capacitors and finally the electrolytics. When you are done, carefully inspect the foil side of the board to make sure that there are no shorts or solder bridges between traces.

The power-supply components, CMOS oscillator and marker generator are on a separate board. I used a Radio Shack® no. 276-170 PC prototyping board. You can use perforated board or wire-wrap techniques with equal success. A detailed layout is available from ARRL HQ for those who'd like to duplicate my technique.[4]

After all components are mounted on each board, install the ICs in their sockets. If you used Molex pins for the sockets, use a pair of needle-nose pliers to gently bend the bridging strips back and forth until they break off cleanly. Make sure the pins are in line and then carefully insert the chips, seating them firmly. U3 has protective diodes across each input, so you should not have any problem with static electricity destroying its input gates.

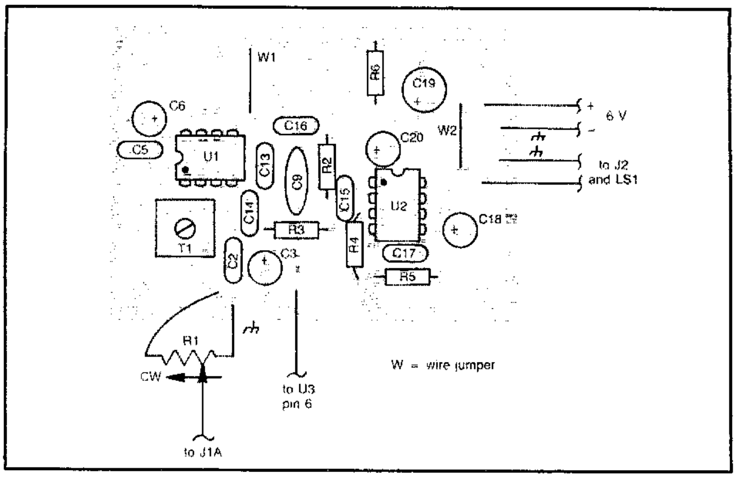


Fig 3—Parts-placement diagram for the modified Neophyte PC board. Parts are placed on the non-foil side of the board. The shaded area represents an X-ray view of the copper pattern. Note that there are no modifications to the etching pattern shown in the original Neophyte article; just components change.

Table 1

Parts Suppliers

All Electronics Corp, PO Box 567, Van Nuys, CA 91408, tel 800-826-5432.

Circuit Specialists, PO Box 3047, Scottsdale, AZ 85257, tel 800-528-1417.

DC Electronics, PO Box 3203, Scottsdale, AZ 85257, tel 800-423-0070.

International Crystal Mfg Co, PO Box 26330, Oklahoma City, OK 73126-0330, tel 405-236-3741.

Jameco® Electronics, 1355 Shoreway Rd, Belmont, CA 94002, tel 415-592-8121.

JAN Crystals, 2341 Crystal Dr, Ft Myers, FL 33906-6017, tel 800-237-3063.

Global Specialties, PO Box 1405, New Haven, CT 06505, tel 800-345-6251.

Mouser Electronics, 2401 Hwy 287 N, Mansfield TX 76063, tel 800-346-6873.

RADIOKIT, PO Box 973, Pelham, NH 03076, tel 603-437-2722.

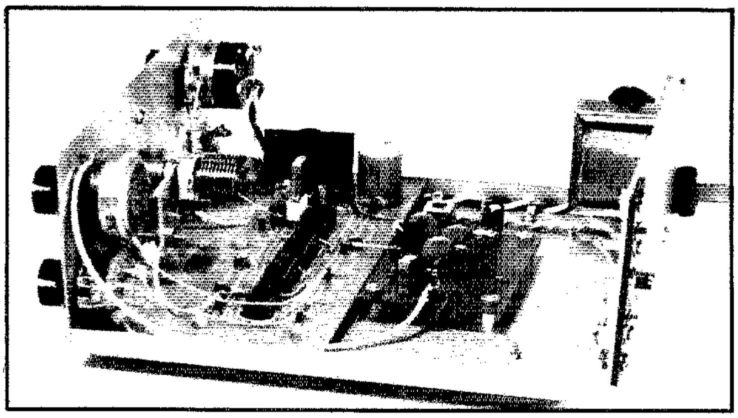


Fig 4—Interior view of the Simple Secondary Frequency Standard.

I mounted both boards to the cabinet with screws and 1/4-inch-long metal spacers. Be sure to ground each board through solder lugs mounted on the underside of the board at each spacer. Fig 4 shows how I mounted the boards so that the lead lengths between the boards, and to C12, are as short as possible. These are

A Bit About CMOS Oscillators

The secondary frequency standard uses a CMOS oscillator to drive a divider chain, and as the Neophyte receiver's local oscillator (LO). A square-wave oscillator like this may not seem like a good candidate for a receiver LO, but balanced mixers (such as the Gilbert-cell mixer used in the NE602N) work quite well with a square-wave LO. Using a square-wave LO can provide 10 to 15 dB more LO rejection than can normally be achieved with a sine-wave oscillator.

CMOS oscillators are usually built around an inverter chip. Oscillators using an even number of cascaded inverters can be tricky to get running properly, but any *odd* number of inverters will always oscillate with a suitable frequency-determining feedback network. Fig A shows a diagram of a basic oscillator circuit.

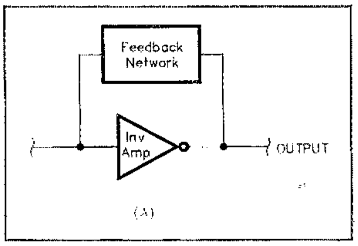


Fig A—Basic oscillator circuit.

A crystal makes an ideal feedback network. Fig B shows a typical crystal-oscillator circuit that uses an inverter. R1 and R2 control the feedback and loop attenuation. R2 ensures that the inverter has a dc path from output to input to bias it on. This resistor should be at least 1 megohm; values of 10 to 22 megohms are commonly used to keep the Q of the crystal from being degraded.

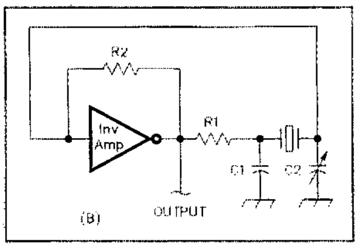


Fig B—Typical crystal oscillator circuit using an inverter.

Both C1 and C2 affect the oscillator frequency; they are usually made equal in value, with C2 variable to permit fine tuning. Just how much tuning is possible depends on the crystal characteristics and the specific oscillator circuit.

Any odd number of inverters can be used, but propagation delay through the total string affects the highest possible operating frequency. Operating frequency is not the only consideration, however.

Many crystals will oscillate readily at their third *overtone*. (An overtone is a complex crystal resonance that occurs at a frequency close, but usually not identical, to an odd-numbered harmonic of the crystal's fundamental frequency.) Usually this is undesirable; a simple solution to this problem is to cascade enough inverters—always using an odd number—so that the propagation delay around the loop is too long for the third overtone to be reinforced at the input. The delay must not be so long that fundamental operation is suppressed, however.

Fig C shows a second way of suppressing unwanted overtone operation. The RC combination in Fig C is a low-pass filter which has a cutoff frequency well below the crystal's third overtone (but *above* the desired oscillator frequency!). This prevents positive feedback at the overtone.—*W6VAT*

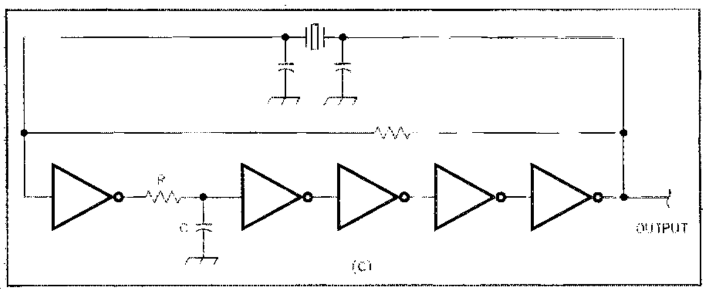


Fig C—One way of suppressing unwanted overtone operation.

the only critical RF leads.

I used 16 miniature test-point terminals for connections to the boards. (Terminals are not necessary, but they make interconnection between the boards and the front-panel controls easier.) Two short pieces of no. 22 tinned wire connect C12 to the digital board.

The power transformer is mounted on the left side of the rear panel, and the ANTENNA INPUT/MARKER OUTPUT terminal strip is on the right side. I installed this particular terminal strip to allow the use of a random-wire antenna; you can use phono or coaxial connectors if you want.

The speaker mounts over louvers on the right rear of the cabinet cover. This keeps the speaker away from the transformer to minimize hum pickup. The PHONES jack is mounted on the front panel for convenience. Shielded wire is used for the leads to T1 and for the audio-output leads from the Neophyte board to the speaker and the headphones. The marker-output lead from the output control is also shielded, but the marker leads from the digital board are short enough so that ordinary hook-up wire can be used.

C12 mounts on a 1 × 1-5/8 × 1/16-inch aluminum plate. The plate mounts on the 1-inch-long screws that hold the dial to the front panel for maximum rigidity. Note the capacitor mounting position shown in Fig 4. I mounted the capacitor this way to minimize lead length to the digital board and to make it easier to attach the temperature-compensating capacitors. The use of a vernier dial may seem unnecessary, but the convenience it provides for zero beating the receiver to WWV or WWVH is worth the cost.

With the exception of U8 (78M06, TO-5 version), all parts are available from the suppliers listed in Table 1. A TO-220 78M06 regulator is available from Mouser. Any small 20- to 25-pF variable capacitor is suitable for C12. Some items, such as the vernier dial and the cabinet, vary in price from supplier to supplier, so check around. Note that mail-order suppliers usually have minimum-order requirements. The frequency standard does not require shielding, so a plastic cabinet works as well as the metal one used on the unit shown. Flea markets, hamfests and your buddy's junkbox are also good places to buy or barter any parts you may need.

Calibration and Operation

Calibration is easy once you are receiving a good signal from WWV. Don't try to calibrate the standard on a weak or fading signal—accuracy will suffer. Calibration is best done when there are no propagation anomalies.[5]

Set the vernier dial to 50, or midrange

Temperature Compensation

You can temperature-compensate the standard to minimize the effects of temperature variation. You may not always be able to receive a usable signal from WWV, and you need confidence that the standard is not very far off frequency during such times. C12 is a 20-pF variable in parallel with a fixed-value NP0 (zero-temperature-coefficient) capacitor (C12A) and a fixed-value N750 negative-temperature-coefficient capacitor (C12B). With C12 set at midrange—10 pF—the fixed capacitors bring the total to 30 pF. To start with, make the two fixed capacitors equal in value (10 pF each). A simple—but somewhat lengthy—procedure is used to adjust the two capacitor values to reduce the frequency drift with temperature to a minimum. This procedure is similar to one described by Irwin Hoff, W6FFC, in November 1968 *QST*.†

To adjust the temperature-compensating capacitors, turn the standard on and let it run for a few days. When the room is as cold as it normally gets, carefully set the frequency close enough to WWV that you can count the beat note (wows) for a period of 30 seconds or so. Write down the number of beats so you won't forget the value. Then, when the room is about as hot as it normally gets, come back and count the beats again. If there has been a change, adjust the vernier dial for a low beat count, and again count the beats over a 30-second period.

Note which way you adjusted C12. If you increased the capacitance of C12, the crystal drifted higher and you need to decrease the value of the N750 capacitor—say, to 5 pF. Then increase the NP0 capacitor to 15 pF so the total capacitance stays at 30 pF with the vernier dial set at midrange. This means you need a small supply of low-value NP0 and N750 capacitors. My unit needed an 8-pF NP0 in parallel with a 12-pF N750 for final compensation.

Repeat this procedure the next day and make any further adjustments to the NP0/N750 capacitor combination to further reduce the drift. If you go too far and drift is reversed, simply back up until the drift is eliminated. It shouldn't take more than a couple of days until the drift is reduced to just a couple of hertz. You can use ceramic capacitors with other negative-coefficient values (N1500, for example), but their effects will be different.

Once these procedures are complete, you will have close control over the standard with only slight adjustments of the vernier dial. As a result, you should have accuracy approaching 1 part in 10^7.—*W6VAT*

†I. Hoff, "The Mainline FS-1 Secondary Frequency Standard," *QST*, Nov 1968, pp 34-38, 152.

on the variable capacitor. Apply power. Assuming all is well, plug in your headphones and advance the RF GAIN control, R1, for a comfortable listening level. You should hear WWV, and the signal can be maximized by tuning T1 to resonance. Use a plastic screwdriver for this adjustment, not a metal one. Once T1 is peaked properly, adjust the vernier dial for zero beat.

Wait for the silent period between 45 and 60 seconds of each minute. Although WWV and WWVH broadcast voice announcements for Geophysical Alert Broadcasts with no accompanying audio tones, the main silent periods extend from 45 to 51 minutes after the hour on WWV, and from 15 to 20 minutes after the hour at WWVH. These are ideal times to calibrate the standard.

Adjust the vernier dial. You will hear one or more beat notes depending on how far off the crystal oscillator frequency is. As you approach zero beat, you will hear a fluttering sound followed by a "wowing" sound very close to actual zero beat. By careful adjustment of the control, you should get the wowing sound to less than one beat per second. It may take several silent periods, so be patient. It is also possible to tune to zero beat on the voice announcements just as you would tune in an SSB signal: Simply tune slowly for maximum voice clarity. Adjustment for zero beat can also be done by using WWV's audio tones.[6] Once the crystal is calibrated, your markers will be quite accurate.

Operation of the standard is the same as with any other marker generator. Couple a small amount of marker output into your receiver or transceiver. Select the marker frequency you want with the MARKER switch, and adjust the marker OUTPUT control for a comfortable level. The RF GAIN control can be used to turn down the audio signal while leaving the markers on. Conversely, you can shut the markers off and leave the Neophyte on.

Stability—Short-Term versus Long-Term

Once you have the crystal zero beat with WWV, your standard's accuracy should be close to 1 Hz in 10 MHz—but what will it be tomorrow? Over the short term—hours to days—the crystal frequency will not hold still. Temperature variations, turning the unit on and off and aging effects cause its frequency to wander about. Crystal aging is a long-term effect that occurs over months and years, and there is little you can do about it. Usually, aging is not severe. It is a function of crystal manufacturing techniques and the crystal drive level. One manufacturer quotes aging rates of 3 to 5 parts per million for the first year, with subsequent aging rates being reduced by 50% to 70% per year.[7]

Short-term stability is of more concern in a standard like this. Temperature variation is the main cause of short-term wandering of the crystal frequency. Anything you can do to reduce or eliminate it will help greatly. You can leave the standard on all the time and keep it in a room where temperature variations are limited. Beyond that, proper selection of the temperature-compensating capacitors (see the sidebar, "Temperature Compensation") is the most important factor in reducing short-term drift.

Other Possibilities

Obviously, the standard is quite useful in the workshop for testing and calibrating other equipment. In addition, you don't have to use 10 MHz if the 2.5- or 5-MHz WWV signal is more consistent at your station. (I doubt that the 15- or 20-MHz signals would be of much use as a standard because of the vagaries of HF propagation.) Chapter 6 of the latest edition of *The ARRL Data Book* shows how to wire the 7490s for different division ratios. Remember, you'll have to retune the Neophyte's front end, too.

In the unit shown, the MARKER switch has two OFF positions for the sake of convenience. If you delete one, you could use it to switch the output to a piece of shielded cable to bring out the 10-MHz signal for other uses.

So there you have it—a simple secondary standard that provides very accurate markers and serves as a WWV receiver to boot. It's easy to build and low-cost, considering its accuracy and usefulness.

Jim Lee has been licensed since 1944. He enjoys DXing and public-service operating when he's not designing and building gear for his shack and workshop. Jim is recently retired from GTE-Sylvania, where he worked as a Satellite Systems Engineer.

Notes

[1]A primary frequency standard is reproducible from specifications. A secondary frequency standard is calibrated by comparison with a primary standard.—*Ed.*

[2]J. Dillon, "The Neophyte Receiver," *QST*, Feb 1988, pp 14-18.

[3]Circuit boards and parts kits are available from Penntek Electronics, as described in the Neophyte article (see note 2).

[4]Write to the ARRL Technical Dept Secretary, 225 Main St, Newington, CT 06111. Enclose a self-addressed, stamped envelope. Be sure to include the name of this article with your request.

[5]J. Schaull, "Adjustment of High-Precision Frequency and Time Standards," *Proc IRE*, Jan 1950, pp 6-15.

[6]You can also tune in WWV or WWVH when tone modulation is present and set the standard oscillator by adjusting C12 until the pitches of both tone sidebands are identical—in other words, by zero-beating the tone sidebands with each other.—*Ed.*

[7]CTS Corp, Knights Division catalog, 400 Riemann Ave, Sandwich, IL 60548.

Recommended Reading

J. Janicke, "A Wide-Range Crystal-Controlled Frequency Standard," *QST*, Jul 1976, pp 27-28.

B. Kelley, "Universal Frequency Standard," *ham radio*, Feb 1974, pp 40-47.

D. Blakeslee, "Double Standards," *QST*, Apr 1972, pp 13-17.

G. Collier, "What Price Precision?," Part 1, *QST*, Sep 1952, pp 42-44, 130, 132; Part 2, *QST*, Oct 1952, pp 26-30, 120, 122, 124.

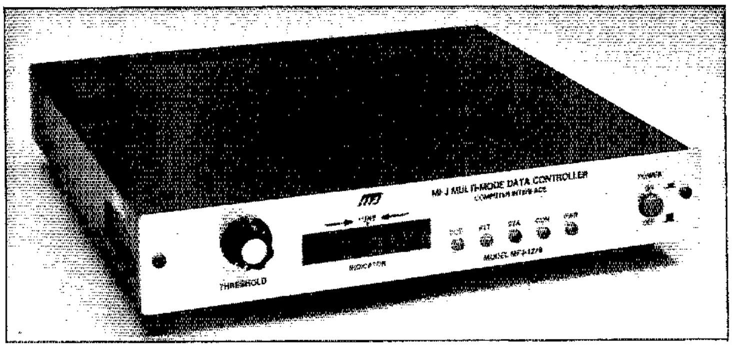
Conducted By James W. Healy, NJ2L
Assistant Technical Editor

MFJ-1278 Multi-Mode Data Controller—Revisited

Editor's Note: We published our review of the MFJ-1278 in July 1989 *QST*. After the purchase of that unit (March 1988), MFJ made substantial changes and improvements to both the hardware and firmware of the '1278.

We received several questions about that review, so we'll take this opportunity to clarify a few things. Because of factors such as *QST*'s lead time, products reviewed sometimes aren't the latest available versions, although we make every effort to ensure that the most recent units are reviewed—and that any late updates are discussed in the review. Comments on the MFJ-1278 reviewed in the July issue were based on the unit that we purchased, which—as received—contained circuit-board revision 6 and firmware version 1.5. (ARRL purchased one subsequent firmware update from MFJ [version 2.1] *based on an advertisement* in *QST*. ARRL received no notification of that or of subsequent updates to the '1278.)

In this issue, we revisit the MFJ-1278. Our intent is to provide the League membership with accurate information on all reviewed equipment. Secondly, our July 1989 '1278 review did not reflect MFJ's recent efforts to improve the '1278. League members should be confident that *QST* reviews are based on the latest available versions of reviewed equipment. Therefore, in this case, we feel that it's in the best interests of ARRL membership, MFJ and ARRL to revisit the MFJ-1278—in its *current* form (June 1989 manufacture)—in this month's Product Review column.



The current-production MFJ-1278 contains circuit-board revision 8 and firmware version 2.3; the unit reviewed here is of the current model. Some comments concerning the next revision, due out this month (September), are included in this review. For background on the previously reviewed MFJ-1278, see "Product Review" in July 1989 *QST*. This month's review mainly covers features that have been added or substantially improved since the release of the version reviewed in July *QST*, and doesn't cover most of the unchanged features of the '1278. Of course, where necessary, I'll discuss features germane to the old and new '1278s.

Setup

Connecting the newer '1278 to a radio is much simpler than doing so with the unit previously reviewed. (The original review unit had an incorrect-value coupling capacitor in the audio-input line, which made it impossible to get enough receive-audio drive from the AFSK OUT jack on my Kenwood TS-440S. This problem has been corrected in the newer units; I had no trouble driving the '1278 with the '440.)

Connecting the '1278 to a computer is simple and straightforward. I used the '1278 with both an Apple® Macintosh® and an IBM® PC. The IBM PC software available from MFJ in the IBM PC Starter Pack is further developed and more refined than MFJ's Macintosh software. Although both software packages work, the Macintosh software crashes too often for serious work. (This may be a compatibility problem with my Macintosh; my computer has the original 64-kbyte ROM. It's possible that the software was developed on a newer Macintosh, and that incompatibility with the ROM routines may account for the problems that I experienced with my Mac.)

Packet-Radio Operation

The unit first reviewed performed well on VHF packet radio, but gave less than optimal results in HF packet-radio operation. I'm glad to report that the new '1278 does very well on VHF *and* HF packet radio. I operated extensively on the HF bands using packet radio, and I'm impressed by the '1278's performance. Even on a crowded channel and/or with fairly weak signals, I was able to carry on QSOs and access packet-radio bulletin-board systems (PBBSs) without difficulty.

I was especially impressed by the new '1278's DCD (data carrier detect) circuit performance. This function, vital to HF packet-radio operation, performs admirably. (The DCD function is what allows reduced packet-collision rates, improving channel throughput.) Refinements such as this go a long way toward improving the viability of HF packet-radio operation with a multimode communications processor!

One of the '1278's new features is the Personal Mailbox, which allows those who connect to your station via VHF packet radio to send and receive messages, list messages, and delete messages left in the Mailbox for them. The '1278's Personal Mailbox feature makes your station into something of a VHF packet-radio-message clearinghouse. Able to store up to about 3 kbytes and a maximum of 30 messages, the Personal Mailbox is an interesting feature.

Yet another of the '1278's added capabilities allows for direct, real-time transfer of pictures (generated by packet radio, SSTV or FAX), to your printer when your station is connected via VHF packet radio to another '1278-equipped station. The IBM PC software provided in the MFJ-1284 Starter Pack allows display of these pictures on your computer screen. Any '1278-received FAX, SSTV or packet-radio pictures that you've stored on disk may be transferred between '1278s in this way.

RTTY and AMTOR

The modem improvements made to the '1278 by MFJ greatly improved not only the 1278's HF packet-radio reception, but also Baudot and ASCII RTTY. I made a lot of RTTY contacts, and even under less-than-optimum conditions, the '1278 provides relatively clean—and entirely usable—copy. Operating RTTY with the '1278 is now a pleasure—it quickly became one of my favorite modes!

Similarly, AMTOR operation shows a

marked improvement in the newer '1278. Although AMTOR is not one of my favorite operating modes, I did a lot of listening and made some contacts, and I'm pleased with the unit's performance.

Incidentally, there has been some confusion with regard to AMTOR operation with the '1278, aroused by the July 1989 '1278 review. The '1278 that ARRL first purchased for review (circuit-board revision 6/firmware version 1.5), which was not capable of AMTOR operation, was photographed for the first review. Before the unit was reviewed, however, it was sent to MFJ for an update to firmware version 2.1, which is AMTOR-capable. Thus, my comments on AMTOR with the earlier '1278.

CW Operation

CW reception is also considerably improved in the current '1278s. Even with relatively weak signals, the unit provides good copy of machine-sent CW. It also provides good copy of well-timed, hand-sent CW. With poorly sent CW, copy is not always acceptable, but that's attributable to the poor sending—not '1278 performance.

Using the unit as a CW keyboard is still a pleasure, and the buffers provide a convenient way to send standard information (rig, QTH, etc), and are good for contesting. The '1278's automatic serial-number incrementing is also handy in contests. The ability of the '1278 to function as an iambic keyer is an additional bonus.

Facsimile and NAVTEX

The old '1278's facsimile reception was quite disappointing, but in the latest version, FAX reception is so good that it is irresistible to tune around for interesting FAX transmissions. The current '1278 provides good copy of all seven supported FAX formats (1, 1.5, 2, 3, 4, 6 and 8 lines per second). Even though the current '1278 doesn't provide gray-scale capability (FAX pictures are displayed in black and white), I received some excellent pictures. I most enjoyed copying news-photo transmissions. Some of these were outstanding, with crisp, clean reproduction and a surprising amount of detail. MFJ even provides a list of frequencies, by mode and format, where FAX activity is common, to help get you started on FAX. An Epson®-compatible graphics printer is required for making printouts of FAX transmissions. FAX operation with the current '1278 is not the mere curiosity it was in early '1278s, but a mode which can easily become an obsession.

The current MFJ-1278 allows disk storage and printing of received FAX pictures—but only if you have software that has provisions to do so. (The software included in the IBM PC Starter Pack has such provisions.) Also, FAX pictures can be *transmitted* with the '1278. There are two catches, though: (1) Only previously received and disk-stored FAX pictures can be retransmitted, and (2) FAX pictures can be transmitted only at the rate (in lines per second) at which they were received. Even with these conditions, the '1278's FAX-transmission capability is interesting, and doesn't limit the '1278's performance in other areas, because FAX operation doesn't require special connections to the radio or computer, and it doesn't restrict operation on other modes.

The latest version of the MFJ-1278, due for release in September, has a revised cabinet, gray-scale capability in FAX and SSTV modes, and side-panel adjustable audio levels for both radio ports. Older versions of the '1278 can be upgraded by MFJ to include the features in this latest version.

Table 1

MFJ-1278 Multi-Mode Data Controller, Serial no. 3016550

Power requirements: 12 V dc at 500 mA, provided by wall-cube supply (included).

Operating modes: AMTOR, ASCII and Baudot RTTY, CW, facsimile, HF and VHF packet radio, NAVTEX, slow-scan television.

Terminal/computer interface: RS-232-C serial interface with DB25 connector; 8-pin TTL serial port.

Computer/'1278 data rates: 300, 1200, 2400, 4800 and 9600 bauds.

Radio interfaces: 5-pin DIN connectors (two). Each provides connections for audio input and output, PTT, ground and squelch (optional).

NAVTEX-reception capability is also provided by the '1278. NAVTEX, an acronym for Navigational Telex, is a relatively new service in which several stations in North America transmit weather advisories, navigational warnings, ice reports, search-and-rescue information, pilot-service messages, LORAN and other information, including NAVTEX transmission schedules, on 518 kHz. NAVTEX is, in effect, a special case of FEC TOR. The '1278 allows you to select the NAVTEX stations which you want to receive (the default is all), and the information categories that you want to hear. Although I was able to hear the NAVTEX station in Boston, atmospheric conditions kept me from being able to test the NAVTEX capabilities of the '1278. Based on the '1278's performance on other modes, I'm confident that NAVTEX performance is good—under the right atmospheric conditions.

SSTV

The MFJ-1278's slow-scan-television operation continues to present some difficulties. According to MFJ Vice President Steven Pan, KF5C, this is caused by synchronization problems related to the current '1278's lack of gray-scale capability (received pictures are displayed in only black and white) in the '1278. In pictures that have gray areas, the '1278 has trouble detecting the synchronization signals. The next update of the '1278 (see "Updates" later in this review) will be capable of displaying received pictures in four shades (black, white and two more in between). This hardware/firmware improvement will also help solve the synchronization problem.

I tested a preliminary version of the '1278 (version 9 hardware/version 3.3 firmware) using some recorded SSTV pictures with gray areas, and the unit performed well. Not only is the synchronization problem solved, but the four-shade pictures from the printer look quite nice. I was not able to test the unit with on-the-air signals, but based on its performance with recorded signals, I'd say it should do well.

MFJ is working on IBM PC software that will allow the display of four-shade SSTV images on screen, as well as that of multishade FAX images. This capability will be worth having, because printing SSTV pictures on a printer is time consuming. You can easily miss several pictures while waiting for one to finish printing.

The Manuals

Two manuals come with the current MFJ-1278. One primarily covers packet-radio operation; the other also covers some aspects of packet-radio operation, and all of the '1278's other modes. At first glance, the manuals don't appear to be much different than the original documentation, although some errors and typos have been corrected. The indexing is still somewhat difficult to use, but I found most of the information that I looked for by checking the tables of contents, index and/or by looking in the appropriate general section of the documentation. Often, the information presented in the Commands chapter (which lists commands in alphabetical order) is complete enough to answer most questions about a particular operation. There are several (mostly minor) errors in the documentation, but these problems (incorrect page references, typos and such) are not major inconveniences.

Overall Impressions

I was impressed by the current version of the '1278—it offers good performance, on a lot of modes, for a reasonable price. It offers a substantial improvement in performance over earlier versions; in the current '1278, each mode (except SSTV) provides truly usable operating capability. If you are interested in a unit which offers more than just packet-radio operation, the '1278 merits careful consideration. Even if you're only interested in packet radio, you may decide otherwise after experimenting with other modes! When you consider the variety of operating possibilities the '1278 offers, including its ability to serve as an iambic keyer, it definitely deserves a second look when shopping for a multimode communications processor.

Updates

MFJ has sweetened the deal for new MFJ-1278 buyers: When you buy a '1278, you'll receive a coupon for one free firmware upgrade. MFJ won't notify you of the availability of such upgrades, but when you contact MFJ and find that a firmware upgrade is available, or when you see one advertised, you can redeem your free-upgrade coupon.

The newest '1278, circuit-board revision 9/firmware version 3.3, is scheduled to be ready for shipment in September. This unit offers a number of improvements over the circuit-board revision 8/firmware version 2.3 unit, and will be documented in a single, new manual. Among the improvements are the SSTV upgrades and multi-shade FAX displays (with a computer running the appropriate software). Other refinements include independent transmit-audio-level controls (for radio ports 1 and 2) located on the side of the cabinet.

According to MFJ, '1278s with serial nos. above 03010508 (firmware version 2.2 or earlier) may be upgraded by the user for $24.95 plus $2 shipping and handling by sending in the old EPROM. This does not include hardware or firmware support for the multi-gray-level modem. Factory-installed multi-gray-level modem and supporting firmware is $49.95 (plus $5 s&h).

For '1278s with serial nos. below 03010508, the factory-installed firmware upgrade for units with firmware version 1.1 or earlier is $24.95 (plus $5 s&h); for units with firmware version 2.1 or later, the user-installed firmware upgrade is $24.95 (plus $2 s&h). This does not include hardware or firmware support for the multi-gray-level modem. Contact MFJ for details on the multi-gray-level modem and firmware for units with serial nos. below 03010508.

All upgrade prices are based on exchanging the old EPROM; units should be sent postpaid to MFJ for all factory-installed upgrades.

Price class: MFJ-1278 (hardware version 9/firmware version 3.3) with wall-cube ac supply, $280; Starter Packs, $25 each. Manufacturer: MFJ Enterprises, PO Box 494, Mississippi State, MS 39762, tel 601-323-5869.

SOLICITATION FOR PRODUCT REVIEW EQUIPMENT BIDS

[In order to present the most objective reviews, ARRL purchases equipment off the shelf from Amateur Radio dealers. ARRL receives no remuneration for items presented in the Product Review or New Products columns.—*Ed.*]

The ARRL-purchased Product Review equipment listed below is for sale to the highest bidder. Prices quoted are minimum acceptable bids, and are discounted from the purchase price(s).

Sealed bids must be submitted by mail and must be postmarked on or before September 27, 1989. Bids postmarked after the closing date will not be considered. Bids will be opened seven days after the closing postmark date. In the case of equal high bids, the high bid bearing the earliest postmark will be declared the successful bidder.

In your bid, please clearly identify the item you wish to bid on, using the manufacturer's name, model number, or other identification number, if specified. Each item requires a separate bid and envelope. Shipping charges will be paid by the successful bidder, FOB Newington. The successful bidder will be advised by mail. No other notifications will be made, and no information will be given by telephone to anyone regarding final price or identity of the successful bidder.

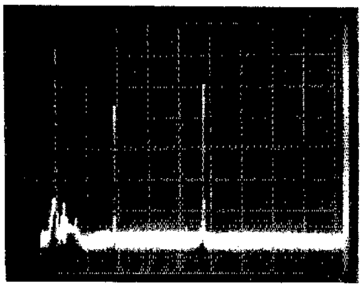
Please send bids to Kathy McGrath, Product Bids, ARRL, 225 Main St, Newington, CT 06111.

Yaesu FT-747GX MF/HF transceiver, s/n 8D040384, including FP-757HD power supply/speaker and *FT-747GX Technical Supplement* (see Product Review, August 1989 *QST*). Sold as a package only. Minimum bid: $680.

New Products

VIDEOSMITH SPECTRUM PROBE

☐ VideOsmith's Spectrum Probe allows you to measure RF signal levels and frequencies on an oscilloscope display, effectively converting the scope into a spectrum analyzer. The Probe provides the amplitude-v-time to amplitude-v-frequency conversion necessary to display the frequency domain on a scope screen. The photo shows a typical Spectrum Probe display with 21.2- and 50.2-MHz input signals.



Spectrum Probe display with 21.2- and 50.2-MHz input signals. The dc pip (generated in the Probe) is visible at the second-from-left vertical graticule line. Only the 21.2- and 50.2-MHz signals were applied to the Spectrum Probe for this test; all other visible signals were generated in the Spectrum Probe.

The 7½-inch-long × 1-inch-diameter, two-ounce Spectrum Probe has a 10-pF input-coupling capacitor, and can be used in 50- and 75-Ω systems. Key manufacturer-claimed specifications are as follows: usable frequency range, 1 to over 100 MHz; dynamic range, >50 dB; vertical logarithmic linearity, ± 3 dB; horizontal linearity, ±10%, typ; vertical gain, 5 mV per dB typ; spurious responses, −40 dB typ; maximum CW input, +15 dBm, 1 V @ 100 MHz; sweep rate, 6 ms per 100 MHz typ; power requirement, 120 V ac @ 35 mA (wall transformer supplied). With a delayed-sweep scope, improved frequency resolution can be had; minimum usable bandwidth is about 500 kHz.

Price: $380. For more information, contact videOsmith, 1324 Harris Rd, Dresher, PA 19025, tel 215-643-6340.—*Rus Healy, NJ2L*

Hints and Kinks

Conducted By David Newkirk, AK7M
Assistant Technical Editor

HOW CAPACITORS CURE HUM FROM POWER-SUPPLY DIODES: ONE EXPLANATION

AK7M: In an editor's note appended to Michael Dees's "Bypass Capacitors Cure Power-Supply Noise" (Hints and Kinks, *QST*, July 1988, p 44), I described how I'd cured a hum-on-received-signals problem by bypassing the rectifier diodes in a transceiver power supply. Here's one ham's response to my request for an explanation of this phenomenon:

☐ The hum phenomenon described by N3EZD and the editor was well known in medium-wave radios built in the 1930s. The hum occurs when amplitude-modulated RF enters the receiver mixer stage via two paths: (1) Energy from the short antenna enters the mixer via the receiver RF stage; (2) the power line, working as an antenna, also supplies RF to the radio via more or less uncontrollable paths (by means of conduction and stray capacitance). The power-line-conducted RF is amplitude-modulated at the line frequency and its harmonics in the power-supply rectifiers, which act as modulators.

Strong signals cause the receiver automatic gain control to reduce the RF-amplifier gain, reducing the level of signal that reaches the mixer via Path 1, whereas the hum-modulated RF from Path 2 remains nearly unaffected and becomes the dominant input signal at the mixer.

The cheapest way to avoid this effect is to short-circuit the "modulator" diodes for RF with capacitors. Indeed, many 1930s-vintage radios had bypass capacitors in parallel with their rectifier tubes. Such capacitors must be able to withstand considerable high-voltage stress. During WW II, and for a period after the war (when capacitors were in short supply), radio repair personnel cured the problem of a destroyed rectifier-bypass capacitor by just removing it from the radio. The radio owner had to tolerate the resulting hum. (Our radio language adopted a new word in those days: *Blinddarmkondensator* [literally, "appendix-capacitor."])

The better way to solve this hum problem is to RF-filter the power supply input and output leads, and to shield the line(s) between the power supply and receiver. *—Helmut Zurneck, DL4FBI, Ritterstrasse 26, 6110 Dieburg, West Germany*

And K4GXY used power-supply-diode bypass capacitors to solve another RF-related problem:

☐ My Heath® HW-5400 transceiver and Tenna Phase III power supply had bad transmit and receive audio problems (distortion and hum) until I bypassed each of the power supply's diodes with 0.01, 0.1 and 1-µF capacitors. The Tenna Phase III power supply does not include ac-line bypassing; connecting capacitors from hot to neutral, and from hot and neutral to ground, did not solve the problem.

SWR-related RF feedback seems to cause the problem. I speculate that RF is rectified and superimposed as AF on the power supply's dc output; I arrived at this conclusion by observing that the superimposed voltage increases with SWR.

Like the ICOM IC-735 and Kenwood TS-430S, the HW-5400 contains a step-tuned PLL VFO.*—John W. Gallagher, PE, K4GXY, 411 S Elm Rd, Lakeland, FL 33801*

MAYBE YOU NEED TO RESET THE MICROPROCESSOR

☐ Most late-model ham equipment is microprocessor-controlled. Occasionally, the microprocessor in such a radio may "lock up" for some reason, rendering the equipment useless. Working part-time at an Amateur Radio store, I've seen many rigs brought in for repair that required no repair other than resetting their microprocessors—a simple task that could have been done by their owners!

Reset procedures vary from radio to radio. In some cases, a panel button must be pressed as the equipment is powered up. Other gear requires that a toothpick or pencil be used to activate a switch through a small hole in the equipment case. Your transceiver's operating manual probably details the procedure necessary to reset the rig's microprocessor.

Certainly, *all* failures in state-of-the-art radios aren't caused by locked-up microprocessors. But it never hurts to give the reset procedure a try—you might save yourself a trip and a service charge. *—Michael A. Czuhajewski, WA8MCQ, Box 232, Jessup, MD 20794*

AK7M: Resetting a rig's microprocessor (also called a *micro* for short, or *CPU* [central processing unit]) may involve one undesirable side-effect: the erasure of frequency, mode, repeater split and other information in memory channels. Be sure to record such information before you try a reset!

In April 1989 Hints and Kinks, Joseph Wavra Jr, WQ5M, described a method of resetting the ICOM IC-02AT that required disassembly of the radio. Our next Hints and Kinks contributor suggests an easier means of resetting the micro in that transceiver:

EASIER RESET FOR THE ICOM IC-02AT CPU

☐ There's a much simpler procedure for resetting the IC-02AT CPU—one that does not require opening the radio. (1) Turn the radio off. (2) Press the FUNCTION button on the side of the radio and hold it on. (3) Turn the radio on. That's it! The '02AT's CPU is now reset, and all of the rig's memories are set to their default value (144.000 MHz).*—Pat Maturo, N1DYI, 233 Harvester Rd, Orange, CT 06477*

AVOIDING STATIC DAMAGE TO THE HEATH µMATIC MEMORY KEYER

☐ Heath suggests that users of the µMatic Memory Keyer ground themselves to protect the µMatic's components from electrostatic discharge (ESD). ESD danger is especially high on winter days when the relative humidity in heated buildings is low. Fig 1 shows my solution to this problem: a grounded metal strip that I touch each time my hand goes to the µMatic paddles. The strip consists of self-adhesive, stainless-steel tape (available in hobby or "home center" stores). The rubber pad also provides an antislip base for the keyer. *—John DeCicco, KB2ARU, 1816 Ave S, Brooklyn, NY 11229*

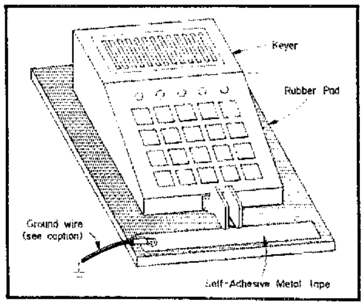


Fig 1—John DeCicco protects his µMatic keyer from static-electricity damage with a grounded length of self-adhesive steel tape. The rubber pad supports the tape and keeps the keyer from sliding on the table. Approaching John's antistatic measures from a commercial angle, computer stores carry "groundable" resistive strips and mats intended to protect computers and keyboards from ESD; such products would also protect the µMatic. Hints and Kinks suggests installing a 1-megohm, 1-watt resistor (or a series-parallel resistor combination of equivalent resistance and power rating) between the metal strip and ground to limit current in the strip ground to an operator-safe level.

PREVENTING MORE SCRATCHES FROM MAGNETIC-MOUNT ANTENNAS

☐ I agree that a surface protection (consisting of polyethylene or another material) can help keep a mag mount from scratching car-finish paint (G. Manning, "Preventing Scratches from Magnetic-Mount Antennas," Hints and Kinks, *QST*, August 1988, p 50). But I've found that the *real* problem is grit and dirt that accumulates between the mount and the auto body. After having tried new protective materials with numerous magnetic mounts, I think the best solution is to start with a new surface protector and clean the dust off the paint and protective material *daily*.

Plastic bags won't scratch clean paint. New magnetic mounts won't scratch clean paint. Even old, rusty magnetic mounts won't scratch paint very much if there is no dust or dirt between them and the body surface. Keeping your car and the magnetic mount clean is the best insurance against scratches.

One more hint: *Don't ever* place a mag mount across a body joint (such as that between the hood and fender). No matter how well-built your car is, its adjacent surfaces vibrate relative to each other when the engine is running. A mag mount placed across body joints will scratch down to the undercoat in less than a week on an average car!—*Howard M. Lang, KB6NN, 3124 H St, Eureka, CA 95501*

STORE YOUR *QSTs* IN THEIR PLASTIC MAILING BAGS

☐ Don't throw away those plastic wrappers *QST* comes in. They're an excellent way to preserve your *QSTs*. After each month's *QST* arrives, I carefully trim one end of the bag to remove the magazine. Reinserting *QST* in its bag is easy: Bend the magazine slightly in its middle and slip it back into the bag. Wonder if I can buy these bags by the dozen from ARRL? —*Bill Eppley, W2SDB, 434 Adams Ave, Cape Canaveral, FL 32920*

AK7M: QST Circulation Manager Debra Jahnke tells me that *QST* bags *aren't* available from HQ because they're custom cut and sealed as *QST* rolls off the presses each month at R. R. Donnelley & Sons, Glasgow, KY. Debbie adds that some members use zip-resealable food-storage bags for storing *QST*.

AN AUDIO-TAPE TRANSMITTER KEYER

☐ Need a simple means of transmitting a canned CW message? Use a code-practice or sidetone oscillator to record the message on an "endless" tape cassette (a telephone-answering-machine tape is fine). Play the tape back through the audio-driven keying circuit shown in Fig 2.

I use this circuit to key an experimental 175-kHz beacon—an application that requires Q1 to key only 10 mA. You may need to add a stage of dc amplification between the rectifier and Q1 to key higher currents.—*Arthur C. Erdman, W8VWX, 224 Chaucer Ct, Worthington, OH 43085*

SERIES-RESONANT CIRCUIT ENHANCES DESIRED SIGNAL IN QRP RIG

☐ During cut-and-try construction of a QRP CW rig that uses push-push doubling to produce 14-MHz drive from a 7-MHz VFO, I discovered that the stages following the doubler had output everywhere *except* 14 MHz! I solved this problem by installing a series-resonant tuned circuit between the doubler and its buffer stage (Fig 3). I have also successfully used series-resonant circuits between the antenna and output stages of monoband rigs to minimize TVI. (By the way, I first submitted something for Hints and Kinks in *1932*, but *QST* didn't publish that hint. I have since recovered from my feeling of rejection and decided to try again!)—*Bob Kuehn, WØHKF, 1871 Silver Bell Rd, Apt 313, Eagan, MN 55122*

CURING CORDLESS-PHONE RFI

☐ After disabling two cordless-phone base units—one base unit and its replacement—with my 100-W transmitter, I knew I needed a *real* RFI solution. I solved the problem by adding ferrite-core RF chokes in *all* cords leading into and out of the base unit. I made each choke by winding a single-layer coil of as much cord as possible on a 4-inch-long ferrite rod (material 33, permeability 800).[1] Nylon cable ties hold the windings in place. I formed each choke as close to the body of the phone base unit as possible for maximum interference suppression.—*Jack G. Hollenbeck, W6JIC, 3166 Bryant St, Palo Alto, CA 94306*

[1]Amidon Associates (12033 Otsego St, N Hollywood, CA, 91607) carries such rods as part no. R33-050-400; Palomar Engineers (PO Box 455, 1924-F W. Mission Rd, Escondido, CA 92025, tel 619-747-3343) carries them as part no. RF-4-33; and RADIOKIT (PO Box 973, Pelham, NH 03076, tel 603-437-2722) carries them as part no. R33-50-400.—*AK7M*

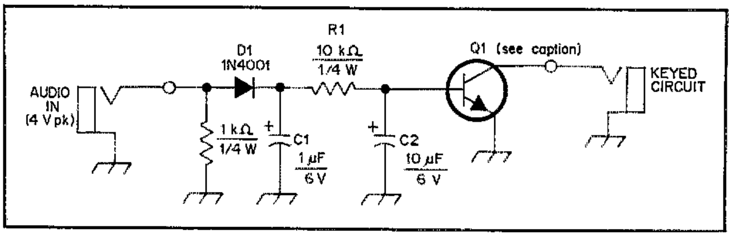


Fig 2—Arthur Erdman uses this audio-driven circuit to key his 1750-meter beacon. D1 rectifies the tape-recorder audio; C1, R1 and C2 filter the rectified audio to drive Q1, and Q1 pulls the keying line low when sufficient drive current flows between its base and emitter. Q1 is any small-signal, silicon NPN transistor capable of withstanding the voltage of the open keying circuit and capable of handling the keyed current. This circuit keys positive (negative-ground) keying lines only.

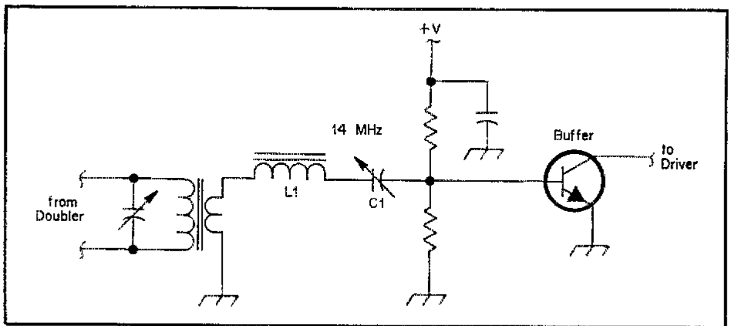


Fig 3—Bob Kuehn added this 14-MHz series-resonant circuit (L1C1) to clean up the output of a push-push doubler in his homemade QRP transmitter. L1 consists of 44 turns of no. 24 enameled wire on a T-68-2 powdered-iron toroidal core. C1 is a small air-dielectric capacitor capable of being set to about 11.5 pF.

How Would You Do It?

Problem: Antenna tuning is a hassle for you because the optimum spot for bringing your random-wire antenna into the house is a hallway and two rooms away from your station. You don't like locking the key with a switch, rock or heavy book and dashing to the window and back before the rig's finals overheat—and the other members of your family are tired of acting as voice-controlled relays ("Key down! . . .Key up!") at tune-up time. How can you stand at your windowsill-mounted Transmatch and key the transmitter *remotely*—without wires, and without a helper? Send your solutions to Hints and Kinks, ARRL, 225 Main St, Newington, CT 06111.

Technical Correspondence

Conducted By Paul K. Pagel, N1FB
Associate Technical Editor

UPDATES FOR "THE ELECTRONIC PARROT"

☐ I'm pleased by the response to my article, "The Electronic Parrot."[1] I have four enhancements for the project that I think *QST* readers would like to know about. (Unless otherwise noted, all references are to pages, schematics and components identified in the original article.)

Hum can be introduced into the microphone line when the Parrot's chassis is connected to the station ground. The path for introducing the hum is through a ground loop from the microphone ground back through chassis ground via the 12-V DC IN jack, J5 (see Fig 2, p 18). The best way to eliminate this path is to use a two-prong, insulated jack at J5, or feed the dc-carrying cable directly to the POWER switch (S13) and P4 through a grommet-lined hole in the chassis. The 12-V positive and negative leads should be routed through ferrite beads. Bypass the leads to chassis ground with 0.001-µF disc-ceramic capacitors. (Of course, the chassis remains at RF ground potential.)

Replace Q1 (a 2N2222) with an MPSA13 (Darlington), and replace R24 (100 Ω) with a 10-kΩ resistor. This eliminates the possibility of the PLAYM output being current limited when active.

Robert Fabry, N6EK, suggested a simple modification that aborts any message being played back whenever the "foot-to-talk" switch is actuated. This is useful, for example, when you start a message just as a station calls. The modification is performed by bringing out the contacts of an unused message button (such as no. 7) to a pair of spare switch contacts in the foot switch. When the foot switch is actuated, the spare contacts close and cause the ST/SP input of the '6258 to be asserted high. When this happens during playback, the message halts and the Parrot goes immediately into standby mode. Since there is nothing in the unused message (by definition!), this modification does not impede normal foot switch operation when the Parrot is in standby mode. In practice, all seven messages are rarely used, so you can place six message buttons on the front panel and dedicate the seventh to this purpose.

Finally, the Electronic Parrot can be modified easily to pass microphone audio through to the transceiver while recording. This is extremely useful, for example, when you want to record a CQ message while trying to hold a frequency. The modification also allows you to hear the new message (through the transceiver monitor) as it is being recorded, so the recording level can be regulated. As shown here in Fig 1, the modification merely involves the addition of two 1N914 diodes to the base of Q1.

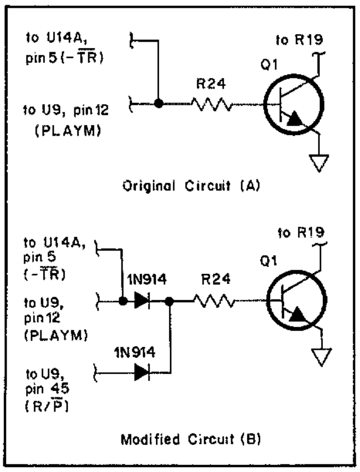


Fig 1—The Electronic Parrot can be modified to pass microphone audio through to the transceiver while recording by adding two 1N914 diodes to the base of Q1.

With the modified circuit, K1 is energized whenever S1 is placed in RECORD and S12 is set to IN. When the Parrot is recording to memory, U9 (see Fig 1B, p 16) passes audio from its input (VIN, pin 16) to its output (DAOUT, pin 30). The output signal is exactly the same as the signal produced when the message is played back; hence, you can tell immediately if you are speaking too softly or loudly, providing a means of setting level controls R2 (MIC GAIN OUT) and R3 (MIC GAIN IN)—see Fig 1A, p 15. When S1 is set to RECORD and S12 is placed in the OUT position, a message can still be recorded without keying the transceiver.—*Kevin D. Balmforth, NC6U, 621 N Ladera Vista, Fullerton, CA 92631*

C64 MEMORY TRANSPLANT

☐ Many amateurs aren't aware that a ready-made ASCII signal is available directly from the C64 USER PORT. The TTL-compatible signal at pin M can be used to modulate an audio subcarrier which, in turn, can be transmitted via AM, FM or SSB. Once the information to be transmitted is in the memory of the initiating C64, a simple one-line command accomplishes this:

```
OPEN 2, 2, 3, CHR$(3 + 32) +
CHR$(32 + 128) : CMD2 : LIST
```

Alternatively, this command may be incorporated into a BASIC program. In this case, data transmission begins when the program is run.

The OPEN portion of the command opens channel 2 to device #2, the modem. The first character-string function (CHR$) sets the data rate and word length. As given, the rate is 110 bauds. For 300- or 1200-baud operation, CHR$(3 + 32) should be changed to CHR$(6 + 32) or CHR$(8 + 32), respectively (see p 350 of the *Commodore Programmers Reference Guide).* The second CHR$ sets various parameters of the transmitted coding, as detailed on p 351 of the *Guide*.

At the other end of the radio circuit, the subcarrier is recovered from the receiver audio, routed through a PLL demodulator, then sent to USER PORT pins B and C (tied together).

To complete the transplant of information directly into the memory of the receiving C64, it's necessary to GET each character in succession from the modem and PRINT the character to the screen. Each time a RETURN is detected in the received data, a RETURN is introduced into the routine via the "dynamic keyboard"[2] (keyboard buffer), thereby implanting it in memory. All of this is accomplished by the BASIC program given in Table 1. (Note: You must ensure that any program you intend to transfer does not already contain program lines numbered 1 through 7. Otherwise, the program presented in Table 1 will not work correctly! If necessary, renumber the statements in the program to be transferred.)

Here's a description of each program statement:

1) The receive modem is OPENed in

[1]K. Balmforth, "The Electronic Parrot," QST, Dec 1988, pp 14-23.

[2]J. Butterfield, "Commodore Dynamic Keyboard," *Compute!*, Oct, Nov and Dec 1985. (These issues are out of print; back issues are not available. For more information, contact your local Commodore user's group or local library—*Ed.*) As described by Butterfield: ". . . dynamic keyboard programming uses a two-step method to let a program give itself direct-mode commands. Step 1 is to print the command at a specific location on the screen. Step 2 is to put a RETURN character in the computer's keyboard buffer, then stop the program with the cursor flashing over the screen command. The RETURN character makes the computer execute the command just as if you'd pressed RETURN."

Table 1

C64 Memory Transplant Program

```
1 OPEN 2, 2, 3, CHR$(3 + 32) + CHR$(32 + 128) : PRINT CHR$(147)
2 GET #2, A$ : IF VAL(A$) = Ø THEN 2
3 PRINT A$;
4 GET #2, A$ : PRINT A$; : A$ = A$ + CHR$(Ø) : IF ASC(A$) < > 13 THEN 3
5 PRINT : PRINT "POKE 152,1 : GOTO 7"
6 POKE 631, 19 : POKE 632, 13 : POKE 633, 13 : POKE 634, 13:
  POKE 635, 13 : POKE 198, 5 : END
7 PRINT CHR$(147) : GOTO 4
```

a manner similar to that of the transmit modem. CHR$(147) removes nonpertinent characters from the screen.

2) GET #2 fetches the first character from memory. If that character is part of the program preamble, its value is zero. Execution of the program is thereby reinitiated immediately.

3) The first valid character is PRINTed to the screen without a carriage return.

4) As program execution is well under way at this point, there is no further need to test for zeros. With the C64, the CHR$(Ø) is a necessary formality when performing this sort of operation. If the character is *not* ASCII code 13 (a carriage return), action loops back to line 3. Each character is PRINTed to the screen as it is received.

5) When a carriage return is detected, POKE 152,1 : GOTO 7, to be executed in line 6, is PRINTed to the screen.

6) The POKE commands place the cursor at the proper screen location, place four carriage returns in the keyboard buffer, then indicate that information is being held in the buffer as a total of five keystrokes (POKE 198, 5). It is the END statement that implements the POKE 152,1:GOTO 7 statement that was printed to the screen earlier (in line 5). In this instance, END does not constitute the end of the program. The latter part of line 5 directs final action to line 7.

7) The screen is once again cleared and the program returns to line 4 to begin processing the next line.

The beauty of this approach lies in its simplicity. There is no need for ancillary programs, intermediate transformations, storage to disk, buffers, etc. Yet the program as received is wholly in memory and can be manipulated in customary fashion. All the other techniques I've seen substitute cumbersome hard-, firm- and software for something the C64 is inherently equipped to do.

Although I worked this out on 2-meter FM, the same procedure can be followed on HF. (However, I highly recommend the use of an audio band-pass filter on HF.) My modem is about as simple as one can get—I designed and built it myself. The modem plugs directly into the C64 USER PORT and requires no external power source. Details of the modem are available from me; please provide a business-size SASE.

Initial inspiration for this project was provided by Virgil Yarbrough, W5YGX (not Virgil Yarbrough, K4IEK[3]). The technique might never have been mastered had it not been for continuing encouragement and invaluable suggestions by Kenneth Bates, KF5WD. After a search of more than two years for a method of getting received data into memory, I am indebted to my son, Bill, for having discovered the final missing link—the POKE instructions in lines 5 and 6 of the receive program.—*Don Goshay, W6MMU, Emerald Beach Village, Golden, MO 65658*

[3] C. Pratt and V. Yarbrough, "Pictures by Packet," *QST*, May 1988, pp 15-17.

Note: All correspondence addressed to this column should bear the name, call sign and complete address of the sender. Please include a daytime telephone number at which you may be reached if necessary.

Feedback

☐ A couple of errors crept into Howard Lester's July 1989 *QST* article, "Interference Standards Revisited." In both photo captions, the US National Institute of Standards and Technology is incorrectly identified as the National Institute of Science and Technology. Also, both photographs were provided courtesy of M. L. "Mike" Crawford of the National Institute of Standards and Technology.

☐ A crystal-frequency typo found its way into "A Four-Stage 75-Meter SSB Superhet," May 1989 *QST*. On page 25, the sentence in the middle of the second paragraph of the third column should read: I found that I could shift a surplus 9.500-MHz HC-6/U crystal to 9.50013 MHz with C14 in place of W1, as shown. *(tnx Charles M. Schwab, Jr)*

The Care and Feeding of Trees

(continued from page 28)

the tree each time. I use a flexible truck tie-down to provide tension to the antenna.

Your Safety in Trees

A fall from a 40-foot tree is just as dangerous as a fall from a 40-foot tower. Yet, many times you see hams scaling trees with no safety equipment! Wear a tower-climbing safety belt for all tree climbs (see Fig 7). Commercial arborists take the matter of safety one step further: They lob a rope over a tree crotch just above the height at which they'll be working. Then they tie the rope to their safety belt. The loose end of the rope can be held by a helper on the ground.

Be sure to use a good quality rope that is heavy enough to support your weight. Before use, inspect the rope for wear. Arborists prefer to use hemp rope rather than nylon, because hemp rope stretches less.

When you're climbing a tree to attach a wire, always have a buddy on the ground available to fetch tools or summon help in an emergency. Be sure your buddy wears a hard hat; tools or branches dropped from even a moderate height can be dangerous.

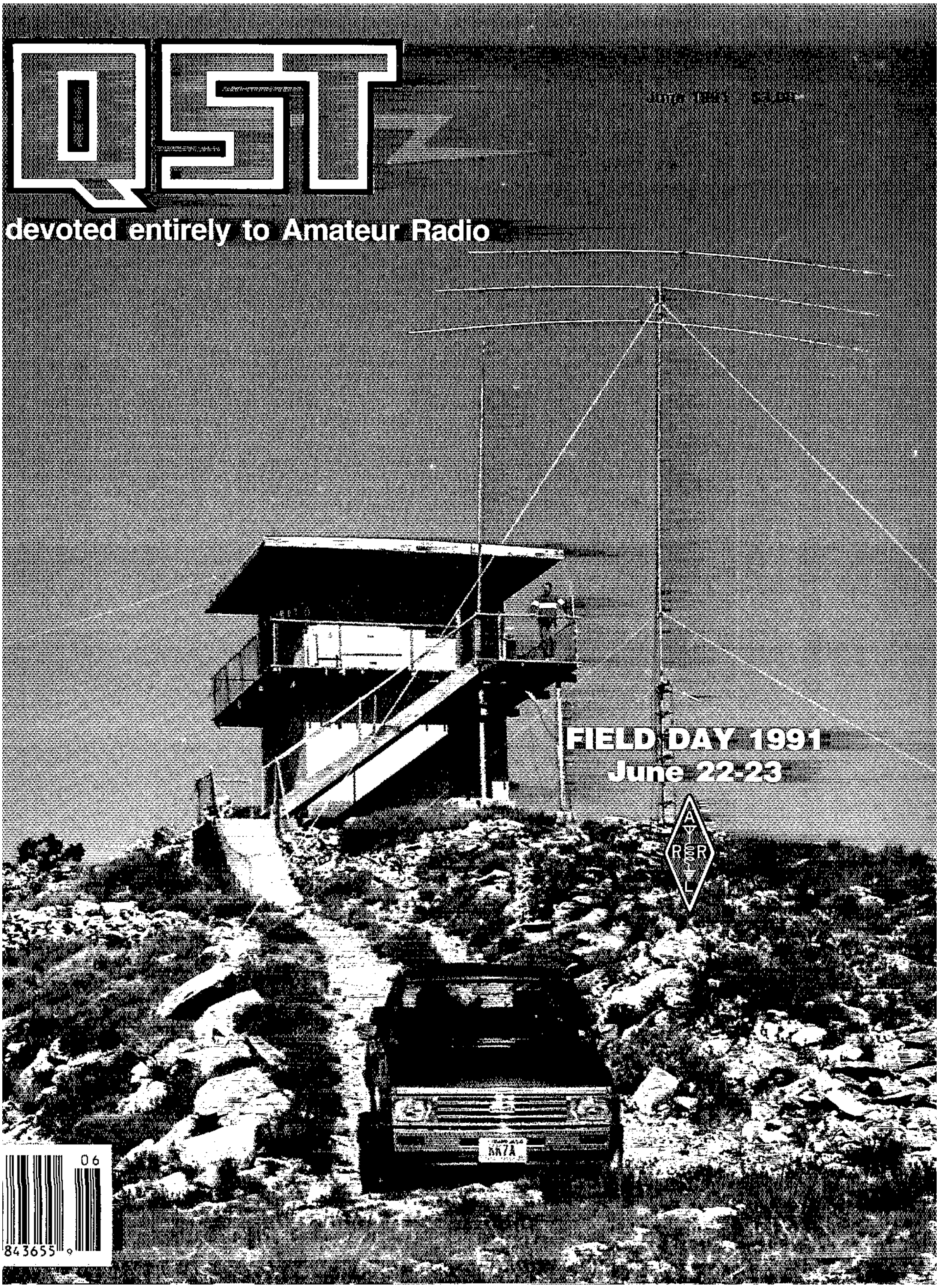
As an alternative to doing it yourself, consider procuring the assistance of a professional to install your tree antenna. A professional can clear away interfering branches and secure an eyescrew in short order. Professional tree trimmers generally work in pairs. They use a ladder or bucket truck to get up into the tree, and then they free-climb throughout the tree. A safety rope, saddle, and safety belt are worn. "A figure that I heard about how much this runs is about $50 an hour," says Maleike. Most antenna tasks can be done by professionals in about an hour.

Summary

Keeping your station in good operating condition is—or should be—a fundamental practice of every radio amateur. Part of that practice includes annual inspection of your antenna system. If trees are a part of your antenna system, take a good look at them. Are you keeping them healthy?

Doug Brede is a former Associate Professor of Horticulture at Oklahoma State University and is now research director for a major west-coast seed company. In addition to having written for QST *before ("The Electronic Voice-Saver,"* QST, *Jun 1980, pp 18-20), Doug has written over 100 technical articles on landscape topics for magazines in the landscaping industry.*

Doug holds an Extra Class license, and operates mostly HF CW. For an antenna, he uses a dipole suspended between two 90-foot-tall Ponderosa pines.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OUR COVER

Jim Larson, KK7A, and Steve Mesko, WB7Y (shown at the railing), from Boise, Idaho, make the abandoned fire lookout atop nearby House Mountain their regular Field Day site. If you can't find a mountaintop of your own, however, there are plenty of excellent alternatives. From New York to San Francisco, hams will take to the woods, beaches, shopping malls and municipal parks for Field Day 1991, June 22-23—Amateur Radio's premier outing. See you there! *(Jim Larson, KK7A, photo)*

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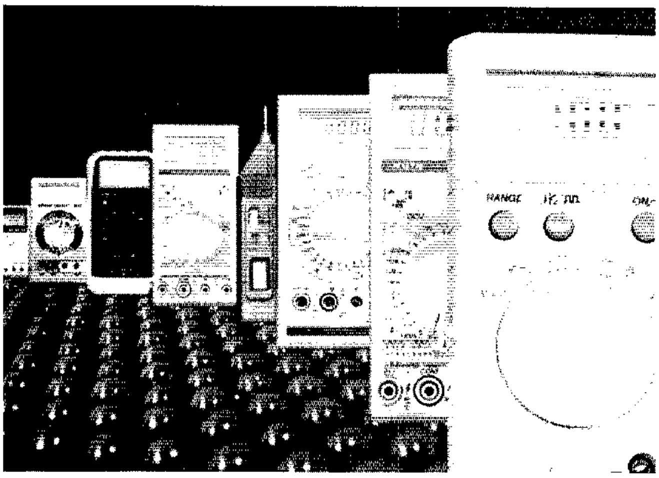

Modern DMMs are feature-laden: Do you need them all? How do you select *the* DMM that meets your requirements?

By Bryan Bergeron, NU1N
30 Gardner Rd, Apt 1G
Brookline, MA 02146

You're packing your gear for a DXpedition to an exotic, desolate and unpopulated island, or maybe a weekend getaway. You have space for only one piece of test equipment. What should you take? Chances are it'll be the most indispensable instrument in the radio amateur's arsenal: a hand-held digital multimeter (DMM).

The modern DMM, a compact and relatively inexpensive device, delivers the functionality of a volt-ohm meter, frequency counter, capacitance checker, inductance meter, logic probe, transistor-gain tester, and semiconductor-junction tester in one easily-operated, palm-sized package. This increase in DMM functionality is made possible by the use of compact surface-mount devices and powerful, microprocessor-controlled analog-to-digital (A/D) converters.

With the variety of DMMs on the market, deciding which one to buy can be difficult. (Table 1 presents a list of DMM vendors.) Much of this indecision can be attributed to inconsistencies and missing details in the promotional literature. Many advertisements fail to mention (or inadequately describe) instrument precision, accuracy, resolution and stability. In this article, I'll discuss these and other terms commonly used to describe DMMs and examine some issues related to DMM selection, including a review of the many features available. (See the Appendix for an explanation of DMM specifications you should know about.)

DMM Features

Though the basics—convenience, special features and price—are prominent factors in DMM selection, your fundamental consideration in selecting a DMM should be determining what types of measurements you'll be making. Will you be engaged primarily in troubleshooting power supplies and antennas, or designing and testing UHF preamplifiers and receiving systems? It doesn't make sense to purchase a 3½-digit, 99-function DMM—regardless of the price—when your work demands the precision of a 4½-digit unit (see Table 2). Similarly, spending an extra $100 for a higher-precision DMM doesn't make sense when you don't need its features. (DMM prices range from less than $100 to about $400, depending on features and purchased optional equipment.)

Basic Functions

Modern DMMs measure ac and dc voltage and current, resistance, and typically offer automatic polarity selection. The dc-voltage and current functions of a DMM are usually expressed in terms of the meter's maximum ranges and basic accuracy. DMMs are typically rated at some continuous-current value, and at a higher current for a defined period of time (eg, 10 A continuous and 20 A for up to 30 seconds).

The specifications used to describe the alternating-current- and -voltage-handling abilities of a DMM in many ways parallel those used for direct current and voltage. In addition to the accuracy figures used in dc-voltage measurements, however, ac-voltage measurement accuracy is often defined as a function of both waveform shape and frequency. For example, the ac-voltage accuracy of a DMM might be expressed as ±0.25% of the reading + 1, from 5 to 600 Hz, for a pure sine wave. With other waveforms, the accuracy of average-responding DMMs (calibrated to read the RMS value of a pure sine wave) deviates from the ideal accuracy figures.

DMM resistance specifications typically include not only basic accuracy and range,

Table 2
Comparison of DMM Digit Count, Full-Scale Count and Resolution

Number of Digits	*Counts (Full Scale)*	*Resolution (% Full Scale)*
2½	199	0.5
3	999	0.1
3½	1999	0.05
3¾	3999	0.025
4	9999	0.010
4½	19999	0.005
4¾	39999	0.0025

Table 1
DMM Vendors

American Reliance, Inc, 9241 East Valley Blvd, Rosemead, CA 91770, tel 818-287-8400.

B&K Precision, Maxtec International Corp, 6470 W Cortland St, Chicago, IL 60635, tel 312-889-1448.

Beckman Instruments, Inc, Electronic Technologies Group, 210 S Ranger St, Brea, CA 92621, tel 714-993-8803.

Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002, tel 415-592-2503.

JDR Microdevices, 2233 Branham Ln, San Jose, CA 95124, tel 800-538-5002.

John Fluke Mfg Co, Inc, PO Box C9090, Everett, WA 98206, tel 800-426-0361.

MCM Electronics, 650 Congress Park Dr, Centerville, OH 45459, tel 513-434-0031.

Omega Engineering, Inc, One Omega Dr, Box 4047, Stamford, CT 06907, tel 800-826-6342.

Radio Shack, One Tandy Center, Fort Worth, TX 76102, tel 817-390-3011.

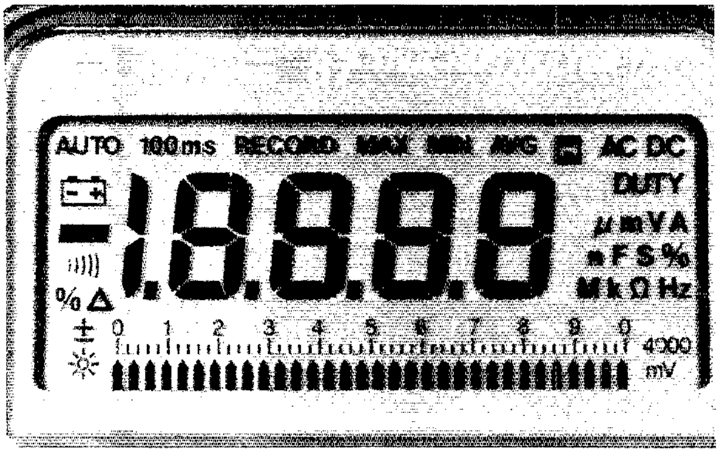

Fig 1—Modern DMMs support a variety of functions and options. As illustrated by the annunciators visible in this DMM liquid-crystal display (LCD), the features include duty cycle, frequency, and relative measurements, as well as autoranging ac, dc, and resistance measurements and autopolarity dc measurements. The segmented bar along the bottom of the display is useful for qualitatively measuring rapidly changing signals. *(photos by the author)*

but maximum test current, maximum open-circuit voltage, and provision for overload protection. Resistance-accuracy figures are often a function of the resistance range used, with lower-accuracy figures associated with the higher resistance ranges. Maximum test current (the current that flows through the test leads when measuring a short circuit) is generally near 2.5 mA for better DMMs. (Higher maximum test currents may damage sensitive components.) Maximum open-circuit voltage (the potential appearing across unterminated test probes) is generally around 500 mV in the better units.

Convenience Features

Many DMMs also provide convenience features that add to the utility of the instrument. Perhaps the most useful of these is autoranging, in which the instrument selects the most appropriate range for the function being tested. The measurement range selected must be large enough to provide adequate precision and ensure that the value falls within the most accurate part of the selected range. Accuracy figures may not be valid throughout an entire range. For instance, the accuracy figures listed for ac voltages measured with the Fluke 80 series are valid only from 5% to 100% of the range used.

Many manufacturers enhance their DMMs by providing a variety of memory functions: touch hold, peak hold, min-max, relative mode, and manual hold. Touch hold captures a reading and displays it from memory after the probes have been removed from the circuit. Often, an audible beep sounds when a stable measurement has been captured. Although peak hold captures the highest peak value measured over a period of time, the min-max feature stores the highest and lowest reading over a period of seconds or days. The relative mode stores a reading and displays the difference between it and any subsequent reading. Finally, the manual hold function commits a reading to memory at the touch of a button.

Although the basic LCD can hardly be considered a convenience feature, enhanced displays can make a DMM easier and more convenient to operate (see Fig 1). Some DMMs (the Fluke 80 series) provide a back-lit LCD), allowing measurements to be made outside at night without the need to fumble with a flashlight. For working at a distance—or for users with poor vision—some manufacturers provide extra-large readouts: 0.8-inch characters instead of the usual 0.5-inch ones. Bar graphs, integrated into the digital display, add many of the features of the analog meters. Some bar graphs are updated faster than numeric displays (40 Hz for the Fluke 87); they make dipping, peaking and nulling fast and easy. Bar graphs are especially useful when the signal to be measured is noisy (standard digital displays are useless when measuring signals with a high noise content).

In addition to the LCD, many DMMs make use of audio feedback for measurement and error-condition alerts. The safety feature on the American Reliance AR 3200 DMM generates a tone whenever 20 V is exceeded. Similarly, the Fluke 87 DMM provides an audible warning signal whenever the lead connection and the function setting disagree (as when the test lead configuration is set up for current measurement and the meter is set for voltage measurement). Some DMMs go beyond the simple alert-tone systems to support hands-free operation without the need to look up from the circuit under inspection. An option on the Beckman HD-153 adjusts the tone pitch so that it is proportional to the magnitude of the reading. At the extreme end of the scale is the Omega HHMM, a *talking* hand-held DMM. This multilingual DMM uses plug-in voice chips to support different languages!

For the forgetful, automatic shutoff and low-battery indicators are necessary features. Automatic-shutoff capabilities vary from turning off the back-lit LCD display after a few seconds to shutting down the entire instrument after an hour or so of no use. Many DMMs provide some indication of low battery conditions, as long as alkaline or zinc-carbon batteries are used. For example, the decimal point on the Beckman HD-100 blinks during the last 200 hours of battery life.

Special Functions

A large component of the attraction of modern DMMs is the wide variety of special functions they can provide. Sometimes, a dozen or more traditional bench-top instruments can be replaced with a hand-held DMM, with little or no loss in functionality. A partial list of special functions supported by DMMs include:

- Frequency measurement—specifications to consider include frequency range, accuracy, frequency measurement period, minimum pulse width, sensitivity, trigger level, and maximum input level. Few hand-held DMMs provide frequency measurement capabilities above a few hundred kilohertz.
- Capacitance—relevant specifications include capacitance range (eg, the B&K Precision 388-HD capacitance range is from 2 nF to 20 μF), test frequency (typically a few hundred Hz), and capacitance accuracy. Like stand-alone capacitance meters, the capacitance function of a DMM is useful for out-of-circuit components only. The capacitance function is especially useful when working with unmarked surface-mount capacitors.
- Inductance—as in the capacitance function, relevant specifications include accuracy, range, and test frequency. For example, the Tenma 72-370 (MCM Electronics) has a range of 1 μH to 200 H, with 2 to 5% accuracy, and a test frequency range of 2 Hz to 1 kHz.
- Transistor h_{Fe}—many DMMs provide transistor sockets to facilitate testing transistor dc gain.
- Diode test—relevant specifications include test-voltage range, resolution, accuracy, and test current. Functional silicon diodes should show a forward voltage drop of approximately 0.6 V, and the full test voltage on reverse. A shorted diode (or other semiconductor junction) will show the same forward and reverse voltage drop.
- TTL level—the functionality of the familiar TTL probe can be replaced by a number of DMMs (eg, the Beckman DM25). Relevant specifications include minimum pulse width.
- Audible continuity test—specifications

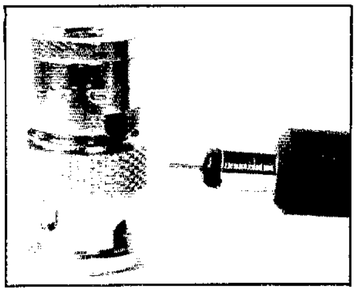

Fig 2—RF measurements are best performed with an RF probe. The Fluke model 85RF assembly shown here is usable to 500 MHz with an accuracy of ±0.5 dB for RF signals with an amplitude of at least 0.5 V.

include trigger resistance and response time. Although these figures vary widely from DMM to DMM, most trigger from zero to a few hundred ohms, with response times around 100 ms. The audible continuity test feature makes it possible to concentrate on the circuitry under test, without the need to look at the meter.

- Duty cycle—what's important here is the duty-cycle range supported. For example the Fluke 87 provides duty-cycle measurements from 0.1 to 99.9%.
- Self test—some DMMs provide an automatic means of checking their own internal fuses and basic operation without opening the case.

Accessories

Most manufacturers offer accessories that extend the functionality of their DMMs. Such add-ons range from DMM holsters to hook-tip, RF, specialized temperature, high-voltage and high-current probes. Holsters are useful in that they not only afford a degree of shock protection, but can also hold test leads, provide a belt hook, and perhaps a tilt bail. RF probes (see Fig 2) are essential for troubleshooting RF gear. Similarly, HV probes make it possible to use the DMM for measurements in tube-type transmitter circuits, high-voltage power supplies, and computer and oscilloscope CRT circuits. Clamp-on current probes allow current measurements of several hundred amperes at reasonable accuracy (2-3%) at frequencies from dc to a few hundred hertz. Some DMMs have built-in temperature-measurement capabilities: All that's needed to accurately measure temperatures is a K-type thermocouple lead (see Fig 3). Virtually any DMM can be extended to support temperature measurement with an external temperature-probe interface, available from DMM manufacturers and numerous third-party vendors.

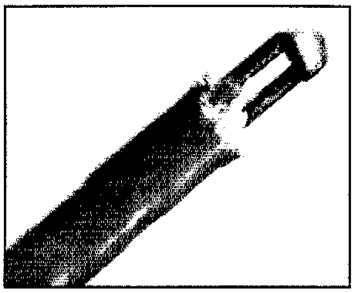

Fig 3—Highly accurate temperature measurements can be obtained with a DMM and thermocouple interface module. Exposed-bead probes, such as the Fluke 80PK-1 (above), are designed for general-purpose temperature measurements from approximately −40 to 260 °C.

Ergonomics

Regardless of its price and variety of functions, a DMM is useless unless the user interface is both easy to learn and efficient. The display layout, the dimensions and weight of the instrument, and the manner in which functions are selected (ie, via a rotary switch or a row of push buttons), define the ergonomics of the system. Pen-type units provide fewer functions, but are lightweight and easy to carry around. In contrast, hand-held units are better than pen-type units if tight spaces must be accessed (the probes are thinner and more flexible than those of pen-type DMMs).

Although packaging in many ways defines the ergonomics of a DMM, it can also influence the life of the instrument. Some DMMs are designed to operate in less than clean-room environments. Specifications range from "splashproof" and "dustproof" to totally sealed units designed for harsh industrial environments. Shock and vibration ratings range from "four-foot-drop resistant" to "meets mil T-28800 specs."

The Future of DMMs

What's in the future for the hand-held DMM? If trends continue, basic functionality should include higher sampling rates, greater resolution and greater accuracy. Frequency-counting capabilities should move up from a few hundred kilohertz to 20 MHz and beyond. If hand-held DMMs follow the lead of bench-top units, we should see hand-held units support RS-232-C/EIA-232-D and IEEE 488 interfaces, allowing data to be collected and analyzed by PC-based programs.[1]

APPENDIX

When selecting a DMM for your work, pay particular attention to the unit's specifications. If the specifications relevant to your needs aren't mentioned, assume the DMM is inferior in those respects. The following information should be helpful in your evaluation of DMM specifications:

Accuracy—a measure of closeness of the displayed value to the actual value of a quantity. Accuracy is a function of the standards used to calibrate the instrument, the precision of the instrument, and the cumulative effects of a variety of environmental factors: temperature, humidity, magnetic and electrostatic fields, mechanical stability, shock, vibration and position.

Digital accuracy is usually specified as plus or minus a percentage of the reading plus a number of counts of the least-significant digit; for example, ±0.05% + 1 count, within a specified environment, 23 °C ±5 °C and 75% maximum relative humidity. That is, an accuracy of ±0.05% + 1 count on a 4½-digit DMM that's used to measure 10.000 V can be expected to have an accuracy of ±(5 mV + 1 mV) out of 10.000 V, or ±6 mV/10.000 V = ±0.06%.

Bandwidth—the difference between the upper and lower frequencies passed by the instrument. Wider bandwidth improves response time, but makes the instrument more susceptible to interference from noise. Bandwidth limitations can become critical when adequate response to time-varying signals is required.

Calibration—determining the accuracy and linearity of an instrument at several points. DMM calibration is normally performed by factory personnel, on an annual or as-needed basis.

Conversion rate—the frequency at which readings are processed by the instrument. Related to conversion rate is the *conversion time*, the maximum time required for an instrument to complete a reading cycle, typically specified for the full-scale reading.

Crest factor—the ratio of a signal's peak value to its RMS value. The crest factor of an ac waveform is a function of its harmonic content; distortion or greater harmonic content increase the crest factor. The crest factor of a DMM is its capacity to process (without saturating the system or degrading accuracies) waveforms that have a large peak value compared to their RMS value.

The crest factor becomes important when you attempt to measure noisy signals or pulses. For example, Beckman produces a DMM with a crest factor of 5:1 (a pure sine wave has a crest factor of 1 ÷ 0.707 or 1.414). A crest factor of 5:1 makes it possible to measure accurately a dc signal (crest factor 1:1) with a superimposed signal that has a peak value of up to 5 times greater than the RMS value being read. If a DMM with a crest factor rating of 5 is used on the 200-V RMS range, the peak value should not exceed 5 × 200 V, or 1000 V. If the peak value exceeds 1000 V, a higher range should be used, because the crest factor rating of a DMM is generally based on full-scale range. Though the crest factor rating of a DMM may be fixed, it is sometimes specified at half and full scale.

Input impedance—the impedance of the instrument, as seen by the circuit being measured, expressed as a dc resistance and a parallel capacitance. A typical input impedance for a modern DMM is 10 to 20 MΩ with a parallel or shunt capacitance of less than 100 pF. The better instruments provide a high input impedance and a low shunt capacitance. A high input impedance

[1]G. Jacob, "DVMs/DMMs: DMMs Communicate, Self-Calibrate, Provide More Functions," *Evaluation Engineering*, Aug 1989, pp 26-30.

minimizes circuit loading, and a low input shunt capacitance increases the frequency range over which you can use the instrument.

Noise—Noise can be introduced into a DMM by mechanical coupling, and electrostatic and magnetic fields. Better-quality DMMs are shielded against electromagnetic interference (EMI). The shielding reduces the effect of externally generated noise on the DMM and minimizes the effect of signals generated within the DMM on the equipment under inspection.

Two noise figures commonly associated with DMMs are common-mode noise rejection (CMNR) and normal-mode noise rejection (NMNR). To understand these terms, assume that each DMM lead normally has a potential with respect to local earth ground. The instantaneous algebraic average of these potentials, relative to a common reference, is called the common-mode voltage. In comparison, the difference in potential between the two leads (the normal case) is the normal-mode voltage. Normal-mode noise can be minimized by twisting the DMM test leads together, thereby reducing interlead differences in inductive and capacitive noise pickup. Unfortunately, this simple technique does not affect common-mode pickup. High common-mode rejection, essential for low-level voltage and current measurements, is largely a function of instrument design. Typical values for CMNR and NMNR in better DMMs are greater than 60 dB above 49 Hz, and more than 140 dB up to 1500 V dc, respectively.

Offset current—the current flowing into an instrument from the circuit being tested during voltage measurement. Low offset current reduces errors that result from circuit loading. A DMM should present a high input impedance, relative to the source or circuit impedance, to minimize offset currents and circuit loading.

Overload protection—provisions for handling unexpected high voltages and currents without permanent damage to the measuring instrument. DMMs vary in the form and extent of overload protection provided. Although fuses are usually used for current protection, less-expensive units may not be fused. Also, fusing is sometimes used on some ranges, but not on others.

Power requirements—what is important here is how DMM power requirements translate into battery cost, size and expected life. Battery life appears to be more a function of DMM design than the total number of features supported. Modern, feature-packed DMMs that make use of CMOS LSI chips have expected battery-life figures in excess of several thousand hours. In comparison, the power requirements of DMMs that use less-sophisticated circuit designs (although often inexpensive) are such that battery life may not exceed 100 hours.

Precision—a measure of the spread of repeated measurements of a given quantity. Precision (sometimes expressed in terms of the number of significant digits) depends on the resolution and stability of the measuring instrument. Although precision is often confused with accuracy, the two are distinct. A DMM or other instrument may provide precise readings that are inaccurate due to errors in calibration or use.

Range—the values of the input variable over which an instrument is designed to provide accurate measurements.

Repeatability—the ability of an instrument to provide consistent and repeatable results. The repeatability of a measurement in no way guarantees accuracy: A measurement may be consistently high or low.

Resolution—the smallest increment of the measured quantity that can be resolved. As illustrated in Table 1, DMM resolution depends on the full-scale range and the number of digits or counts that can be displayed. The display resolution is the ratio of the smallest count to the maximum count, eg, 1/20,000 or 0.005% for a 4½-digit display. A 3½-digit DMM can display 3 whole digits (0-9) plus a leading "half digit" (0 or 1). A 4½-digit DMM can display 4 whole digits plus a leading half digit (ie, 0-19999), a total of 20,000 counts. The 3¾- and 4¾-digit DMMs can display three and four whole digits, respectively, plus a leading "three quarters" digit between 0 and 3. So, if a 3½-digit DMM has a resolution of 1 part in 2000 (0.05%) over a full-scale range of 199.9 mV, then the instrument can resolve levels of 0.1 mV. The resolution of even the best instrument is limited by the signal-to-noise ratio of the system under inspection.*

Response time—the time between test-probe contact with the circuit under inspection and a stable reading on the instrument. DMM response time is typically different for ac and dc voltage, current, resistance, and other types of measurements. Response time varies from a few tenths of a second to several tens of seconds depending on the DMM design and the type of measurement being performed. Response time is generally worse for high-resistance measurements. In addition, most DMM response-time figures assume manual ranging. Autoranging generally increases response-time figures.

Sample rate—the rate at which voltage, current, or other parameters are sampled by the instrument. The sampling rate of a DMM is basically the sampling rate of its A/D converter. Sample rates vary from about 1 Hz on less-expensive units to 40 or 50 Hz on more capable DMMs (bench-top DMMs can provide sample rates in the 100-kHz range).

Sensitivity—the ability of an instrument to measure low-level quantities. In general, DMMs are not designed to make low-level measurements, and may provide insufficient sensitivity, stability, and accuracy at low signal levels. Because of their lack of sensitivity, high input-offset current, high input-offset voltage, and low input resistance (compared to more-sensitive instruments such as nanovoltmeters and electrometers), DMMs are unsuitable for measuring currents below 1 nA, resistances above 100 MΩ, voltages with a source resistance greater than 1 MΩ, or current if the input voltage burden must be less than a few hundred millivolts (or when measuring currents from sources of a few volts or less).

Stability—the ability of an instrument to maintain its nominal operating characteristic, as a function of changes in time (temporal stability), ambient temperature (thermal stability), relative humidity, and other environmental factors. Because DMM component values are expected to drift over time, instrument specifications are normally given in terms of time since calibration. For example, accuracy specifications typically apply for one year after purchase (assuming a short period between calibration and sale of the instrument). The calibration period is commonly specified as one year.

Ambient temperature can affect accuracy. Specifications are therefore normally given for a particular operating temperature range, eg, 18 to 28 °C. Outside the specified operating temperature range, a temperature-correction coefficient, such as ±(0.005% + 0.1 count)/°C, must be used to correct the displayed measurement. Corrections for the ambient temperature would come into play, for example, if you are working on an antenna or other outdoor equipment in the dead of winter or in the trunk of your automobile in the middle of summer. Although relative humidity, like ambient temperature, affects the accuracy of a DMM, instrument manufacturers rarely specify a relative-humidity correction coefficient. Instead, specifications typically list a maximum relative humidity value, eg, 75%.

Standardization—the process of adjusting an instrument so that the readings at one specific value are in correspondence with an internationally recognized voltage, resistance, or frequency standard.

True RMS vs averaging—whether the instrument responds to the true RMS (root-mean-square) value of a waveform or the average value. Most analog meters and inexpensive DMMs are average-responding meters on the ac voltage and current ranges: They use a diode bridge to change the ac signal to dc and drive the display. To obtain the RMS voltage or current, a constant calibration factor is used. Although the use of a fixed calibration factor works for pure sine waves with no harmonics, it can introduce substantial errors when square waves, sawtooth waves or sine waves with harmonics are measured.

True RMS DMMs do not employ a constant calibration factor to determine the RMS value of the voltage or current under investigation. Instead, an on-board microprocessor calculates the root of the average of all the squared values of current or voltage over a period of time. Some true RMS DMMs use only the ac component of the signal; these instruments are accurate only for signals symmetrical about zero.

When using ac-true RMS DMMs, you must measure the ac component and dc components separately, and take the root of the sum of their squares for the (ac + dc) RMS value. DMMs rated as true RMS (ac + dc) make this calculation for you.

Voltage burden—the voltage drop across a DMM or other instrument during current measurement. Obviously, the voltage burden should be as small as possible.

Error Sources

Errors are commonly categorized as either *systematic* or *random*. Systematic errors are related to deficiencies in the instrument or measurement system. For example, loading caused by an instrument with an insufficiently high input impedance results in consistently lower-than-actual voltage readings. Random errors, in comparison, are accidental and inconsistent. Although noise and environmental factors are normally associated with random errors, they may also contribute to systematic errors.

*J. F. Keithley, J. R. Yeager and R. J. Erdman, "Low Level Measurements," 1984 Keithley Instruments, Inc, Cleveland, OH.

Antenna Here is a Dipole

You've probably heard this phrase in many QSOs. Just what *is* a dipole antenna, and why are they so popular?

By James W. ("Rus") Healy, NJ2L
Assistant Technical Editor

Dipole antennas have been widely used since the early days of radio. Simplicity and effectiveness for a wide range of communications needs are the reasons for this—and they're also the properties that make dipoles worthy of your consideration. There's more to building and installing an effective dipole antenna system than choosing the wire and insulators, as you'll see. Next month, I'll discuss choosing the right feed line for your dipole, and related subjects.

What is a Dipole?

The dipole gets its name from its two halves—one on each side of its center (see Fig 1). (In contrast, a *monopole* has a single element, usually fed against ground as a vertical.) A dipole is a *balanced* antenna, meaning that the "poles" are symmetrical: They're equal lengths and extend in opposite directions from the feed point. In its simplest form, a dipole is an antenna made of wire and fed at its center as shown in Fig 1. (This may look familiar: You may have received a QSL card with a sketched dipole, resembling Fig 1, to denote the antenna the other station used during your contact.)

To be *resonant*, a dipole must be electrically a half wavelength long at the operating frequency. A dipole's resonance occurs at the length at which its impedance has no reactance—only resistance—at a given frequency. As it turns out, that resonant impedance range is compatible with many common coaxial feed lines. Within limits, however, resonance isn't necessary for a dipole to be effective, as I'll explain a bit later. Resonant half-wave dipoles range in size from about 16 feet for the 10-meter band (28-29.7 MHz) to 260 feet for the 160-meter band (1.8-2 MHz). See Table 1.

The lowest frequency at which a dipole is resonant is known as its *fundamental resonance*. A dipole works best at and above its fundamental-resonant frequency. But if a total-length limitation imposed by property boundaries or the spacing of available supports keeps you from doing this, make the antenna as long as you can, even if it's not a half wavelength. Resonances repeat, for half-wavelength-long dipoles, at *odd multiples* of the fundamental-resonant frequencies. For instance, a dipole resonant at 2.5 MHz is also resonant at 7.5 MHz, 12.5 MHz, and so on. These higher-frequency resonances are known as *harmonic resonances.*

As I mentioned earlier, a dipole doesn't have to be resonant to work well. More important than resonance are good construction and efficient power transfer from the transmitter to the antenna. Using an antenna tuner, you can match dipoles that are far longer or shorter than resonant length, but the feed line plays an important role in efficient power transfer, as I'll discuss next month. If you're primarily interested in operating on only one band, a resonant dipole is a good choice. If you're interested in multiband operation with a single antenna, the picture is a bit different. In this situation, it's a good idea to make the antenna resonant at the lowest frequency you plan to use it on (that's where the antenna is longest, because antenna length is proportional to wavelength).

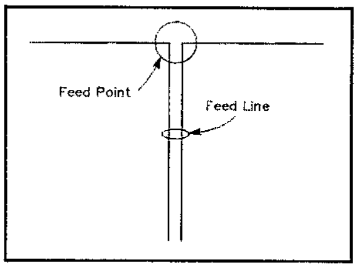

Fig 1—One of the simplest antennas used by hams, the dipole is also one of the most effective, considering the relatively small space it requires. In its simplest form, a dipole is a wire fed at its center.

Table 1
Approximate Lengths of Half-Wave Dipoles for the MF/HF Ham Bands*

Frequency	*Length*
28.4 MHz	16 ft, 6 in.
24.9 MHz	18 ft, 10 in.
21.1 MHz	22 ft, 2 in.
18.1 MHz	25 ft, 10 in.
14.1 MHz	33 ft, 2 in.
10.1 MHz	46 ft, 4 in.
7.1 MHz	65 ft, 11 in.
3.6 MHz	130 ft
1.8 MHz	260 ft

*General equation for half-wave dipole length: $\ell = 468 \div f$, where ℓ is length in feet and f is frequency in megahertz. This equation yields good starting points; you may have to lengthen or trim your antenna to achieve resonance. See the sidebar entitled "Dipole Construction and Adjustment."

Why are Dipole Antennas so Popular?

For almost any kind of MF/HF operation, dipoles are easy to build and install, and they give good results when put up at any reasonable height. "Reasonable heights" are anywhere from a few feet and up, depending on the band. A good general height guideline is half a wavelength or more, but that's impractical for many of us, especially on 40, 80 and 160 meters. At the least, a dipole should clear any surrounding buildings, and other large obstacles, for good performance.

Many hams do quite well with dipole antennas that are electrically low; for instance, an 80-meter dipole strung between two trees at 50 feet (less than a quarter wavelength) allows me to work Europeans regularly on 80-meter CW with a 100-watt transceiver. As a bonus, this antenna works even better at higher frequencies, where it's electrically much farther above ground, as I'll also discuss later.

Variations on the Theme

Part of the beauty of dipole antennas, like many other simple things, is their flexibility. Dipoles can be installed in an infinite number of configurations other than the classical flat-top arrangement (Fig 1). Some of the more common variations include the inverted V (sometimes called the drooping dipole—Fig 2A [page 26]); parallel-multiband dipole (Fig 2B); sloping dipole (*sloper*—Fig 2C); vertical dipole (Fig 1, rotated 90°); folded dipole (Fig 2D); and trap dipole (Fig 2E).

Inverted-V dipoles are probably more common than flat-top versions. As you might expect, the inverted V gets its name from its shape. The main advantages of inverted Vs are that they need only one high support, and that you can get more total wire into the same horizontal space using

Dipole Construction and Adjustment

Dipoles can be made of almost any kind of wire or tubing, but how well they work and how long they last is determined by the quality of the parts and care you use in building them. With that in mind, here's what it takes to make a dipole antenna.

• *Wire.* Stranded and solid copper, and copper-plated steel (Copperweld), are the most popular types used for antenna construction. Don't use soft, solid copper (such as house wire) for long unsupported runs in resonant antennas; solid wire can stretch enough after installation to detune the antenna. Use reasonably large wire (no. 16 or larger) for permanent antennas. No. 18 or smaller wire is generally okay for low-profile or temporary antennas, or those cut for 14 MHz or higher frequencies. There's little difference between antennas made from insulated and uninsulated wire, although the presence of insulation generally lowers the resonant frequency of a given length of wire by a bit. Insulated wire is heavier and thicker, which, depending on its color, can make it more or less visible than its uninsulated equivalent. Davis RF (see "Where to Get the Pieces") carries uninsulated, stranded no. 14 copper that's made of 168 strands of wire. This is good stuff for dipoles (or home-brew balanced feed lines) because it's very flexible and easy to work with, doesn't stretch, and resists breakage well.

• *Insulators.* A dipole should have insulators (Fig A) at its center (feed point) and at each end, where ropes (or other restraints) support the antenna. The center insulator serves two primary purposes: (1) it separates and supports the feed-line conductors, making for strong mechanical wire joints that minimize stress on solder joints; and (2) it gives you a convenient place from which to support the dipole with a rope, if your dipole is center-supported. End insulators serve another purpose: They provide an isolated support point at the high-voltage ends of the antenna wire. (Potentials at the ends of a resonant dipole can be in the kilovolts—even with just a 100-watt transmitter!)

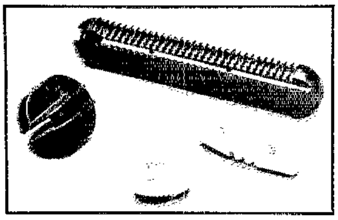

Fig A—Several varieties of insulators are commonly available to hams. The lower-center ceramic unit and the plastic insulator on the left are current Radio Shack products. The others, and close variants, are available from many mail-order sources (see "Where to Get the Pieces").

Plastic, ceramic or porcelain insulators are fine for most applications. Home-made varnished hardwood is also acceptable. There's no need to use a special center insulator at a dipole's feed point—the impedance, and therefore the RF voltage, there is low—although doing so can make construction easier.

• *Rope.* Nylon, Dacron and similar materials are best. Avoid polypropylene; it rapidly deteriorates in sunlight. Also avoid hemp and other natural materials. They tend to stay damp and rot in the center after getting rained on, with no outwardly visible signs of damage. If you select nylon rope, use the braided variety and carefully seal its cut ends by melting them with a match or cigarette lighter. This rope is very strong, but unlike Dacron, it also initially stretches as much as a few percent.

To make a dipole that'll stay up and that's easy to work on, using the right knots is important. Learn (or relearn) to tie a *bowline* (an unsliding loop); a *clove hitch* (for attaching rope to poles, tower legs, and such); a *taut-line hitch* (a sliding knot for adjusting the tension in a rope); and a *sheet bend* (for joining the ends of two ropes). These knots are simple to tie, and are described in every edition of the Boy Scout *Handbook* and *Fieldbook*, as well as some merit badge booklets (look under Boy Scouts of America in the Yellow Pages for local suppliers of BSA materials). Another good reason to be acquainted with these knots: When (if) you start working on towers (or other supports) and bigger antennas, these knots can save your *life*, not to mention your hardware.

• *Soldering.* To make permanent

this configuration. This is often an important advantage on the lower-frequency bands, where real estate and support height suitable for putting up a full-size dipole are at a premium. Inverted Vs usually work almost as well as horizontal flat-top dipoles when the dipole's height is the same as the feed-point height of an inverted **V**. It's important to keep the antenna ends high enough above the ground so that people, vehicles and such can't come into accidental contact with them.

Another common dipole configuration is the multiband parallel version. In such an antenna (Fig 2B), multiple dipole elements are fed at the same point, with a single feed line, and supported by spacers attached to the longest dipole element. The main advantage of parallel dipoles is multiband coverage with resonant elements on each band, allowing the use of a single coaxial feed line for several bands without

Where to Get the Pieces

Here's a brief list of suppliers of wire, insulators, feed line, connectors, and other items you'll need for making and installing dipole antennas. For a more complete list, see the advertisements in this and other issues of *QST*.

• Radio Shack stores (antenna wire, coaxial cable, ceramic and plastic insulators, connector-sealant tape and other supplies). See 1991 catalog, page 137.

• Davis RF, PO Box 230, Carlisle, MA 01740, tel 508-369-1738 or 800-484-4002, extension 1356 (high-flexibility antenna wire, coaxial cable, several varieties of prefabricated balanced line [and parts to make your own], ceramic insulators, aluminum tubing and other supplies). Catalog available.

• Ocean State Electronics, PO Box 1458, Westerly, RI 02891, tel 401-596-3080, fax 401-596-3590 (antenna wire, coaxial cable and connectors, 300-Ω twinlead, insulators). Catalog available.

• Certified Communications, Rte 2, Pittman Rd, Landrum, SC 29356, tel 803-895-4195 (coaxial cable, balanced feed line).

• The Radio Works, PO Box 6159, Portsmouth, VA 23703, tel 804-484-0140, fax 804-483-1873 (antenna wire, coaxial cable and connectors, balanced feed line, baluns, insulators, rope, sealant and other supplies). Catalog available.

• Most major Amateur Radio equipment dealers (Amateur Electronic Supply, Ham Radio Outlet, and other *QST* advertisers) carry parts for dipole construction.—*NJ2L* connections that will stand up to wind and weather, you'll need a soldering device that can quickly heat the wires to be joined. A 30-W iron probably won't do an acceptable job with wires larger than no. 16; a 100-W or larger soldering gun is best. If you're using relatively heavy wire and ceramic or porcelain insulators, you can use a propane torch (preferably with a soldering tip) for soldering. (If you do this, heat the joint first, then remove the flame and let the heat of the wires melt the solder into the hot junction.) Use 60/40 (or similar) rosin-core solder (available from Radio Shack and most hardware stores). Use caution when soldering close to plastic insulators; too much heat will damage them. Don't breathe solder or insulation fumes!

• *Tape, sealant and similar protective coverings.* Protect your solder joints and feed-line connections from the weather after soldering by tightly wrapping them with high-quality electrical tape (such as Scotch 33 or 88) or silicone adhesive tape, or covering them with Coax-Seal (or equivalent). Solder joints at end insulators can be sufficiently protected by spraying them with clear lacquer, available from most hardware and home-supply stores. Weather-proofing properly soldered end-insulator joints is optional, but *seal the center insulator* as if you were planning to use it underwater. The last thing you want is rainwater in your coax!

In dipole construction, it's important to make strong mechanical junctions in the wires. An antenna that depends solely on solder joints to handle wind stresses will surely fall down sooner than one that's made with good mechanical connections. RF interference can also result from deteriorated solder joints. Fig B shows how to make a solid mechanical connection at an insulator.

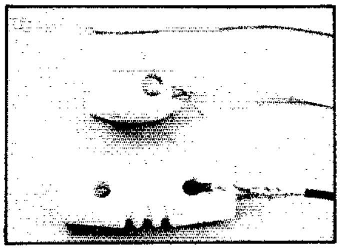

Fig B—Secure end-insulator connections are important to long antenna life. Top to bottom: Leave part of the insulation from the wire end to protect the wire where it goes through the insulator eye; wind several turns of wire back on itself to make a strong mechanical connection; solder the joint; and spray it with clear lacquer to prevent corrosion.

Bringing a Dipole "On Frequency"

To resonate a dipole that's fed with coaxial cable, select a band and cut the wire a couple of feet longer than the appropriate length shown in Table 1. Then, install center and end insulators and attach the coaxial feed line (Fig C shows how to attach coaxial feed line to a dipole). Support the antenna a few feet above ground, measure the SWR and trim the antenna (equally from each end) to raise the resonance to the desired frequency. If the antenna is too short, splice in some additional wire, or attach equal amounts at the end insulators and let it hang from them. Copper-and-brass split-bolt clamps, made for attaching copper ground wires together and available from most home-improvement stores, are great for making these additions.

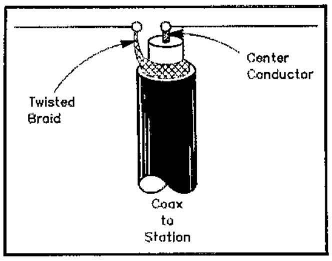

Fig C—Coaxial cable feeding a dipole antenna. The center insulator is omitted for clarity. When measuring and adjusting a dipole fed with coax, keep in mind that the stripped coax center-conductor and shield lengths *add to the antenna length.*

Selecting supports and installing antennas is the subject of many other articles. See the references listed under "Further Reading" for a few of these.—*NJ2L*

Further Reading

For more information on antenna construction and installation, see the references listed below. The issues of *QST* cited here may be available at your local library; if not, contact the Technical Department Secretary at ARRL Headquarters (see p 3 of this issue) for any photocopies you need. (There is a nominal charge for this service.)

• G. Hall, Ed., *The ARRL Antenna Book*, 15th ed (Newington: ARRL, 1987). If you're aware of this book, you may think that it's a highly technical reference intended for those with lots of antenna knowledge and experience. In truth, it's intended for hams at all experience and license levels, and even those who aren't yet licensed. All of the subjects I've covered in this article are treated from basic to detailed levels in *The ARRL Antenna Book*, and it should be the key reference in your quest for antenna wisdom.

• C. Hutchinson and L. Wolfgang, Eds, *The ARRL Handbook for Radio Amateurs*, 1991 ed (Newington: ARRL, 1990). Chapter 17, "Antenna Fundamentals," provides a good technical introduction to dipole theory and feeding.

• D. Brede, "The Care and Feeding of an Amateur's Favorite Antenna Support—The Tree," *QST*, Sep 1989, pp 26-28, 40.

• W. Calvert, "The EZY Launcher," elsewhere in this issue.—*NJ2L*

the need for an antenna tuner. An inherent disadvantage of parallel dipoles, however, is narrower bandwidth than single dipoles provide.

Two other fairly popular dipole variations are the trap dipole and the folded dipole. Traps are tuned circuits (consisting of inductance and capacitance) that electrically isolate the inner and outer sections of the antenna at certain frequencies, providing multiband resonant coverage from a single antenna. At a trap's resonant frequency, it presents a high impedance and therefore isolates the outer segments of the dipole, making the antenna electrically shorter than it is physically. At frequencies below the trap's resonance, it has a low impedance, which makes it transparent to RF (ie, it doesn't isolate any part of the antenna).. Traps aren't used only in dipoles:

range over which you can use the instrument

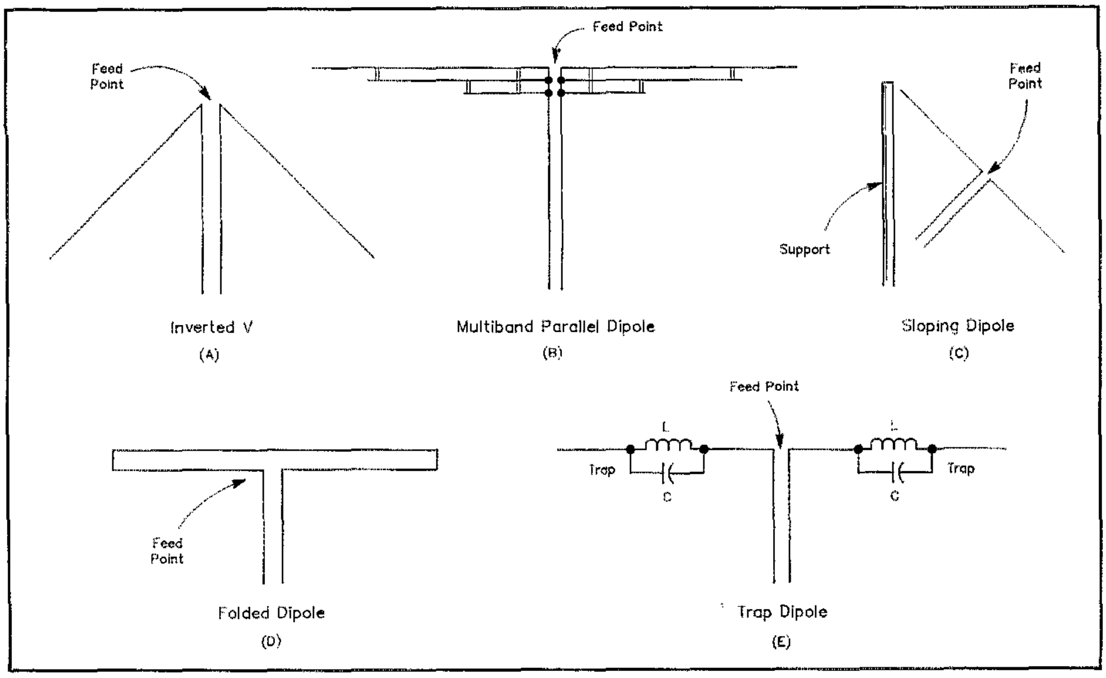

Fig 2—Variations on the dipole are numerous: at A, an inverted V; at B, a multiband parallel dipole; at C, a sloping dipole (sloper); at D, a folded dipole; and at E, at trap dipole. Dipoles of the multiband parallel, trap and folded varieties can be installed in sloping or inverted-V configurations.

Trap Yagi beams and verticals are also popular. Folded dipoles are a bit less common in Amateur Radio use; they use full-length parallel wires shorted at the ends, and have feed-point impedances that provide good matches to balanced feed lines. FM-broadcast receivers usually use folded dipoles made from TV twinlead. *The ARRL Antenna Book* and *The ARRL Handbook* cover trap and parallel dipoles in more detail (see "Further Reading").

The Dual-Band Dipole

Two popular ham bands, especially for Novice and Technician Class operators, are those at 7 and 21 MHz. As mentioned earlier, dipoles have harmonic resonances at odd multiples of their fundamental resonances. Because 21 MHz is the third harmonic of 7 MHz, 7-MHz dipoles are harmonically resonant in the popular ham band at 21 MHz. This is attractive because it allows you to install a 40-meter dipole, feed it with coax, and use it without an antenna tuner on both 40 and 15 meters.

But there's a catch: The third harmonic of the Novice 40-meter allocation (7100-7150 kHz) begins at 21,300 kHz; yet the Novice segment of 15 meters is 21,100-21,200 kHz. As a result of this and other effects, a 40-meter dipole does not provide a low SWR in the 40- *and* 15-meter Novice segments without a tuner.

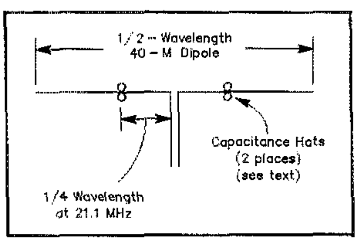

Fig 3—Figure-8-shaped capacitance hats, made and placed as described in the text, can make your 40-meter dipole resonate anywhere you like in the 15-meter band.

An easy fix for this, as shown in Fig 3, is to *capacitively load* the antenna about a quarter wavelength (at 21.1 MHz) away from the feed point in both wires. Known as *capacitance hats*, the simple loading wires shown lower the antenna's resonant frequency on 15 meters without substantially affecting resonance on 40 meters.

To put this scheme to use, first measure, cut and adjust the dipole to resonance at the desired 40-meter frequency, as described in the sidebar called "Dipole Construction and Adjustment." Then, cut two 2-foot-long pieces of stiff wire (such as no. 12 or no. 14 house wire) and solder the ends of each one together to form two loops. Twist the loops in the middle to form figure-8s, and strip and solder the wires where they cross. Install these capacitance hats on the dipole by stripping the antenna wire (if necessary) and soldering the hats to the dipole about a third of the way out from the feed point (placement isn't critical) on each wire. To resonate the antenna on 15 meters, adjust the loop shapes *(not while you're transmitting!)* until the SWR is acceptable in the desired segment of the 15-meter band. You can make all these adjustments with the dipole just a few feet off the ground; raising the antenna to its permanent height shouldn't shift the SWR much. Recheck the antenna's 40-meter resonance before raising it, though.

Feed-Line Considerations

The antenna wire and insulators, how you put them together and where you string them up is only part of a dipole-based antenna *system*. Next month, I'll cover selecting and using a feed line for your dipole(s). In the meantime, I suggest that you have a look at the two parts of Dave (WJ1Z) Newkirk's article, "Connectors for (Almost) All Occasions," in the April and May issues. QST

Build a Universal VFO

This VFO can be built for any of several popular HF bands. It has two power-output levels for driving active or passive mixers. A frequency offset circuit is included.

By Doug DeMaw, W1FB
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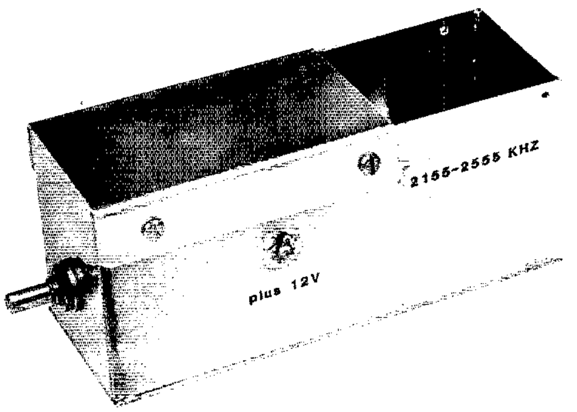


Nothing is truly "universal," but this VFO comes close. For one thing, it is universal with respect to providing low or high output power. The addition of one capacitor and one jumper wire makes this possible. For another, the VFO PC board requires no pattern changes regardless of operating frequency. All that's necessary for getting this VFO to cover your chosen frequency is to select the proper component values. These are presented in Table 1.

This VFO can used with nearly any circuit that requires a tunable oscillator. For example, you may want to use it with a direct-conversion or superheterodyne receiver that you're planning to build. You can also use it with your favorite transmitter circuit or, perhaps, as a signal generator.

Circuit Information

Fig 1 shows the circuit for the universal VFO. A few pointers are in order here. Q1 and its associated components form a Hartley oscillator circuit. Although generic MPF102 types can be used at Q1 in place of the 2N4416, the oscillator output may be lower than that achievable with a worst-case 2N4416. All other things being equal, JFET-oscillator output power is largely dependent on the device standing current, a quantity closely related to device I_{DSS} (zero-gate-voltage drain current). The greater the I_{DSS}, the more power output. The MPF102's I_{DSS} is specified as 2 to 20 mA, while the 2N4416's is specified as 5 to 15 mA.[1]

VFO stability will be best if you choose proper capacitors for the frequency-determining part of the oscillator. NP0 ceramic capacitors are best for use at C1, C5 and C7 in Fig 1. Trimmers C3 and C4 offer best stability if they are miniature air trimmers or NP0 ceramic units. Avoid using low-cost plastic trimmers in any VFO.

A toroid coil at L1 is okay if you use thermally stable core material and if you cement the coil turns securely to the toroid after the assembly is wound. At MF and HF, no. 7 powdered iron core material is the most stable,[2] but may be hard to obtain. No. 6 material is the next best (and an entirely practical) choice. Thus, I recommend T-68-6 toroids available from Amidon, Palomar, RADIOKIT and other suppliers for L1 in this VFO. General Cement Corp Polystyrene Q Dope is an excellent coil cement for keeping the turns in place on the core. Ceramic coil forms provide good VFO stability. They are often available as surplus. The turns on these coils should also be coated with Q Dope.

Main-tuning capacitor C2 must be a double-bearing type (bearing at each end of the rotor) for best stability. It should turn easily to prevent backlash. The temperature coefficient of aluminum is not as good as that of brass. Therefore, try to find a variable capacitor that has plated brass or steel plates.

Now, back to the overall VFO circuit. Output from Q1 is taken from its source and supplied to a JFET buffer stage, Q2. The high input impedance of Q2 (100 kΩ because of R3) ensures minimum loading of Q1. This buffer is RC coupled to linear amplifier Q3, which uses negative or degenerative feedback to make it stable and to provide good bandwidth. This eliminates the need for tuned circuits after the oscillator. Low-level output can be taken at 50 ohms from the secondary of T1. C12 is optional, should you want to take your low-level output at 200 ohms, which yields a higher RF output voltage.

An additional class-A linear amplifier (Q4) is available when greater output power is needed. An example of this need is when we require, say, +7 dBm for injecting into a diode-ring mixer or balanced modulator. To activate Q4, merely add C20 and W1 to the PC board and take the output from T2's secondary.

D3 and D4 in Fig 1 perform as a dc switch that adds C4 to the circuit. This is a frequency-offset control that can be used to shift the VFO off the receiver frequency during standby periods, thus avoiding an annoying carrier on frequency. The oscillator continues to run and this prevents short-term drift between receive and transmit. You may want to use the offset circuit to provide the necessary 700-Hz offset (lower) for the transmit mode of a transceiver or trans-receiver. The minimum capacitance of C4 needs to be low (1 or

ARRL Lab Test Results

Testing performed in the ARRL Lab showed the following:

Frequency range: 2.137-2.586 MHz.

Frequency shift (via the OFFSET CONTROL *terminal)*: Max frequency—2.4 kHz; min frequency—5.9 kHz.

Frequency drift: less than 100 Hz in initial 4 minutes.

Power output: 12.0-V supply—22.3 dBm.

[1]Notes appear on page 29.

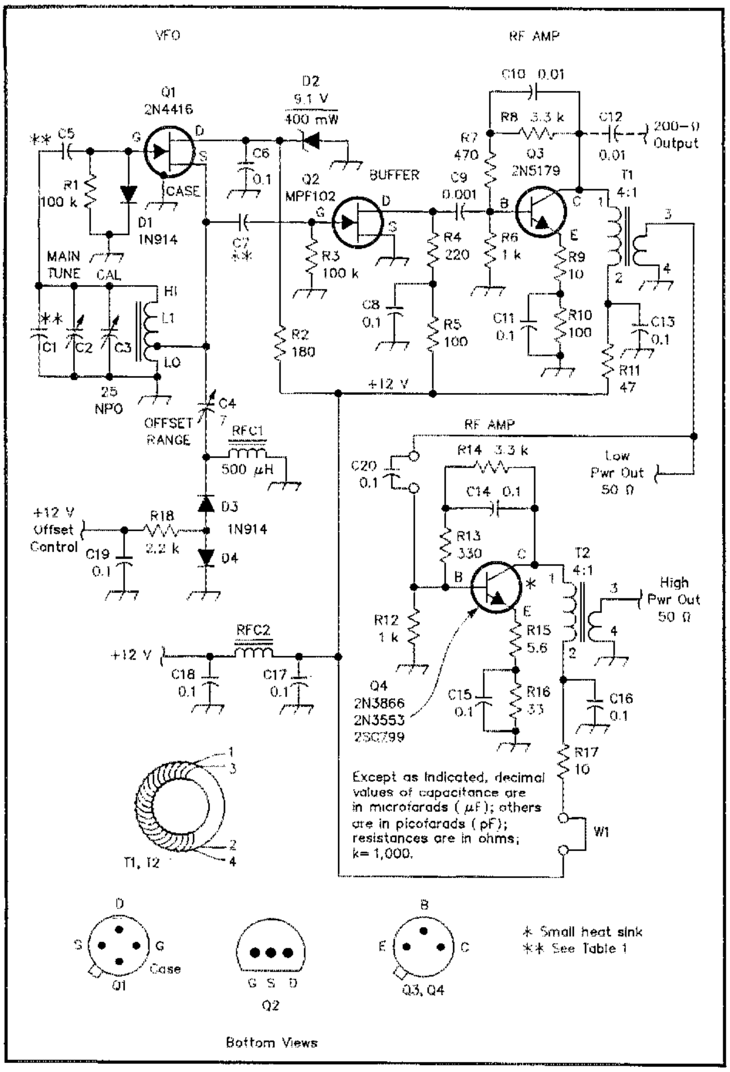


Fig 1—Schematic diagram of the universal VFO. Capacitors are disc ceramic unless otherwise indicated. Resistors are ¼-W carbon film or carbon composition. Numbered components not appearing in the parts list are identified only for parts placement on the PC board.

C1, C2, C5 and C7—See Table 1. These are NPO ceramic.

C2—Air variable, double-bearing type (see Table 1).

C3—25-pF air trimmer or NPO ceramic trimmer.

C4—Small 7-pF air trimmer. Johnson 189-502-004 (see text).

C12—Optional 0.01-µF capacitor for obtaining 200-ohm output.

C20—Added when Q4 is made operational.

D1, D3, D4—Small-signal silicon diode, type 1N914.

D2—9.1-V, 400-mW or 1-W Zener.

L1—See Table 1.

RFC1—Miniature 500- or 1000-µH RF choke.

RFC2—12 turns of no. 26 enamel wire on an Amidon FT-25-43 ferrite toroid (850 mu).

T1, T2—Primary has 16 turns of no. 26 enam wire on an Amidon FT-37-43 ferrite toroid. Secondary has 8 turns of no. 26 enam wire.

W1—Wire jumper used when Q4 is activated.

Table 1
Component Information

f(MHz)	*C1(pF)*	*C2(pF)*	*C5, C7(pF)*	*L1*
1.8-2	220	100	100	24 µH; 71 turns of no. 30 enamel on a T-68-6 toroid core. Tap at 18 turns from bottom end.
3.5-4	150	50	68	9.5 µH; 44 turns of no. 26 enamel on a T-68-6 toroid core. Tap at 11 turns from bottom end.
5-5.5	130	50	47	5 µH; 33 turns of no. 24 enamel on a T-68-6 toroid core. Tap at 8 turns from bottom end.
7-7.3	110	25	47	3.6 µH; 27 turns of no. 24 enamel on a T-68-6 toroid core. Tap at 7 turns from bottom end.

C3 is a 25-pF NPO ceramic trimmer. C4 is a 7-pF air trimmer. The total capacitance of C2 may be reduced to restrict the VFO tuning range. C1, C5 and C7 are NPO ceramic.

2 pF maximum) to avoid too great a frequency change when this trimmer is switched into the circuit.

Construction Notes

Single-sided, glass-epoxy circuit board is best for the VFO in Fig 1. Etched, plated and drilled boards for this project are available.[3] VFOs are least affected by outside influences (heat, stray RF energy and humidity) when they are contained in their own shield boxes. Filter dc leads entering the VFO box to prevent stray RF currents from entering the compartment. I used 0.001-µF solder-in feedthrough capacitors as terminals for feeding + 12 V to the VFO and the offset circuit.

The Fig 1 VFO draws 120 mA of dc at 12 V when all four stages are operating. D2, Q3 and Q4 account for most of this current. You can fashion a low-cost enclosure from sections of double-sided PC board. C2 and L1 of Fig 1 need to be located within the VFO box. Most of the parts for this project are available from a mail-order supplier.[4]

Fig 2 shows an interior view of the VFO. My version is built for use from 2155 to 2555 kHz. It is the LO for a 160-meter receiver that has a 455-kHz IF.

Fig 3 presents an etching pattern for the VFO PC board. Fig 4 shows a part-placement guide.

Some Closing Comments

Examination of Fig 2 shows that a partition is soldered across the inner walls of the VFO box. It acts as a heat shield to minimize long-term drift. Q1 is thus isolated from Q3 and Q4, which radiate

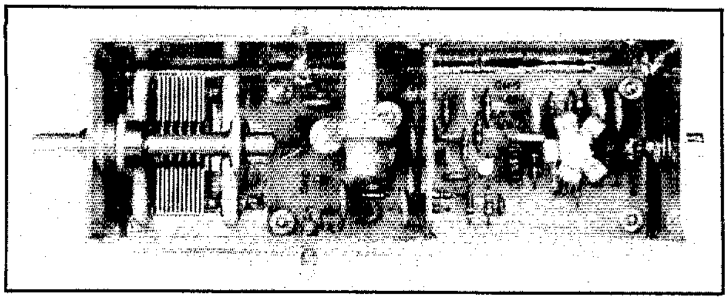


Fig 2—Interior view of the VFO. The box is made from sections of double-sided PC board. Dimensions are (HWD) 2½ × 2 × 6 inches. The two dc connectors are 0.001-μF feedthrough capacitors. The PC board is attached to the bottom of the box with four metal spacers. Q4 has a small push-on heat sink to aid cooling.

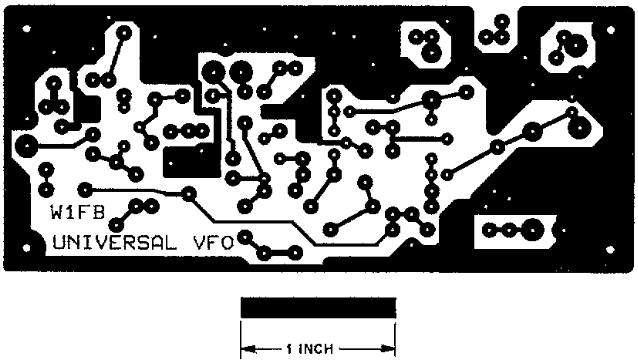


Fig 3—Circuit-board etching pattern for the VFO PC board. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper.

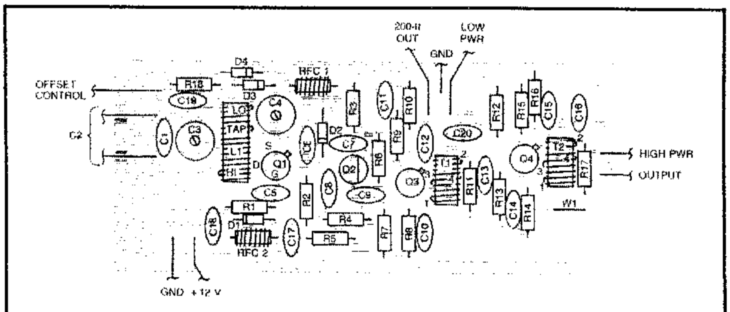


Fig 4—Part-placement guide for the VFO. Parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. Component outlines are not necessarily representative of the shapes of the actual parts used.

heat. The baffle is made from double-sided PC board and is located on the Q1 side of D2. The bottom of the partition is notched to allow it to fit over the components in that part of the circuit. The upper edges of the baffle plate are tack soldered to the walls of the VFO box. A U-shaped aluminum cover is used over the front part of the VFO box to further prevent heat from entering the critical Q1 circuitry. The back end of the box has no cover. This permits heat to escape from the enclosure.

You will also note that *L1* is mounted on a plastic rod that is screwed to one wall of the VFO box. This toroidal inductor is held in place on the plastic rod with two drops of epoxy cement. You can use a piece of wooden dowel rod to support L1 if you can't find a piece of plastic rod. The end of the rod is drilled and tapped for a no. 4-40 or 6-32 screw.

Frequency stability for the completed circuit is quite good at 2.0 MHz. Special thanks to Zack Lau, KH6CP, of the ARRL staff for his help in making this VFO so stable. Drift was considerable until he installed a new 2N4416, a better C4 trimmer[5] and an improved coil at L1. The heat shield was Zack's idea also.

The output waveform from Q4 is not a sine wave. Distortion is present. This generally is not a problem when the VFO is used as an LO to drive a diode mixer. If you need greater spectral purity, add a filter. *The ARRL Handbook* and *The ARRL Electronics Data Book* contain suitable filter designs.

If you intend to order the toroids for this project from Amidon Associates, Inc, please note their new address. The company has new owners.[6]

Notes

[1]Z. Lau, "Adjusting the Power Output of JFET VFOs," "Hints and Kinks," *QST*, Apr 1989, pp 38-39.

[2]G. Hermann, "Choosing Toroidal Cores for less Oscillator Drift," Hints and Kinks, *QST*, Oct 1988, p 38.

[3]Far Circuits (N9ATW), 18N640 Field Ct, Dundee, IL 60118, tel 708-426-2431 after 6 PM Central time. Price: $3.85 plus $1.50 shipping to US addresses.

[4]Oak Hills Research (KE8KL), 20879 Madison Ave, Big Rapids, MI 49307. Send $1 for parts catalog.

[5]Johnson 189-502-004 trimmer capacitor (C4) available from RADIOKIT, PO Box 973, Pelham, NH 03076, tel 603-635-2235.

[6]Amidon Associates, Inc, PO Box 956, Torrance, CA 90508, tel 213-763-5770.

Strays

I would like to get in touch with...

☐ anyone who has a schematic for an Encomm S-225 2-meter transceiver. I also need the Touch Tone encoder pad that plugs into the prewired 6-pin receptacle on the rear panel. Nat Barr, KB2KLW, 830 Shore Rd, Long Beach, NY 11561.

☐ anyone who has a manual for a Swan FM-2X. Robert Dhom, WB9AZN, Rte 5, Box 71, Newton, IL 62448.

☐ anyone who knows how to add AM transmit capability to a Ten-Tec Paragon transceiver. Henry Clark, W2IQ, Rte 6 Box 301, Dandridge, TN 37725.

Transforming the Balun

In this *QST* breakthrough, W2DU's peerless 1:1-current-balun design serves as the basis for excellent ferrite-bead-choke current baluns capable of 4:1 and 9:1 impedance transformation.

By John S. Belrose, VE2CV
ARRL Technical Advisor
17 Tadoussac Dr
Aylmer, PQ J9J 1G1 Canada

Much has been written in recent years on balanced-to-unbalanced RF transformers (*baluns*),[1,2,3,4,5] and they are a popular discussion topic at club meetings and on the air. The over-the-air discussions make for interesting listening. Some amateurs have their preferred balun type. Some do not want to hear about baluns! Many radio amateurs, it seems, do not understand baluns or when they should be used. Manufacturers of antenna products or antenna-system tuning units (ASTUs) advertise the superiority of their balun over the competition's. What are we to believe?

Baluns fall into two basic classes: voltage and current.[6] The *current balun* of the type developed by Walt Maxwell, W2DU,[7]—a balun consisting of ferrite beads slipped over a length of coaxial cable—is the best so far devised. By *current balun* I mean a balun that, with each of its balanced-output ports terminated in unequal resistances, forces essentially equal, opposite-in-phase currents into each resistance. The traditional toroidal balun is a *voltage balun* in that, terminated as just described, it produces equal, opposite-in-phase *voltages* across the two resistances.

For minimal radiation from a balanced transmission line, the currents on both of its conductors must be equal in amplitude and opposite in phase; that is, there must be no current discontinuity on the radiator at the antenna feed point. In other words, the currents driven into each arm of a dipole radiator should be equal. For antennas fed with a coaxial transmission line, the goal to achieve is little or no current on the outside surface of the coax shield. *In general, these requirements cannot be met without a current balun.*

Voltage Baluns

We can better judge the performance of current baluns by first taking a look at a typical voltage balun. The standard bifilar toroidal balun[8] is a voltage balun. Two common versions of this balun allow 1:1 and 4:1 impedance transformations. Some voltage-balun implementations perform worse than others, of course; in general, however, the toroidal voltage balun is an efficient device. Fig 1A graphs the input-impedance-versus-frequency performance of a typical 4:1 voltage balun. This balun has a grounded center tap. Terminated with a balanced, non-center-tapped 200-Ω load, as it would be used when connected to a balanced transmission line or an antenna, its input-impedance-versus-frequency response is excellent: It appears as close to 50 Ω across the HF range. Terminated with a center-tapped 200-Ω load (center tap connected to input common [transceiver ground]), the voltage balun does not work quite so well. Its impedance rises with frequency, indicating to me that its output is not quite balanced.

Fig 1B graphs power loss in the 4:1 voltage balun—insignificant for frequencies below 20 MHz, and less than 1 dB at 30 MHz. (I measured the balun's insertion loss by connecting two identical baluns in series, balanced terminals connected to balanced terminals, and terminating the output balun in 50 Ω. I attributed half of the observed total loss to each balun.)

[1]Notes appear on page 33.

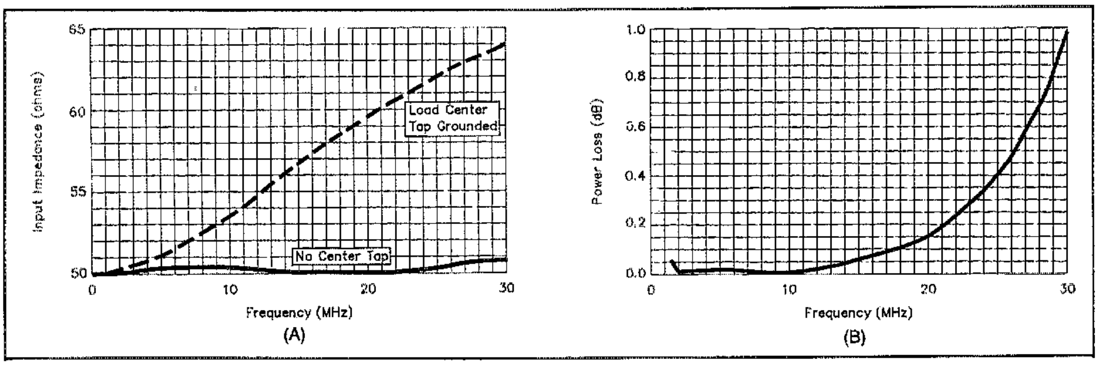


Fig 1—At A, input impedance for a typical 4:1 voltage balun terminated with a balanced 200-Ω load with no center tap (solid curve) and a center-tapped 200-Ω load with its center tap connected to input common (dashed curve). The solid curve indicates excellent HF-range performance (relatively constant impedance-versus-frequency response) with a balanced, no-center-tap load. The dashed curve indicates that a 4:1 voltage balun exhibits an undesirable transformation-ratio shift across the same range when driving a balanced, grounded-center-tap load. The balun consisted of 11 bifilar turns of no. 18 wire wound on two stacked cores of Q1 ferrite. B shows the balun's power-loss-versus-frequency characteristic.

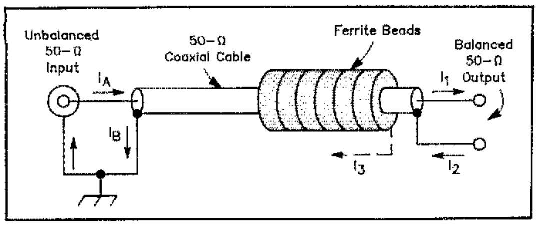
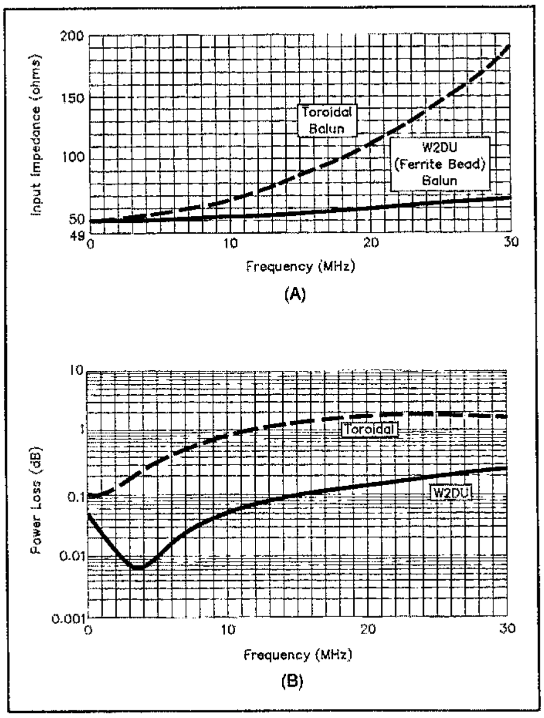


Fig 2—The W2DU 1:1 balun consists of a length of coaxial cable and ferrite beads (50; see text and the article cited at note 9 for material) that choke RF-current flow on the outside of the cable shield. The arrows associated with conductors show the relative direction of RF-current flow at one instant during the signal cycle—input currents I_A (center conductor) and I_B (shield), balanced output currents I_1 and I_2, and outside-of-shield output current I_3 (shown by a dotted arrow because it is choked off by the ferrite beads). Result: A *current* balun that exhibits a good input impedance-versus-frequency characteristic (see Fig 3). Although the drawing shows a 50-Ω balun made from 50-Ω coax, you can use 75-Ω coax to construct an equivalent 75-Ω balun.

Fig 3—At A, input impedance versus frequency for a W2DU ferrite-bead-choke, 1:1 current balun (solid curve) and a bifilar, toroidal 1:1 current balun (dashed curve). (The W2DU balun is from Antennas Etc, PO Box 4215, Andover, MA 01810, tel 508-475-7831, fax 508-474-8949. The bifilar-choke current balun is the type used by MFJ [MFJ Enterprises, Box 494, Mississippi State, MS 39762, tel 601-323-5869, fax 601-323-6551] in their differential-T tuner Model MFJ-986.) The W2DU balun exhibits a superior impedance-versus-frequency response. Both baluns were terminated with balanced 50-Ω loads. Graph B shows power-loss-versus-frequency curves for the same baluns (solid curve = W2DU balun, dashed curve = toroidal balun) under the same conditions.



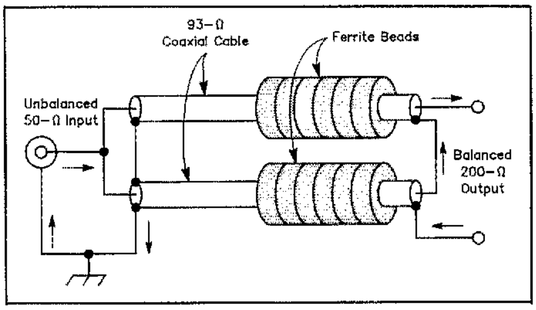


Fig 4—A 4:1 current balun based on two ferrite-bead coax-shield chokes. Each choke consists of a length of 93-Ω coax (RG-62A for powers on the order of 100 W, and RG-133A for the 1-kW level) and 50 beads (see text and the article cited at note 9 for material). The arrows associated with conductors show the relative direction of RF-current flow at one instant during the signal cycle. Fig 5 shows an RG-62A version.

A 1:1 Current Balun

A W2DU ferrite-bead-choke balun—a *current* balun—consists of a length of coaxial cable (of the required impedance) with ferrite beads around its shield. See Fig 2. (Remove the cable's outer jacket so the beads fit tightly around the shield as shown in Fig 2.) W2DU used 50 beads of no. 73 ferrite (for example, Amidon no. FB-73-2401) on about 12 inches of Teflon-dielectric cable to make a practical balun for the 1.8 to 30 MHz.[9]

The ferrite beads choke RF-current flow on the outer braid surface, thus forcing RF current to flow on the *inner* braid surface. Because this low-loss path parallels the high-loss, bead-choked outer-surface path, most of the current flows on the inner braid surface and the beads dissipate little power. The output currents (I_1 and I_2) are equal in amplitude and opposite in phase—just what's necessary to feed a balanced line. The input RF currents flow on the coaxial cable's center conductor and inner braid surface. This device is a balun, even though at first sight it may not look like one because I_3 is very much less than I_1 or I_2.

Advantages of this balun:

- It forces nearly equal currents into each leg of a balanced transmission line, *even in cases where the antenna itself is unbalanced,* such as an off-center-fed dipole;[10]
- Its excellent power-loss- and impedance-versus-frequency characteristics are much superior to those of a bifilar current balun wound on a ferrite toroid (see Fig 3);
- It has excellent power-handling capability, and can function quite satisfactorily when working into highly reactive loads. This is so because the magnetic flux produced by currents flowing on this balun's wires cannot saturate its ferrite beads.

The windings of toroidal baluns produce magnetic flux that can saturate their core material. This harms balun performance and causes heating that may destroy the balun. Core saturation is not a consideration with ferrite-bead-choke baluns. You need only take care to choose coaxial cable of the appropriate impedance and power/voltage rating, and ferrite beads (of a material suitable for the operating frequency) that fit snugly over the coaxial shield.

Disadvantages of this balun:

- The beads are lossy at HF, and under some circumstances can get extremely hot. The beads nearest the balun's balanced output heat the most. Tests indicate that heating is not a concern at a transmitter power of 125 watts. For high power (1 kW CW), however, you must use a design intended for higher power.[11]
- An *apparent* disadvantage is that only 1:1 ferrite-bead-choke baluns are available,

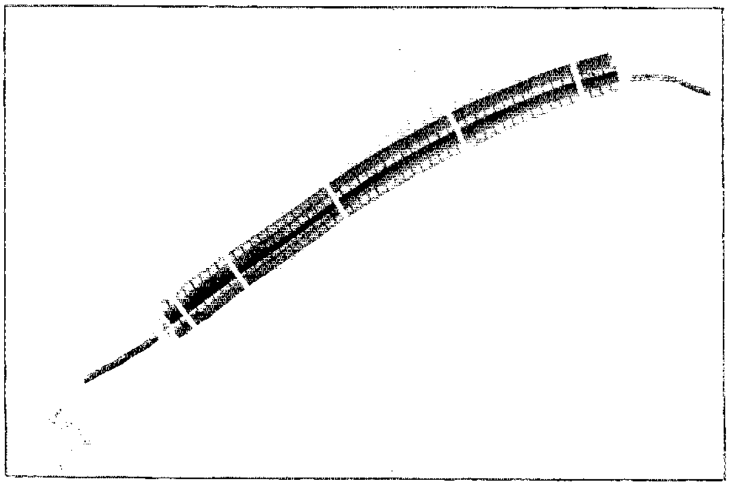


Fig 5—Nylon wire ties hold this RG-62A-based 4:1 current balun together. This version requires only weatherproofing to ready it for outdoor use.

whereas a 4:1 transformer would be useful in many applications.

A 4:1 Ferrite-Bead-Choke Current Balun

I have devised a 4:1 ferrite-bead-choke current balun (Figs 4 and 5) based on two equal lengths of 93-Ω coaxial cable (RG-62A at power levels near 100 W; RG-133A should suffice at the 1-kW level[12]), each fitted with 50 ferrite beads. Connecting these line sections' inputs in parallel and their outputs in series results in output-current polarities correct for a 4:1 balun, in a configuration that has a center tap. Fig 6A shows that this new 4:1 balun design exhibits all of the excellent characteristics of the W2DU 1:1 balun.

This balun should ideally be constructed with 100-Ω coaxial cable, but because the balun is physically short with respect to the wavelength, 50-Ω coax might work just as well. Experimentation confirms this expectation, as Fig 6B reflects. Both versions work as 4:1 transformers. The 93-Ω-coax version introduces less reactance, as comparison of the Θ curves in Figs 6A and 6B reveals.

The off-center-fed antenna system Peter Bouliane and I were investigating[13] when we devised the 4:1 current balun was, in effect, center tapped because we fed it via two equal lengths of 93-Ω (RG-62A) coaxial cable configured as a balanced 186-Ω transmission line. What's the best way to connect such a balanced, coaxial-cable transmission line to a 4:1 ferrite-bead-choke current balun? The line's center conductors connect to the balun's balanced output terminals, of course. For the line braid—that is, both of the line's coax-section braids connected together—two possibilities exist: (1) Connect the braid to the balun center tap at the balun output terminals, or (2) connect the braid to the ASTU (or transceiver) ground. Connecting the braid to the ASTU/transceiver ground is by far the better arrangement. Doing so balances the transmission-line currents (that is, the currents flowing on the center conductors of the feeder's two coaxial lines). Connecting the braid to the ASTU/transceiver, *with no RF connection between the balun center tap and equipment ground,* also minimizes the braid current.[14] So much for the concept of virtual ground![15] This type of transmission line operates best when a real wire path connects its braid to the chassis of the transmitter/ASTU that feeds it.

A 9:1 Ferrite-Bead-Choke Current Balun

A 9:1 version can be fabricated by appropriately connecting *three* ferrite-bead-

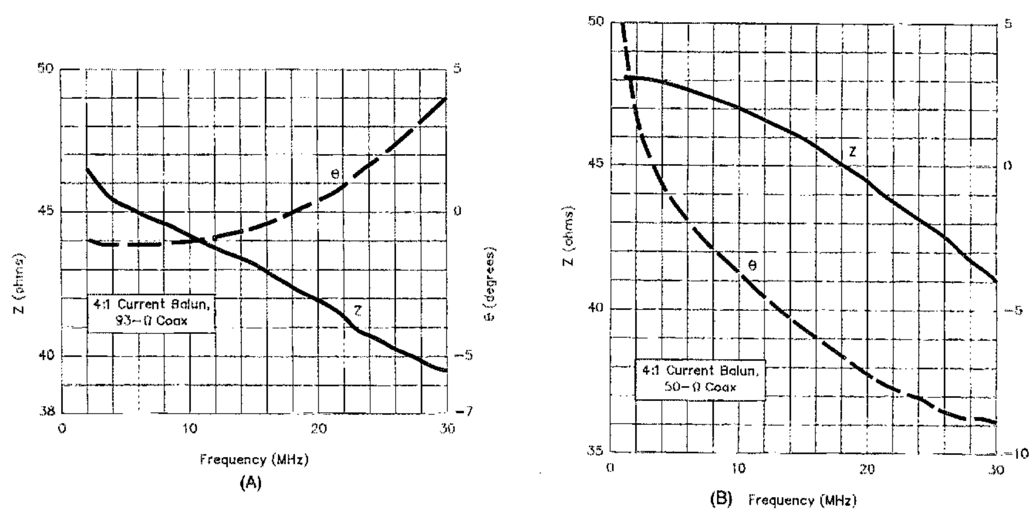


Fig 6—Input impedance (Z, solid curves) and phase angle (Θ, dashed curves) versus frequency for two 4:1, ferrite-bead-choke current baluns (A, based on 93-Ω coax; B, based on 50-Ω coax; both with center tap connected to input/transceiver ground). Negative Θ values indicate capacitive reactance; positive Θ values indicate inductive reactance. The 50-Ω-coax version is classed as "more reactive" because its input phase angle strays farther from 0 degrees—purely resistive impedance—than the input phase angle of its 93-Ω-coax counterpart. Both baluns are usable, however.

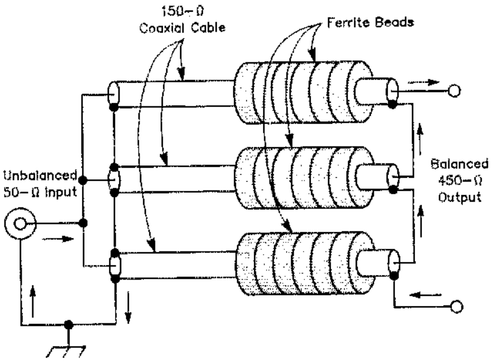


Fig 7—Three ferrite-bead-choke baluns can be combined as shown here for a 9:1 impedance transformation. Each choke consists of a length of 150-Ω coax and 50 beads (see text and the article cited at note 9 for material). The arrows associated with conductors indicate the relative direction of RF-current flow at one instant during the signal cycle.

choke coaxial baluns (each constructed from 150-Ω coax) as shown in Fig 7—that is, with the inputs in parallel and the outputs in series.[16]

Conclusion

If your MF/HF antenna system presently includes a voltage balun *and works well*, the modest performance improvement you may achieve by replacing that balun with a ferrite-bead-choke current balun probably isn't worth the time and effort involved. If, however, you're installing a new antenna system or reworking an old one, *you cannot go wrong* if you use a ferrite-bead-choke current balun where a balun is required. If the feeder of which the balun is part operates at a high SWR, you *must* use a current balun—and a ferrite-bead-choke current balun is best.

With some antennas—antennas that are not symmetrical with respect to their feed lines, for example, or antennas that, with respect to their feed, are asymmetrical with the ground (for example, off-center-fed dipoles, full-wave delta loops installed apex-up with lower-corner feed, and sloping dipoles)—a current balun *must* be used for best results. Whenever your MF/HF application calls for a current balun, a *ferrite-bead-choke* current balun—a type capable of 4:1 and 9:1 impedance transformation as well as the 1:1 ratio afforded by Walter Maxwell's original design—will work best.

Notes on Evaluating Baluns

A *1:1 toroidal, bifilar current balun* has no center tap to ground. In effect, its two windings act as chokes in each side of the line connecting a balanced load to an unbalanced input. Although such baluns are not very effective devices (see the dashed curves in Fig 3), they are used by hams and are available commercially.

Toroidal 4:1 and 6:1 current baluns are available commercially. Those I have seen consist of two cascaded baluns: a standard 4:1 or 6:1 voltage balun at the input, and a choke (current) balun at the output. I have not tested these devices.

The *1:1 ferrite-bead-choke current baluns* tested were terminated in a balanced, center-tapped 50-Ω load with its center tap connected to input common (transceiver ground). This balun design must be tested in this way, since it otherwise appears as merely a short piece of 50-Ω coax terminated in 50 Ω.

Terminating it in a balanced, center-tap-to-common 50-Ω load forces it to function as a balun. The 4:1 and 9:1 current baluns described in the text make the basic 1:1 ferrite-bead-choke balun more versatile.—*VE2CV*

Notes

[1]W. Maxwell, "Some Aspects of the Balun Problem," *QST*, Mar 1983, pp 38-40.

[2]R. Lewallen, "Baluns: What They Do and How They Do It," *The ARRL Antenna Compendium*, Vol 1 (Newington: ARRL, 1985), pp 157-164.

[3]A. Roehm, "Some Additional Aspects of the Balun Problem," *The ARRL Antenna Compendium*, Vol 2 (Newington: ARRL, 1989), pp 172-174.

[4]I. White, "Balanced to Unbalanced Transformers," *Radio Communication*, Dec 1989, pp 39-42.

[5]R. Measures, "A *Balanced* Balanced Antenna Tuner," *QST*, Jan 1990, pp 28-32.

[6]See note 2.

[7]See note 1.

[8]A description of these baluns first appeared in *QST* in R. Turrin, "Broad-Band Balun Transformers," *QST*, Aug 1964, pp 33-35, which was based on C. Ruthroff, "Some Broadband Transformers," *Proc IRE*, Vol 47, Jul 1959, pp 1337-1342. Responding to the availability of new ferrite materials, Turrin revisited the subject in "Application of Broad-band Balun Transformers," *QST*, Apr 1969, pp 42-43 (also see Feedback, *QST*, Nov 1969, p 73).
The ARRL *Handbook* first described toroidal 1:1 and 4:1 baluns—apparently a distillation of Turrin's 1964 article—in the Transmission Lines chapter of its 1968 edition. This treatment remained relatively unchanged until the 1991 *ARRL Handbook* expanded its balun coverage—still in the Transmission Lines chapter—to differentiate between voltage and current types.
The ARRL Antenna Book first covered toroidal baluns in the Transmission Lines chapter of its 13th edition (1974); this material appears to distill Turrin's 1969 article.—*Ed.*

[9]*The ARRL Handbook* indicates that the balun works well when the coax jacket is left in place, and when other ferrite materials are used. See L. Wolfgang and C. Hutchinson, eds, "The W2DU Balun," *The ARRL Handbook for Radio Amateurs*, 1991 ed (Newington: ARRL, 1990), pp 16-9 and 16-10.—*Ed.*

[10]J. Belrose and P. Bouliane, "The Off-Center-Fed Dipole Revisited: A Broadband, Multiband Antenna," *QST*, Aug 1990, pp 28-34.

[11]See note 3.

[12]This type of coax is uncommon, and may not be available in small quantities.

[13]See note 10.

[14]Measured, in the braid-to-balun-center-tap case, on the wire connected to the balun center tap, and in the braid-to-transceiver/ASTU case, on the wire connected to equipment ground.

[15]J. Belrose, "Tuning and Constructing Balanced Lines," Technical Correspondence, *QST*, May 1981, p 43.

[16]The 150-Ω coax required (RG-125, for example) is difficult to obtain. As discussed in the text associated with Fig 6, coaxial cable of other impedances may be used, however. The effect will be to introduce more reactance, which, in any case, can be readily tuned out. [Another solution would be to build your own 150-Ω-line sections from wire, insulating spacers and copper or brass tubing.—*Ed.*]

Strays

I would like to get in touch with...

☐ anyone who has a service manual for a Cushman Electronics model CE-4B service monitor. Peter Simpson, KA1AXY, 12 Ruthellen Rd, Holliston, MA 01746.

I would like to get in touch with...

☐ anyone who has operating instructions for a Palomar Electronics Corp model FC 40 solid-state frequency counter. This is not the same manufacturer as Palomar Engineers, which advertises in *QST*. George Nixon Jr, N9EJS, 2021 S Wolf Rd, Apt 203, Hillside, IL 60162-2155.

☐ anyone using a Racal RA-71 (not an RA-17) amateur receiver. Wayne Steiner, NØTE, Rt 1, Box 114, Burlington, KS 66839-9633.

The EZY Launcher

Lazily lift a line to a lofty limb with this little launcher.

By Wade A. Calvert, WA9EZY
21114 94th Ave N
Port Byron, IL 61275

Would you like to raise your 75-meter flattop? Do you get a queasy feeling whenever you consider how you're going to get that nylon rope over that "perfect" limb at 50 feet? Try the EZY Launcher!

The EZY Launcher is made from a Zebco model 202 spin-casting reel (complete with fishing line), a Marksman slingshot, a piece of flat steel stock, a wood dowel, two small hose clamps and some no. 10 hardware. I obtained all the parts at a local hardware store for less than $15. If your hardware store isn't as well stocked, chances are you can get the fishing reel and slingshot from a sporting goods, discount or catalog-sales store. The accompanying photographs show how easy it is to build an EZY Launcher.

Construction

A view of the disassembled EZY Launcher is shown in Fig 1. Table 1 contains the parts list. The U-shaped bracket is formed from a piece of 3/4-inch-wide, 1/8-inch-thick steel (or aluminum). Each leg is approximately 2-3/4 inches long, with a 1-3/4 inch gap between the legs. Adjust this gap to comfortably fit your hand and allow your thumb to operate the fishing reel's release button at the rear. To determine the gap width, grasp the slingshot in your shooting hand. Measure the distance from the side of the slingshot handle nearest you to the second knuckle of the middle finger of your shooting hand; to this dimension, add about 1/8 to 1/4 inch. Cut the metal stock long enough to allow for the leg lengths, the bracket's horizontal portion and the bends at each leg. Using a vise, bend the flat stock at the required gap distance to make the horizontal part of the bracket. Then, cut the legs to length.

Drill two 3/16-inch-diameter holes at the top of one of the bracket legs on the centerline. Locate the first hole 3/8 inch from the top of the leg. Make the second hole 1/2 inch down from the first hole. Deburr the holes and countersink them on the outside of the bracket. Drill a single 3/16-inch-diameter hole 3/8 inch down from the top of the other leg on its centerline. Deburr the hole and remove any sharp edges from the bracket.

Place the slingshot against the bracket and check for grip clearance. Drill two mounting holes in the slingshot handle. Position the first hole 3/8 inch up from the bottom of the wooden part of the handle on its centerline. Locate the second hole 1/2 inch from the first. These holes should line up exactly with the holes in the bracket. Attach the slingshot to the inside of the bracket using two no. 10 1-inch-long flat-head machine screws. To keep the screw ends flush with the nuts, I used no washers beneath the nuts.

Drill a 3/16-inch-diameter hole lengthwise through the center of a 3-inch-long dowel. A drill press comes in handy here, but a satisfactory job can be done with an electric hand drill and reasonable care. Use a 3-1/2-inch-long no. 10 machine screw to attach the dowel to the bracket leg opposite the slingshot. The bolt head should be inside the bracket. Secure the dowel using a no. 10 flat washer and nut.

Attach the fishing reel to the dowel using two small hose clamps. Grip the slingshot

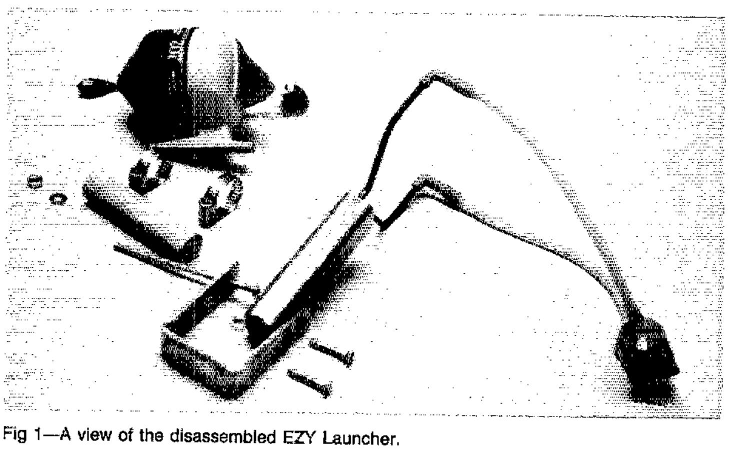


Fig 1—A view of the disassembled EZY Launcher.

Table 1
Parts List

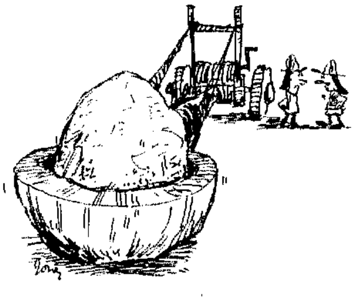
Qty	Item
1	Zebco model 202 spin-casting reel (or equivalent)
1	Marksman Co model 3010 slingshot (or equivalent)
1	1/8 × 3/4 × 12-inch piece of flat steel (or aluminum) stock
1	3/4- × 3-inch hardwood dowel
2	3/4-inch hose clamps
2	No. 10 × 1-inch flat-head machine screws
1	No. 10 × 3-1/2-inch round-head machine screw
3	No. 10 nuts
1	No. 10 flat washer
1	No. 10 lock nut
1	1/2-oz sinker

and rotate the dowel until your thumb can rest comfortably on the release button. Slide the reel forward or backward if necessary.

Operation

Safety First!

Remember: A slingshot is not a toy! Wear eye protection and take any other precautions necessary to ensure the safety of people and property. Never shoot near power lines. Practice shooting in a flat, open area until you're confident in your ability to shoot predictably.



What do you mean, storm the castle. . .
I thought we were going to launch my dipole!

Remove the metal ring at the end of the fishing line. Make a 1-inch loop of line at the end. Carefully deburr the eye of a 1/2-oz sinker. Push the line loop through the sinker eye, pass the loop around the sinker body and pull it tight. This method of fastening the sinker to the line makes it easier to get the sinker off the line and provides a means of connecting light nylon line once the sinker has passed over the tree limb and returned to ground. (Please have regard for the trees. Doug [W3AS] Brede's article[1] is recommended reading.—*Ed.*)

When you're ready to shoot, wind the sinker tightly against the reel. Make sure that the reel crank is down and out of the way of the shot. If it isn't, press the release button while holding the sinker in place with your free hand, and wind the crank until the sinker is tight against the reel and the crank is down. Position the sinker in the pouch with the sinker eye pointing down. Take short shots until you get the feel of the Launcher. Control the shot distance with the release button. The button not only releases the line for casting, it also acts as a brake when depressed further. You can set the degree of drag by adjusting the black adjustment wheel on top of the reel. When rewinding the line, apply a small amount of drag to it using your thumb and forefinger.

That's it! Have fun with the EZY Launcher. It's sure to make your antenna-raising easy.

[1]D. Brede, "The Care and Feeding of an Amateur's Favorite Antenna Support—the Tree," *QST*, Sep 1989, pp 26-28 and 40.

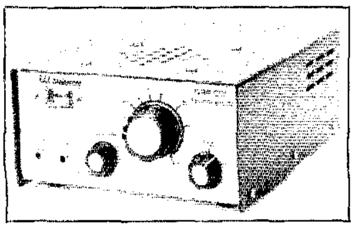
Wade Calvert was first licensed as WA9EZY in 1962 and holds an Extra Class license. He has a BSEE degree from the University of Iowa. After spending 21 years in the electric utilities industry, Wade now owns and runs Calvert Electronic Systems, where he's engaged in the design and manufacture of professional audio recording and testing equipment. Wade's interests include DXing, ragchewing, homebrewing amateur gear, songwriting and music production.

New Products

The ARRL and QST *in no way warrant products described under the New Products banner.*

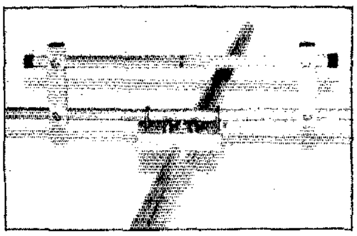
QRP TRANSCEIVERS

☐ The portable QRP transceiver designed by Gary Breed, K9AY (see *QST*, Dec '90, p 44, and Jan '91, p 17), is available as a kit that includes parts, circuit boards, wire, hardware, speaker, knobs, case and front panel. All you add is a battery, CW key and antenna. The completed transceiver measures 6 × 7.25 × 3 inches and weighs less than two pounds. Models are available for 20 meters (model no. 180-K20), 40 meters (no. 180-K40) and 30 meters (no. 180-K30). Each costs $159.95 plus $5 s/h. A&A Engineering, 2521 W LaPalma #K, Anaheim, CA 92801; tel 714-952-2114, fax 714-952-3280.



ANTENNA FEED SYSTEM

☐ The Balanced Double Gamma Feed features a natural balun that supplies both sides of a grounded driven element with equal power, regardless of frequency, through a rectangular loop at its electrical and mechanical center. The manufacturer claims low SWR bandwidth in its monoband HF, VHF and UHF Yagis, high gain, an optimum radiation pattern and improved impedance matching. Retail prices range from $50-395. Ham-Pro Antennas, a division of Kopps Corp, 7449 Fox Hills Dr, Citrus Heights, CA 95610, tel 800-879-7569.



New Books

COLLINS BOOKS

☐ Instruction books for the Rockwell/Collins models 30L-1 and 30S-1 linear amplifiers are available, complementing seven other books on S-line and KWM equipment authorized by an agreement between Rockwell/Collins and Vista Technology. The 30L-1 book is published from the 8th Edition and costs $25. The 30S-1 book is published from the 12th edition and sells for $30. Vista Technology Inc, 3041 Rising Springs Ct, Bellbrook, OH 45305; tel 513-426-6700.

Conducted By James W. Healy, NJ2L
Assistant Technical Editor

QST Compares: Dual-Band Hand-Held FM Transceivers

By James W. ("Rus") Healy, NJ2L

What we've heard from you about our comparative wattmeter review in February *QST*, not surprisingly, shows that *QST* readers like the concept of comparative reviews and are hungry for more of them.

This installment of *QST* Compares: covers a very popular class—dual-band hand-held FM transceivers. We chose one popular full-size rig from each major manufacturer: Alinco's DJ-560T, ICOM's IC-32AT, Kenwood's TH-77A, Standard's C228A, and Yaesu's FT-470.[1] Four of these radios cover the 144- and 440-MHz bands; the new-to-the-US Standard C228A covers 144 and 220 MHz. It's included here because the 220-MHz band has at least as much of a following as the FM segment of the 420- to 450-MHz band in many parts of the US and Canada.

To best perform this review, five ARRL Headquarters staff members, each with different operating interests, volunteered (with some arm-twisting from the Product Review Editor) to be involved: *QST* Copy Editor Brian Battles, WA1YUA; Laboratory Supervisor Jon Bloom, KE3Z; Field Services Manager Rick Palm, K1CE; Deputy Field Services Manager Luck Hurder, KY1T; and Associate Technical Editor Joel Kleinman, N1BKE. Laboratory Engineer Mike Gruber, WA1SVF, performed the lab testing. The five staffers who participated in the field-operations segment of this review all tried the five radios for one week each, and then provided their impressions. The reviewers evaluated these radios as users most often operate them: Outdoors, in vehicles, day and night, usually with the supplied battery packs and antennas.

On many counts, the reviewers' observations about a given radio were consistent, but in others—mainly ease of programming, ease of use and other ergonomic considerations—they sometimes varied all over the board from "excellent" to "yecch!" This underscores the importance of choosing the right radio for your needs based on trying out all the models you're considering buying. The differences in features between radios may not be as important as the ways those features are implemented from rig to rig. With that in mind, here we go. We'll tackle the HTs in alphabetical order.

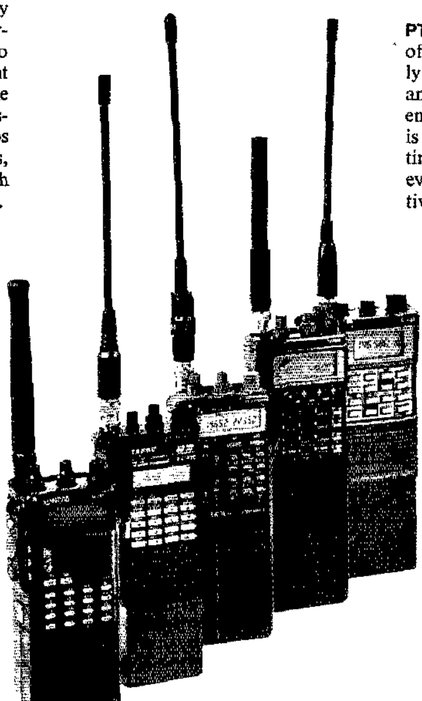
[1] B. Hale, "Yaesu FT-470 Dual-Band Hand-Held VHF/UHF Transceiver," Product Review, Sep 1990 *QST*, pp 32-35.

ALINCO DJ-560T

Alinco's DJ-560T is its first dual-band HT offered in the US Amateur Radio market. Its very wide UHF receiver coverage (400-520 MHz, well up into the UHF public-service allocations) and relatively low price make it attractive, but the radio also has drawbacks.

Automatic band-changing capability is one of the DJ-560T's slick features. In this mode, the radio watches activity on both bands, and when it finds a signal on one of the bands, it automatically gives you transmit capability on that band. (Usually, you have to manually switch bands, as only one can be active at a time for transmit.)

The reviewers like the radio's software; it has lots of functions, as Table 1 shows. Its automatic power shutoff—a feature the DJ-560T shares with its Kenwood, Standard and Yaesu counterparts—impressed the reviewers. The DJ-560T also has a large, easy-to-use keypad and knurled, well-spaced volume, squelch and tuning knobs. On the other hand, its dark-green keypad labels are hard to read (one reviewer even deemed them "useless") in low-light situations, especially because the keypad isn't illuminated. The liquid-crystal display's backlighting doesn't suitably light even the most significant part of the VHF-frequency display. The display is difficult to read when the radio is viewed at an oblique angle.



Alinco's battery-retention scheme is delicate and awkward; it's easy to drop the pack when removing it from the radio, and it doesn't seem very secure when attached. (Four tabs attached to the battery slip into slots in the rig's base.) The stock battery's capacity is adequate only for casual use: A full charge doesn't make it through a 10-minute high-power (2-watt) QSO, even though the stock pack has average capacity among those compared here. The other rigs (except the ICOM IC-32AT, which has higher output and a lower-capacity battery) fared better with their standard batteries.

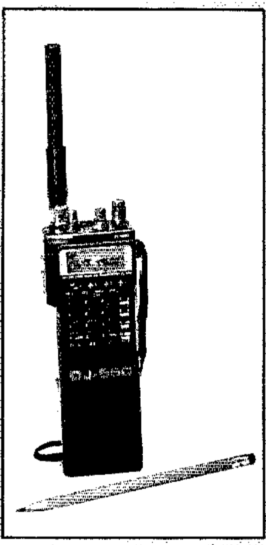
Transmitted and received audio drew "muddy," "muffled," "tinny" and "inadequate" assessments from the evaluators. The DJ-560's 1¼-inch speaker is surely part of the reason for this.

In terms of programming ease, the reviewers were again divided: Three deemed the radio reasonably easy to program and use, but two complained that some of its features are nonintuitive and even "a pain." One described the '560 as "not user-friendly."

DJ-560T users didn't like the nub on its PTT button (it's easy for your finger to slip off, unkeying the radio), the rig's relatively uncomfortable presence in your hand, and the "howling screech" that the radio emits after PTT release when the battery is low. The stock antenna had trouble getting signals in and out where others didn't, even though the DJ-560T's receiver sensitivity is on par with the rest of the radios.

The DJ-560's manual is somewhat anemic. In fact, our radio came without a manual—we had to call Alinco to get one. (By their own admission, they had shipped an unknown quantity without documentation.) We promptly received a photocopy that's somewhat hard to decipher but fairly clearly written. In the step-by-step operating instructions, the manual's small graphics make it challenging to figure out the radio's workings, though; in the descriptive sections, the manual shows miniature key labels instead of referring to them by name. No information is included on connecting a packet-radio TNC to the DJ-560T.

In general, the DJ-560T has good control software (features) but less impressive hardware. As-is,



Alinco DJ-560T, Serial no. 0000866

Manufacturer's Claimed Specifications	***Measured in the ARRL Lab***
Frequency coverage: Receiver, 130-174 MHz, 400-520 MHz; transmitter, 144-148 MHz, 440-450 MHz.	As specified.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: Better than 0.18 μV (−122 dBm) for 12 dB SINAD.	146 MHz, −122 dBm; 430 MHz, −118 dBm.
Two-tone third-order IMD dynamic range: Not specified.	20-kHz offset from 146 MHz, 53 dB; 20-kHz offset from 440 MHz, 72 dB.
Adjacent-channel rejection: Not specified.	20-kHz offset from 146 MHz, 57 dB; 20-kHz offset from 440 MHz, 55 dB.
Squelch sensitivity: Not specified.	146 MHz, −129 to −121 dBm.
Receiver audio output: Not specified.	260 mW into 8 Ω at 10% THD with standard battery.
Transmitter	*Transmitter Dynamic Testing*
Power output with standard battery: 2 W.	146 MHz, 2.4 W; 440 MHz, 2 W.
Spurious signal and harmonic suppression: Better than 60 dB.	As specified. The DJ-560T meets FCC requirements for spectral purity for transmitters in its power-output class and frequency range.
Transmit-receive turnaround (PTT release to 90% of full audio output): Not specified.	Squelch on, approx 190 ms; squelch off, approx 135 ms.

this inexpensive radio is fine for most applications, and it's the only HT that offers such wide VHF *and* UHF receiver coverage. One staff critic liked this radio a lot, but another said it was his least favorite. This underscores the differing needs and desires of HT users, but it's nonetheless clear that better transmitted and received audio, improved battery-usage efficiency and more effective lighting of the display and controls would greatly boost this radio's value.

ICOM IC-32AT

The IC-32AT, ICOM's only full-size 144/440-MHz HT, has some features unique to the radios covered in this review. For instance, it can deliver more than 5 W of RF output with its standard battery pack—fully twice that of some of the others. It also has the largest, easiest-to-read frequency display of the rigs compared here. In addition, the IC-32AT is compatible with the huge variety of ICOM (and aftermarket) IC-2-series accessories.

A relatively large radio, the IC-32AT is the most rugged rig we tested. WA1YUA put it succinctly: "It's heavy enough to use as a weapon in the close quarters of a

Table 1
Dual-Band Hand-Held Transceiver Features

	Alinco DJ-560T	*ICOM IC-32AT*	*Kenwood TH-77A*	*Standard C228A*	*Yaesu FT-470*
Dual frequency displays	Yes	No	Yes	Yes	Yes
Simultaneous dual-band receive	Yes	No	Yes	Yes	Yes
Automatic band switching	Yes	No	Yes	No	No
Expanded receiver coverage (VHF/UHF)*	Yes/Yes	Yes/No	Yes/No	Yes/Yes	Yes/No
Cross-band full-duplex operation	Yes	Yes	Yes	Yes	Yes
Memory channels (total)	42	20	42	20	42
Band, memory and programmed scan modes	Yes	Yes	Yes	Yes	Yes
Selected memory-channel lockout	Yes	Yes	Yes	Yes	Yes
Separate audio outputs	No	No	Yes	Yes	No
Standard battery capacity (V/mAh)	7.2/700	13.2/275	7.2/600	7.2/700	7.2/600
High power output (W) with standard battery (VHF/UHF)*	2/2	5.5/5	2/1.5	2.8/2.5	2.3/2.3
High/low power output selection (VHF/UHF)*	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Automatic battery-saving mode(s)	Yes	Yes	Yes	Yes	Yes
Automatic power-off	Yes	No	Yes	Yes	Yes
Automatic repeater-offset selection (VHF/UHF)*	No/No	No/No	Yes/No	No/No	Yes/Yes
Supply-voltage range	7.2-12	7.2-13.8	6.3-16	6-16	5.5-15
Dimensions (H/W/D, with standard battery)	6.7/2.2/1.2″	7.1/2.6/1.4″	5.7/2.3/1.2″	6.3/2.6/1.4″	6.5/2.2/1.3″
Weight (lb, with standard battery)	1	1.3	0.9	1.1	0.9
Suggested retail price	$399.95	$629.95	$599.95	$689.95	$478.95

*220 MHz is actually a VHF band, but is referred to here as UHF for simplicity.

ICOM IC-32AT, Serial no. 07608

Manufacturer's Claimed Specifications	*Measured in the ARRL Lab*
Frequency coverage: Receiver, 138-174 MHz, 440-450 MHz; transmitter, 144-148 MHz, 440-450 MHz.	As specified.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: Better than 0.25 µV (−119 dBm) for 12 dB SINAD.	146 MHz, −123 dBm; 430 MHz, −120 dBm.
Two-tone third-order IMD dynamic range: Not specified.	20-kHz offset from 146 MHz, 58 dB; 20-kHz offset from 440 MHz, 59 dB.
Adjacent-channel rejection: Not specified.	20-kHz offset from 146 MHz, 62 dB; 20-kHz offset from 440 MHz, 61 dB.
Squelch sensitivity: Less than 0.158 µV (−123 dBm).	146 MHz, −128 to −120 dBm.
Receiver audio output: >400 mW into 8 Ω at 10% distortion.	551 mW into 8 Ω at 10% THD with standard battery.
Transmitter	*Transmitter Dynamic Testing*
Power output with standard battery: 144 MHz, 5.5 W; 440 MHz, 5 W.	146 MHz, 5.7 W; 440 MHz, 4.7 W.
Spurious signal and harmonic suppression: Better than 60 dB.	As specified. The IC-32AT meets FCC requirements for spectral purity for transmitters in its power-output class and frequency range.
Transmit-receive turnaround (PTT release to 90% of full audio output): Not specified.	Squelch on, approx 100 ms; squelch off, approx 100 ms.

crowded flea market!" (I don't know about *that*, but it certainly gets the point across!) ICOM's hallmark transmitted and received audio are also IC-32AT strong points; the radio's size allows a large speaker (by HT standards), and all its users got good transmitted-audio reports. The knobs atop the rig are well spaced and feel solid.

Especially in its high-power-output mode, the IC-32AT drains the charge from the stock battery relatively quickly. ICOM rates the stock BP-70 for only 2 hours of VHF use (and a scant 1.5 hours on UHF), assuming 1 minute of transmit, 1 minute of receive and 8 minutes of standby. To their frustration, the reviewers found that this rating is accurate; one user barely made it through a 20-minute QSO on a full charge. A look at the table of specifications shows why this is so: The BP-70 is rated at 13.2 V and 275 mAh, whereas the batteries supplied with the other radios are 7.2 V/600-700 mAh units that store between 20 and 40% more energy than the stock ICOM battery.

With the exception of its simple direct frequency entry, the IC-32AT is initially somewhat difficult to program; it has lots of functions, but lacks intuitive programming sequences and keypad labels. Once you've learned to program the radio, though, it's easy to use. The IC-32AT's single-frequency display leaves no doubt about what band you're on.

The ICOM documentation left mixed impressions with the reviewers. They agreed that it's complete and has clear step-by-step instructions, but they feel that it's written for those who are already familiar with ICOM's programmable HTs. This may confuse first-time users.

Once again, the evaluators were divided when it came time to suggest changes or improvements for the IC-32AT. Some felt that a dual-frequency display and simultaneous dual-receive capability should be included, and others preferred the simplicity of the current design. Also, evaluators would like a better keypad layout, buttons that allow 1-MHz frequency changes, an illuminated keypad and automatic repeater-offset selection. This radio is nice for home-station use because of its relatively high power output and solid construction (it won't be dragged off a tabletop by a speaker/mike, for instance). One reviewer liked the IC-32AT better than any other rig he tested, but most preferred others, as you'll see.

Of the HTs reviewed, the IC-32AT is most like two separate radios in one box. Its basic performance is good, but its engineers didn't integrate the two bands to the degree they have been in the other reviewed radios. With its new IC-W2A, which has simultaneous dual-receive capability and is much smaller than the IC-32AT, ICOM appears to have addressed many of the rough edges found by the IC-32AT reviewers, but only a closer look in a future review will tell for sure.

KENWOOD TH-77A

The smallest and lightest radio reviewed here, the Kenwood TH-77A, like the ICOM IC-32AT and Alinco DJ-560T, drew considerably varying commentary from the reviewers. They liked the radio's display and some of its nice touches, but weren't fond of its programming. As a side effect of its small enclosure, this radio has the smallest buttons and controls of all the rigs in this comparison, and it's therefore difficult for some users to manipulate. Its display lighting is effective and stays on for a few seconds after you press the tiny **LAMP** button below the PTT switch. Other buttons are mounted on the left side of the radio, including the very small, recessed **POWER** button, which some evaluators had trouble locating and actuating.

Users rated the TH-77A's audio output reasonable, but tinny and distorted in high-noise environments. Transmitted-audio reports were consistently good. Battery life was on par with that of the other similarly equipped radios, and the rig is solidly made.

Surprisingly, the evaluation team was almost evenly divided on the TH-77A's programming ease. One deemed it "easy" to program, and another said it was "a pain in the neck." Here again, we see how much variation exists in people's conceptions of

Kenwood TH-77A, Serial no. 20900880

Manufacturer's Claimed Specifications	*Measured in the ARRL Lab*
Frequency coverage: Receive, 136-174 MHz, 438-450 MHz; transmit, 144-148 MHz, 438-450 MHz.	As specified.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: Better than 0.18 μV (−122 dBm) for 12 dB SINAD.	146 MHz, −123 dBm; 430 MHz, −121 dBm.
Two-tone third-order IMD dynamic range: Not specified.	20-kHz offset from 146 MHz, 60 dB; 20-kHz offset from 440 MHz, 65 dB.
Adjacent-channel rejection: Not specified.	20-kHz offset from 146 MHz, 67 dB; 20-kHz offset from 440 MHz, 56 dB.
Squelch sensitivity: Less than 0.1 μV (−127 dBm).	146 MHz, −135 to −124 dBm.
Receiver audio output: >200 mW into 8 Ω at 10% distortion.	211 mW into 8 Ω at 10% THD with standard battery.
Transmitter	*Transmitter Dynamic Testing*
Power output with standard battery: 144 MHz, 2 W; 440 MHz, 1.5 W.	146 MHz, 2.9 W; 440 MHz, 1.8 W.
Spurious signal and harmonic suppression: Better than 60 dB.	As specified. The TH-77A meets FCC requirements for spectral purity for transmitters in its power-output class and frequency range.
Transmit-receive turnaround (PTT release to 90% of full audio output): Not specified.	Squelch on, approx 100 ms; squelch off, approx 100 ms.

what's easy and what's difficult. All the reviewers lamented that the TH-77A's keypad frequency entry is time-consuming, in part because it's hard to tell what band you're entering the frequency on. Most of the reviewers also reflected that, even though the keypad has a good feel and is effectively backlit, the radio is somewhat difficult to operate once programmed because the radio has so many functions and the keypad buttons are *very* small. WA1YUA observed that the TH-77A requires "the attention of a neurosurgeon to fiddle with the controls (forget mobiling!). It's just too inconvenient to be fun to use."

The TH-77A instruction manual, although complete, suffers from weak translation from the Japanese and contains several typos. The manual's elusive instructions on direct frequency entry doubtless contribute to the relative difficulty of performing those operations.

On the nifty side, the TH-77A comes with a removable plastic cover that protects the keypad (a flexible window allows you to operate the Function key while the cover is in place). The multifunction LCD has dual S meters and icons for at least a dozen functions (including a battery-charge indicator), making it easy to determine how the rig is operating. The TH-77A also features automatic repeater-offset selection in the 144-MHz band, and has two energy-conservation modes (battery saver and timed automatic shutoff). Like the Alinco DJ-560T, the TH-77A features automatic band changing, too.

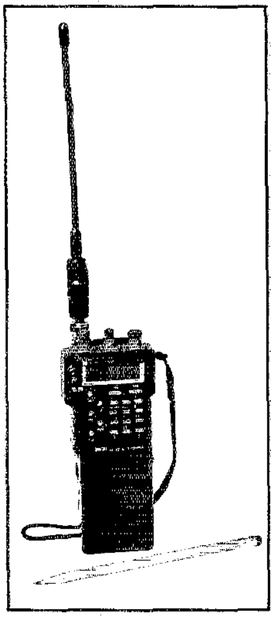
In short, the TH-77A is a feature-packed, smoothly finished radio (in typical Kenwood fashion), but it almost tries to do *too* much for a package of its size. A larger enclosure and display, or a slightly less ambitious set of features, would bring this rig closer to the top of the five reviewers' lists.

STANDARD C228A

The C228A is Standard's first US-market Amateur Radio VHF HT marketed under

Table 2
Dual-Band Hand-Held Transceiver Accessories
Std = standard, Opt = optional, N/A = not available.

	Alinco DJ-560T	*ICOM IC-32AT*	*Kenwood TH-77A*	*Standard C228A*	*Yaesu FT-470*
Flexible antenna	**Std**	**Std**	**Std**	**Std**	**Std**
Belt clip	**Std**	**Std**	**Std**	**Std**	**Std**
Wrist strap	**Std**	**Std**	**Std**	**Std**	**Std**
Battery pack and charger	**Std**	**Std**	**Std**	**Std**	**Std**
Drop-in battery charger	N/A	Opt	Opt	Opt	Opt
Protective case(s)	Opt	Opt	Opt	Opt	**Std**
Mobile bracket	N/A	N/A	Opt	Opt	Opt
Mobile power/charging cable(s)	Opt	Opt	Opt	N/A	Opt
Speaker/microphone(s)	Opt	Opt	Opt	Opt	Opt
Earpiece/microphone	Opt	N/A	N/A	N/A	Opt
Headset	Opt	Opt	Opt	Opt	N/A
High-capacity battery packs	Opt	Opt	Opt	Opt	Opt
Alkaline-cell case(s)	N/A	Opt	Opt	N/A	Opt



Standard C228A, Serial no. OXU 010062

Manufacturer's Claimed Specifications	*Measured in the ARRL Lab*
Frequency coverage: Receiver, 130-175 MHz, 200-245 MHz; transmitter, 144-148 MHz, 220-225 MHz.	As specified.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: Better than 0.158 μV (−123 dBm) for 12 dB SINAD.	146 MHz, −123 dBm; 220 MHz, −123 dBm.
Two-tone third-order IMD dynamic range: Not specified.	20-kHz offset from 146 MHz, 69 dB; 20-kHz offset from 220 MHz, 69 dB.
Adjacent-channel rejection: Not specified.	20-kHz offset from 146 MHz, 62 dB; 20-kHz offset from 220 MHz, 61 dB.
Squelch sensitivity: 0.1 μV (−127 dBm).	146 MHz, −128 to −119 dBm.
Receiver audio output: 200 mW into 8 Ω at 10% distortion	245 mW into 8 Ω THD at 10% with standard battery.
Transmitter	*Transmitter Dynamic Testing*
Power output with standard battery: 144 MHz, 2.8 W; 220 MHz, 2.5 W.	146 MHz, 2.1 W; 223 MHz, 1.8 W.
Spurious signal and harmonic suppression: Better than 60 dB.	As specified. The C228A meets FCC requirements for spectral purity for transmitters in its power-output class and frequency range.
Transmit-receive turnaround (PTT release to 90% of full audio output): Not specified.	Squelch on, approx 40 ms; squelch off, approx 30 ms.

its own name. (Heath carried Standard products under the Heath label until they recently left the Amateur Radio business.) The reviewers found the C228A rugged and ergonomically pleasant, with an easily readable, effectively backlit liquid-crystal display. Its controls are logically laid out and labeled, making for easy programming and use. Especially popular were its easy band-changing via its **144** and **220** buttons, comfortable physical size and shape, and separate audio outputs for each band. Its tuning ease (via keypad, the tuning knob atop the radio, and in 100-kHz or 10-MHz steps) also drew praise.

The C228A produces adequately loud and decent-fidelity received audio with its supplied battery pack. The rig also brought consistently good transmitted-audio reports. The C228A's automatic-power-shutoff feature hints at the C228A's power-efficient design: The '228 uses its battery capacity maximally, faring better (in one particularly demanding reviewer's experience) than any of the other radios—even though its stock battery has only average capacity among the rigs covered here.

The C228A's stock antenna is thin, and flexible enough that it doesn't jab you in the ribs like the stubby antennas supplied with some radios. The antenna and radio work well together, too, getting signals in and out of places where some others had trouble.

The evaluation team rated the C228A's instruction manual a notch above average, deeming it reasonably complete, well-illustrated, clearly written and easy to navigate. The manual's step-by-step instructions are a big help. The documentation lacks information on connecting a TNC to the radio, however.

In addition to wishing for a little more transmitter output and an easy way to cancel direct-frequency-entry operations, the reviewers' few complaints include the placement of the C228A's concentric 144-MHz **VOL**ume and **SQUELCH** controls (too close to the antenna jack). Also, the keypad's small and closely spaced keys make it hard for large-fingered users to manage them easily. That this was the rig's most-mentioned deficiency tells you that the C228A doesn't give you much to complain about!

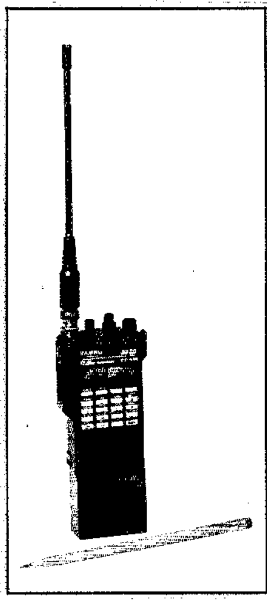
The only 144/220 HT currently available, the Standard C228A is a nice, if expensive, package. It should be popular among Novices looking forward to upgrading to Technician, new licensees entering ham radio at the Technician Class level, and others who want these two bands in one hand-held box. Extended receiver coverage in both the 100- and 200-MHz ranges is the icing on the cake.

YAESU FT-470

The FT-470 has established itself well in the dual-band HT marketplace over the last couple of years and continues to enjoy good sales. Reasons for this are many, as the team of reviewers discovered. For instance, this reasonably rugged radio is easier to use than most of its competition. Its useful liquid-crystal display is well illuminated, and so is its keypad. The reviewers also complimented the FT-470's physical size and shape—a significant response, because comfort is high on everyone's list of important HT characteristics. One way Yaesu takes maximum advantage of top-panel space without crowding controls together is by using a single squelch control and concentric volume/balance controls to determine the audio-output level and the relative levels of VHF and UHF receiver audio.

The rig's receiver produces adequately loud and clear audio output with acceptable fidelity. Its transmit audio sounds good, too. A charge of the FT-470's stock battery pack lasts for several hours of listening and scanning, and also holds up well during QSOs. And the radio's battery-saving modes help conserve the charge.

Some reviewers needed a little longer than others to learn how to program the FT-470, but the instruction manual made learning the rig easy. The manual's high quality and clear writing (with the exception of some typographical errors) assist newcomers with lucid explanations of the radio's features and programming. The manual includes a section called "Getting



Yaesu FT-470, Serial no. 0L280845

Manufacturer's Claimed Specifications	*Measured in the ARRL Lab*
Frequency coverage: Receiver, 130-180 MHz, 430-450 MHz; transmitter, 144-148 MHz, 430-450 MHz.	As specified.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity: Better than 0.158 µV (−123 dBm) for 12 dB SINAD.	146 MHz, −124 dBm; 430 MHz, −124 dBm.
Two-tone third-order IMD dynamic range: Better than 65 dB (offset not specified).	20-kHz offset from 146 MHz, 53 dB; 20-kHz offset from 440 MHz, 58 dB.
Adjacent-channel rejection: Better than 60 dB (offset not specified).	20-kHz offset from 146 MHz, 65 dB; 20-kHz offset from 440 MHz, 62 dB.
Squelch sensitivity: Not specified.	146 MHz, −135 to −121 dBm.
Receiver audio output: 500 mW into 8 Ω at 5% distortion.	195 mW into 8 Ω at 5% THD with standard battery.*
Transmitter	*Transmitter Dynamic Testing*
Power output with standard battery: 2.3 W.	146 MHz, 2.4 W; 440 MHz, 1.9 W.
Spurious signal and harmonic suppression: Better than 60 dB.	As specified. The FT-470 meets FCC requirements for spectral purity for transmitters in its power-output class and frequency range.
Transmit-receive turnaround (PTT release to 90% of full audio output): Not specified.	Squelch on, approx 250 ms; squelch off, approx 150 ms.

*Refer to Sep 1990 *QST* Product Review for more information.

the Most from Your Batteries," which is a particularly nice touch. A handy quick-reference card and a schematic of the radio round out the documentation. You'll have to garner TNC-interfacing information from the schematics.

On the unfavorable side, the FT-470's keypad keys are too closely spaced for comfortable operation by hams with large fingers, and its keypad/display lighting stays on only while the **LAMP** button is held, making nighttime programming a two-handed job. During memory scanning, one reviewer had trouble telling whether received signals were on VHF or UHF because both bands drive a single signal-strength bar on the display.

Special features noted by the evaluators include the FT-470's musical keypad (potentially quite useful for vision-impaired operators). (If the tones annoy you, you can shut them off with a couple of keypresses.) The rig's separate keypad and PTT "locks" were also popular, as was its low-battery display icon and programmable battery saver. Other impressive features include the radio's scanning modes (detailed in the September 1990 *QST* review), the choice of carrier- or time-operated scan hold, and automatic repeater-offset selection.

The reviewers wished that the FT-470 had separate audio outputs for each band, better keypad spacing and an indicator to show when the battery is charging.

The FT-470 embodies solid performance enhanced by lots of nice touches (including its standard vinyl protective case), and has relatively few drawbacks. The rig's easy programming, good ergonomic design and comfortable size make it the clear reviewer favorite among the 144/440-MHz models this month. Considering that only the Alinco DJ-560T costs less among the five radios compared here, the FT-470 is also a true bargain in the dual-band HT market.

Caveats

We tested these radios only in their standard configurations. We did not test optional battery packs and other nonstandard accessories. With the exception of mobile antennas, all reviewer comments pertain to operation with the rigs' standard flexible antennas. Because some aspects of HT operation vary with the power source and antenna used, consider using optional battery packs and antennas. For instance, battery-pack charges don't last long, so a second pack is a must. The optional high-capacity units available for each of these rigs are just about mandatory for anyone but the most casual users.

As you evaluate our comments and test results pertaining to receiver-audio-output levels, keep in mind that many of these transceivers (except, perhaps, the IC-32AT) produce considerably more distortion-free receiver audio when used with higher-voltage battery packs or run from an automotive power supply. (The table in September 1990 *QST*'s FT-470 review reflects this.) Also, an external speaker works wonders for these and other hand-held radios; a speaker crammed into a 2½-inch-wide box that's already bursting with electronics simply can't compete with even a modest external speaker.

Conclusions

All of these radios performed without trouble during testing and review. That's a testament to modern manufacturing practices and quality control, especially considering what we put them through!

As stated earlier, the reviewers generally came to no clear consensus in the areas of programming and operating ease. But there were exceptions. The Standard C228A was noncontroversial. Everyone loved it. Yaesu's FT-470 was similarly popular, drawing fire from only one reviewer for the size of its keypad keys—a common complaint with the other radios.

What says even more about the five radios tested is that the reviewers came to use the Standard C228A and Yaesu FT-470 as references when quantifying the performance of the other rigs. All of the radios sport a wide array of features, but how the features are implemented heavily in-

(continued on page 44)

MORE ON CURING TVI WITH 300-Ω FILTERS AND 4:1 TRANSFORMERS

☐ In March 1989 Hints and Kinks, Jim Rafferty, N6RJ, reported curing TVI in 75-Ω systems with 300-Ω high-pass filters and 4:1 transformers.[1] This cure has been making the rounds in many of the 6-Land newsletters for several years. It works, and I have been investigating *why* it works. After all, a 75-Ω high-pass filter should work fine in 75-Ω cable!

The only reason an effective 75-Ω filter may not work in a 75-Ω coaxial-cable system is that a common-mode signal exists. (A common-mode signal travels down coax, particularly on the outside of the coax braid, as if the coax is just one wire of a two-wire circuit.) If coax is doing its job, the RF currents on its center conductor and shield wire are of the same magnitude but opposite in phase. When this is so, the coax acts like the transmission line it is, providing source and return paths for the signals it carries. Cheap (RF-leaky) coax, poorly installed connectors or poorly designed electronic equipment may cause or support common-mode signal transmission.

In cases where such common-mode signals cause interference solvable with a 300-Ω filter bracketed by 75-to-300-Ω transformers, a choke made of ferrite beads slipped over the cable can solve the problem just as well. Neither solution attacks the *cause* of the common-mode signal involved. Seeking to eliminate the cause of common-mode interference at my station, I replaced suspect TV feed line—cheap RG-59—with Belden 9114, an RG-6-type cable that has braid and a continuous aluminum-foil shield. This eliminated my HF TVI without my having to install filters. (I solved 6-meter TVI by replacing an old antenna-mounted TV preamp with a Radio Shack 15-1118.) Result: A TV system that's interference-free without low-pass filters.

Of course, it's not always practical to replace TV feed line. If this is true in your case, try a ferrite-bead shield choke or the filters-and-transformer solution. The latter solution is inexpensive and seems to work every time.—*Steve Lund, WA8LLY, 10180 Mill Station Rd, Sebastopol, CA 95472*

Maybe the Transformers Do Most of the Filtering!

In experimenting with 300-Ω-filter-and-transformer combinations, I was puzzled by the poor performance I achieved with Radio Shack 75-Ω high-pass filters compared with the results obtained with other methods. I had always "calibrated out" the frequency response of the transformers before measuring filter response. One day, I measured the frequency response of transformers connected back-to-back. Lo and behold, they had a better high-pass characteristic than 75-Ω RS filters! Figs A and B show the details.

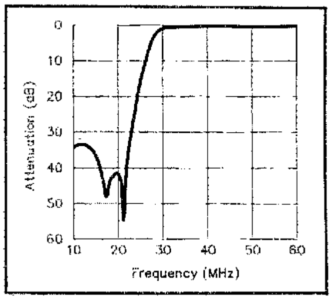


Fig A—Measured attenuation of a Radio Shack (no. 15-579) 75-Ω high-pass filter.

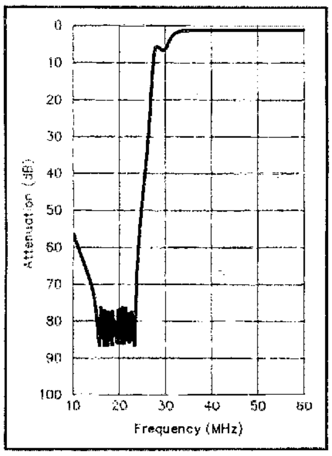


Fig B—Measured attenuation of back-to-back RMS CA2600F transformers (commonly used in CATV systems). Together, they reject MF/HF energy better than the 75-Ω Radio Shack *filter* evaluated in Fig A.

All 75-to-300-Ω TV-feed-line transformers are not created equal. The stopband frequency response of those used in the CATV industry generally starts dropping off around 45 MHz due to the low permeability (μ) of the cores used, making for good high-pass filtering and insertion loss under 1 dB at TV frequencies. On the other hand, the cores used the Radio Shack 75-to-300-Ω transformers I've tested have a much higher μ and work well all the way down to 10 MHz. Such a wide response isn't necessary, increases transformer loss at higher TV frequencies, and allows the transformers to work better on differential-mode medium- and high-frequency (MF/HF) signals than they should.

Used in conjunction with a 300-Ω high-pass filter, two Radio Shack 75-to-300-Ω transformers *can* reduce or eliminate common-mode MF/HF TVI. Understandably, though, transformers better optimized for TV frequencies may work somewhat better in this application—perhaps without a high-pass filter!—*WA8LLY*

REDUCING TVI IN CABLE-FED TVs

☐ I'm a CATV trunk-line technician. In most of the amateur CATVI cases I've seen, interfering signals get to the TV set on the *outside* of the drop cable's shield braid. (The *drop* is the cable between your house and the pole.) This occurs because the drop cable acts as a random-wire antenna for MF/HF signals.

In every case of such interference I've handled, I solved the problem by wrapping 8 to 10 turns of the CATV cable through a TV-deflection-yoke ferrite core. (Locate the coil within 2 or 3 feet of the point at which the cable connects to the TV system.) This places approximately 60 to 80 μH of inductance in series with the drop-cable shield—an inductance that acts as a broadband choke because of the core characteristics and the low distributed capacity of the winding. Because installing the choke doesn't affect RF transmission inside the cable and doesn't break the coax shield, the choke does not affect the drop's leakage and impedance characteristics.

In stubborn cases, an additional core or cores can be used to choke common-mode MF/HF conduction on the TV system's ac line cord(s).—*Mark S. Graalman, WB8JKR, 5004 South Ave, Toledo, OH 43615-6429*

WJ1Z: A *deflection yoke* is a coil assembly that mounts around the neck of a TV CRT (*cathode-ray tube*, also called a *picture tube*). The magnetic fields of its coils *deflect* (steer) the tube's electron beam(s) to draw the picture you see, in light emitted by electroluminescent phosphors, on the inside surface of the CRT screen. Deflection-yoke coils are usually wound on cores consisting of *ferrite*, an iron-bearing

[1] J. Rafferty, "300-Ω Filter in 75-Ω TV Coax Cures Shield-Conducted TVI," *QST*, Mar 1989, p 41.

ceramic-like material that increases the coils' inductance while supporting and shaping the coils' windings. Radio amateurs sometimes wind interference-suppression chokes on discarded deflection-yoke cores; you may be able to find such cores at shops that repair TVs or computer monitors.

Better yet, consider using *new* toroidal cores instead. Assuming loop 10 turns of coax through one of Mark's cores results in an 80-μH choke, the A_L (inductance [in this case, millihenries] per 1000 turns) value of his cores works out to 800—roughly midway between that of a 1.14-inch-diameter Mix-43 ferrite toroid (A_L = 603) and a 1.14-inch-diameter Mix-77 ferrite toroid (A_L = 1140). You may have trouble winding much CATV coax around a core of this size, though, so consider using 2.4-inch cores (A_L = 1240 for Mix 43, and A_L = 3130 for Mix 77) and winding 6 to 8 turns of coax through them. Check with Amidon (2216 E Gladwick St, Dominguez Hills, CA 90220, tel 213-763-5770, fax 213-763-2250), Palomar Engineers (Box 455, Escondido, CA 92033, tel 619-747-3343), Ocean State Electronics (Box 1458, Westerly, RI 02891, tel 800-866-6626, fax 401-596-3590) or other suppliers to see who carries what.

Although deflection-yoke cores can help suppress MF/HF interference, they're intended for use only at frequencies up to a few tens of kilohertz. Concerning the toroidal cores I've mentioned, Palomar Engineers' *RFI Tip Sheet* suggests that "Mix 77 is the best below 40 MHz [and] Mix 43 can be used from 1-1000 MHz and is the best from 30-150 MHz." The frequencies mentioned are for *the interfering signal*, not the interfered-with signal. Thus, use a Mix-43 core to suppress interference from a 50- or 144-MHz transmitter. A Mix-77 core would be the better choice if, for instance, a 10-MHz transmitter is the cause.

QUICK POWER AND ANTENNA DISCONNECTS FOR EQUIPMENT LIGHTNING SAFETY

□ Summer is almost upon us, and with it come unexpected, violent thunderstorms. Like every ham, I quickly dash to the shack to disconnect coax and pull power plugs at the first loud thunderclap to protect my investment in amateur gear. This behavior conditions other family members: My nonham husband awakes me out of a deep sleep to announce an impending storm with "Your radios!"

This is fine if the ham is home and can attend to the situation. When the ham *isn't* home, one of the family's nonhams may attempt to do this simple chore. Alas, he/she is confronted with a vast conglomeration of cables, patch cords, coax and what not. Having no idea where to begin, they may indiscriminately disconnect everything in sight, leaving your station in complete disarray. (I speak from experience!)

I solved this problem by simplifying and streamlining equipment disconnection. All my equipment plugs into heavy-duty ac outlet strips, making it simple to pull the plugs first. Then I identified the coaxial jumper that absolutely has to be pulled: the one that protects the most equipment. About 3 inches up the cable from its PL-259 connector, I wound a piece of masking tape around the coax and painted it *red*. (Marking one such jumper may not be enough: You may need to label an additional cable for VHF/UHF equipment.)

Now, even my kids know: If I'm not home, pull the plugs and disconnect the red coax!—*Claudia J. Lang, KC3GO, 3444 Bench Dr, Pittsburgh, PA 15236*

WJ1Z: The sensitive electronics common in modern Amateur Radio stations can be damaged by the current induced by lightning strokes miles away; in fact, weather-induced static damage can occur even if lightning is absent. So, protecting your gear against atmospheric electricity is a good idea. The best way to do this is to *keep your gear entirely disconnected from power, ground and antenna wiring when you're not using it.* This end-runs the questions of whether or not someone will disconnect the gear in time, and whether or not they'll be safe as they do so. Some background:

- This hint describes a precaution against indirect lightning strokes—a precaution that does not substitute for the protection afforded by the proper grounding and lightning suppression necessary in every outdoor antenna system. Indoor antennas can be struck, too.
- Disconnecting antenna and ac-power leads may not fully protect gear left connected to ground. The best way to protect station electronic equipment against lightning damage is to *disconnect all wires from the equipment and move the equipment away from station wires and cables.*
- If severe weather is already so close that you can see lightning flashes and/or hear thunderclaps, *you may be risking your life* by disconnecting antenna, ground and power leads. Keep a weather eye out and disconnect your gear *well before* severe weather moves into your area; better yet, keep it disconnected whenever you're not using it.

Also consider applying Claudia's big red switch idea to your station's ac supply. Install and identify a main ac-cutoff switch in your station. (Such a switch *does not* constitute lightning protection; lightning capable of leaping thousands of feet through the sky won't stop at a fraction-of-an-inch air gap!) Instruct family members on how to kill the power swiftly and safely if an electrical emergency—electrical shock, for instance—occurs in your station. Get everybody on the same wavelength about what to do and who to call if the unthinkable happens. *Every second counts.*

LED OVERVOLTAGE INDICATOR FOR ZENER-DIODE PROTECTIVE CLAMPS

□ Zener diodes, either singly or in series, are sometimes connected across the output of an RF power amplifier transistor to protect the device from overvoltage. So used, they *clamp* the overvoltage—caused by impedance mismatches, parasitic oscillations or operator error—to the value determined by the diode. An LED connected in series with a Zener clamp provides a visual indication of current flow in the clamp circuit, thus warning that overvoltage is occurring in the protected circuit.

When adding an LED to a Zener clamp circuit, add the LED's forward voltage drop (1.6 to 4) to the Zener diode voltage to obtain the approximate clamping level. For example, four 15-V Zener diodes (D1-D4 in Fig 1A) connected in series across the output of an IRF511 power MOSFET (Q1, V_{DS} = 60) should adequately protect the device if each diode's *actual* Zener voltage does not exceed 15. (Remember also a given diode's actual Zener voltage may fall within ±10% of the marked value.) The voltage drop added by an LED might push the clamp circuit's conduction threshold voltage far enough over the IRF511's maximum voltage rating to allow transistor destruction before the LED begins to glow. In this situation, a single 50-V Zener in series with the LED would be a wiser choice. (In any case, keep the diodes' leads short, lest your protective circuit itself cause instability.)

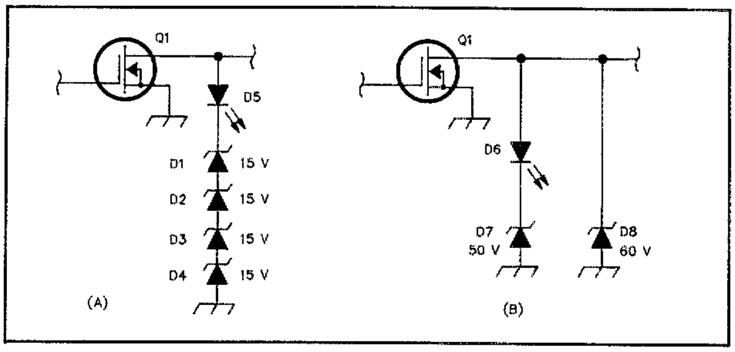


Fig 1—Sherman Lovell adds an LED indicator (D5) to a Zener-diode (D1-D4) protective clamp as shown at A. An LED open-circuit failure would disconnect the protective diode(s), though, so Sherman suggests the circuit at B as an alternative: D8 protects Q1 if D6 opens. The voltage ratings shown for D1-D4, D7 and D8 are for illustration purposes only. At D1-D4 and D7, use diode(s) equal in total voltage and dissipation ratings to the diode(s) replaced. D8's dissipation rating should equal that of the diode(s) replaced; see text for its voltage rating.

When you first apply power to the circuit, do so carefully. Bring up supply voltage and RF drive slowly while watching the LED and monitoring circuit current. LEDs can typically dissipate 75 to 100 mW; this equates to forward currents no higher than about 80 or 90 mA.

Snag: LED failure in Fig 1A disconnects the Zener diodes(s) and removes transistor protection when it's most needed. Fig 1B presents a safer, though more complex, alternative: Connect a second Zener diode (D8), one with a slightly higher voltage rating than D7, in parallel with D6-D7. If D6 fails open, D8 protects the transistor.—*Sherman M. Lovell, WY7F, 4722 15th Ave NE #9, Seattle, WA 98105*

VCR BELTS DRIVE CAPACITORS

☐ We of the Beaumont Amateur Radio Club own two Heathkit HW-101 transceivers to loan out to members (especially new Novices). The last time we checked out the transceivers, we noticed that their variable-capacitor drive belts were dry-rotted and needed replacement. We wanted to replace the belts soon, so instead of checking to see if they are still available from Heathkit, we found excellent replacements locally. We used VCR drive belts! They are of good quality, widely available and reasonably priced.—*Beaumont Amateur Radio Club, W5RIN, PO Box 7073, Beaumont, TX 77706*

FEEDBACK: KENWOOD MC-48/ TW-4000A RECEIVE-ONLY UP/DOWN OPERATION

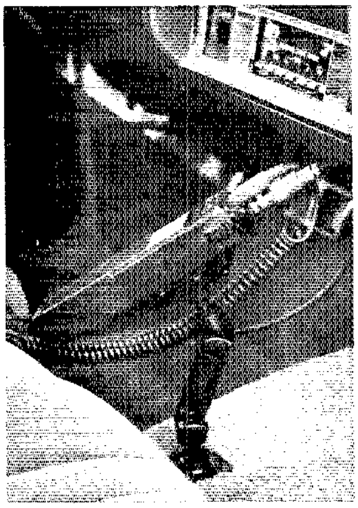
☐ Step 5 of Stanley Sears's modification[2] should read, "Solder this wire to the PTT switch on the **C** (common) terminal." The PTT line stays keyed all the time if Step 5 is performed as originally described. —*Randal A. Leval, AH6GR, Technical Specialist, Pacific Section, 1600 Ono Dr, Wailuku, HI 96793*

[2] S. Sears, "Receive-Only Up/Down Operation with the Kenwood TW-4000A Transceiver and MC-48 Microphone, Hints and Kinks, QST, Nov 1988, p 39.

New Products

HAND-HELD MOBILE MOUNT

☐ The Rig Saver Universal Hand-Held/Mobile radio mount allows you to safely place your hand-held transceiver, scanner or small mobile rig where you can see the display and access the controls. A vinyl-coated plate protects the rig from scratches and the mount can be adjusted to any angle. The Rig Saver mounts on the console, center hump, engine enclosure or dashboard. The Slimline model is $24.95 and the heavy-duty model is $29.95, plus $3 s/h for each. Townsend Electronics, Box 415, Pierceton, IN 46562, tel 800-338-1665.

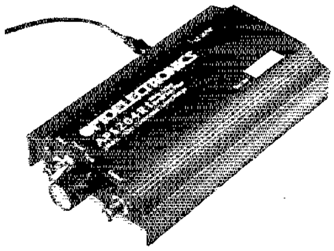


BOOM-MIKE HEADSET

☐ The Contester from the Hy-Gain Amateur Radio products group (of Telex Communications) features a noise-cancelling dynamic boom microphone that favors 800-1000 Hz for maximum voice intelligibility. The rotatable boom shuts off in the upright position. The headphones have 50-15,000 Hz frequency response, a five-foot unterminated cord and washable cotton "socks" that slip over the foam-filled ear cushions. The suggested list price is $102 from Telex Communications Inc, 9600 Aldrich Ave S, Minneapolis, MN 55420, tel 612-884-4051, fax 612-884-0043.

RECEIVER BANDPASS FILTER

☐ The Optoelectronics Model APS-204 Band Pass Filter separates closely spaced radio signals with a constant 4-MHz bandwidth and continuous electronic tuning



across 20-1000 MHz. It's designed for use in dense urban areas or where many radio transmitters must operate in close proximity. The unit is housed in a rugged aluminum extrusion measuring 4 × 1½ × 7 inches, consumes 6 watts at 12 Vdc and has an on/off switch and 10-turn potentiometer for selecting the filter's center frequency. The manufacturer claims a 10-dBm maximum noise figure with a 15-dBm typical third-order intercept. The retail price is $995 from Optoelectronics Inc, 5821 NE 14th Ave, Ft Lauderdale, FL 33334, tel 800-327-5912 or 305-771-2050, fax 305-771-2052.

Product Review

(continued from page 41)

fluenced the reviewers' opinions. The evaluation team agreed that Alinco's DJ-560T, the least-expensive rig reviewed here, doesn't have some of the features and polish of its higher-priced competition. That said, the DJ-560T isn't a bad radio; but to add that polish would drive its price up considerably.

Kenwood's TH-77A and ICOM's IC-32AT fall squarely in the middle of the opinion polls, faring about equally, but for different reasons. The IC-32AT is a rock-solid powerhouse that lacks some of the slick band-to-band integration that the others embody; the Kenwood TH-77A is loaded with features, but is uncomfortably small and complicated to operate.

Only the Kenwood TH-77A documentation includes information on connecting packet-radio TNCs (terminal-node controllers). Considering how widespread packet-radio operation has become, the lack of this information in VHF/UHF-radio documentation is surprising, although many packet operators don't use HTs for packet.

Still, manufacturers should recognize that if you can only afford (or only *want*) one FM transceiver, a dual-band HT is a good choice. These radios give you portability, flexibility in operation and power-supply requirements, reasonable power output, and a second band for much less than the price of another rig. TNC interconnection information therefore really ought to be included.

Even though these radios all have similar missions, they're not comparable in some areas. As with any other major radio purchase you're considering—and let's face it, several hundred dollars or more constitutes a major Amateur Radio purchase for most of us—order the instruction manuals from the manufacturers and make an effort to get hands-on experience with the radios you're considering *before* deciding which one is right for you.

Technical Correspondence

Conducted By Paul Pagel, N1FB
Associate Technical Editor

The publishers of *QST* assume no responsibility for statements made herein by correspondents.

REVERSE-BIASED-DIODE SWITCHING SYSTEM

☐ The diode switching circuit described in "A Diode-Switched Band-Pass Filter,"[1] is similar to one I have used in the past. My circuit, however, uses reverse-biased diodes supplied from a pull-up resistor (see Fig 1). With this circuit, reverse bias is automatically applied unless the filter section is selected by the application of +9 V.

Instead of RF chokes, low-value resistors (270 Ω) are used to establish a frequency-insensitive diode-current return path and a better off-state termination than that provided by an RF choke. The resistor values could probably be decreased (depending on the number of paralleled circuits) to provide better termination of the off-state sections and prevent interactions between filter sections. Too low a resistance value would increase the on-state insertion losses.

Table 1 summarizes results of measurements I took some years ago using common 1N914 diodes and the more exotic HP2800-series diodes. These results indicate that (1) Diode switching such a filter network appears to be feasible for all but the most demanding applications; (2) reverse bias, surprisingly, has no discernible effect on insertion loss at the levels and frequencies tested; (3) the common 1N914 diode does a respectable job at HF. All my measurements were made at a power level of +10 dBm in a 50-Ω system. Return-loss measurements (with the diodes biased on) yielded values in the 18- to 24-dB range, indicating a good termination. Return loss in the off state was 3 dB across the HF range.—*Ralph Fowler, N6YC, 35120 E Moran Rd, Pearl River, LA 70452*

Table 1
Diode Insertion-Loss Comparisons

Diode Type	*On-State Insertion Loss (dB)* 3.5 MHz	30 MHz	*Off-State Insertion Loss (dB) (with or without −9 V dc bias applied)* 3.5 MHz	30 MHz
1N914	2.5	2.5	97	62
HP2800	4	3.5	80	57

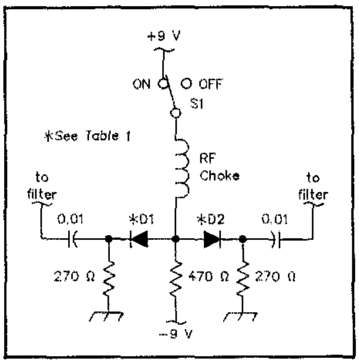


Fig 1—Ralph Fowler's reverse-biased-diode filter-switching system. Reverse bias is automatically applied to the circuit until S1 is closed.

COMPUTER PROGRAM UPDATE AVAILABLE

☐ A few years ago, I wrote a *QST* article on the design and construction of a battery charger.[2,3] The article contained a program that determines critical parts values for the charger and predicts the charger's resulting performance. That program was written in BASIC.

I now have an updated, compiled version of that program that runs on IBM PCs and clones. I'll send a free copy of the program to anyone who sends me a PC- or MS-DOS-formatted 5¼-inch disk in a self-addressed, stamped mailer bearing 52 cents First Class postage.—*Warren E. Dion, N1BBH, 108 West Main St, No. 16, Terryville, CT 06786*

[1]D. DeMaw, "A Diode-Switched Band-Pass Filter," *QST*, Jan 1991, pp 24-26.
[2]W. Dion, "A New Chip for Charging Gelled-Electrolyte Batteries," *QST*, Jun 1987, pp 26-29.
[3]PC boards (150-PCB, $7.95), kits (150-KIT, $49.95) and the UC3906 chip (150-CHP, $7.50) for the charger are available from A & A Engineering, 2521 W La Palma Ave, Unit K, Anaheim, CA 92801, tel 714-952-2114.

NEGATIVE HIGH-VOLTAGE KEYING CIRCUIT

☐ The CMOS Super Keyer II[4] is an outstanding contribution to CW operation. The output circuit, however, keys only rigs with positive low-voltage key lines. For interfacing the keyer to negative key-line transmitters, readers are referred to Jim Galm's article, "Cheap and Easy Control Signal Level Converters."[5] I chose another alternative for use with my Drake T-4XC.

The circuit shown in Fig 2 is borrowed from Jim (WB4VVF) Garrett's Accu-Keyer.[6] The PNP transistor I use is an NTE288, which is equivalent to the ECG288, GE223 and SK3434. This transistor has a collector voltage rating of 300, costs about 90 cents and is suitable for use

[4]J. Russell and B. Southard, "The CMOS Super Keyer II," *QST*, Nov 1990, pp 18-21. See also Feedback, *QST*, Feb 1991, p 63.
[5]J. Galm, "Cheap and Easy Control-Signal Level Converters," *QST*, Feb 1990, pp 24-27. See also Feedback, *QST*, Mar 1991, p 27.
[6]J. Garrett, "The WB4VVF Accu-Keyer," *QST*, Aug 1973, pp 19-23.

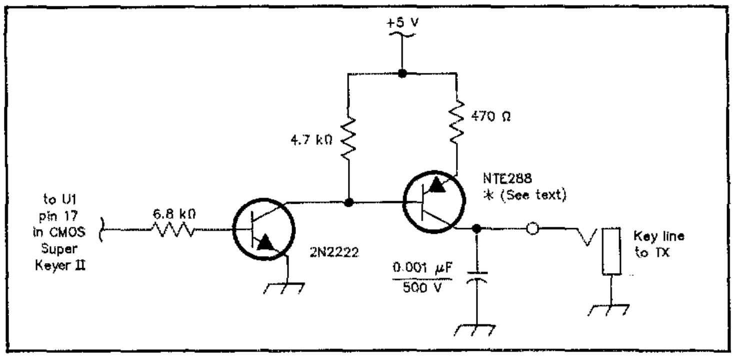


Fig 2—CMOS Super Keyer II interface for negative-voltage key lines. Notes: (1) C1 in the CMOS Super Keyer II circuit is removed and replaced by the 0.001-μF 500-V capacitor connected to the junction of the key line and the collector of the NTE288; (2) transmitter key-line negative voltage must be no greater than −300 using an NTE288, ECG288, GE223 or SK3434; (3) the interface can be installed inside the keyer with the +5-V line tied to the +4.5-V battery terminal. Do not use this circuit to grid-block key a vacuum-tube amplifier that draws grid current; the keying transistor can be subjected to damaging reverse current in such applications.

with low-current grid-block keying lines. (Don't use it to grid-block key an amplifier stage that draws grid current!) I run my interface from a separate +5-V supply, but it should be possible to use the 4.5-V battery of the keyer without excessive current drain.—*Dick Foster, W2IE, 2100 Cross Creek Trail, Round Rock, TX 78681*

[Instead of modifying every piece of ancillary gear to suit your transmitter's high-voltage keying line, consider modifying your transmitter's key line to present a low and more-compatible voltage to the modem outside world: Mount the high-voltage keying-transistor circuit inside the transmitter. In most older rigs that have high-voltage keying lines there's plenty of room to do so. One approach for the Kenwood TS-820 was described in "The TU-300—Modified," *QST*, Dec 1983, pp 38-40.—*Ed.*]

WEATHERFAX SOFTWARE UPDATE

□ Jerry Dahl's article "A Weather-Facsimile Package for the IBM PC"[7] proved to be quite popular. Now, there's a new version (3.0) of the software available.[8] Added features included in this version are:

- Support for very-high-resolution displays (1280 × 1024 × 16; 1024 × 768 × 256; 800 × 600 × 256; 640 × 480 × 256) for VGA cards using the Tseng 3000/4000 chip sets. (The ATI 1024 × 768 mode is not supported because that graphics card does not provide the BIOS call needed by the software for pull-down menus.)
- Inclusion of 20 NOAA/NESDIS image-enhancement and logarithmic curves.
- Palette interpolation lets you set a few color palette levels and the software fills in the in-between values.
- A skip-line option reduces the size of certain fax images. Skipped lines are averaged with saved lines.
- An automatic file save option that saves images to disk using a month/day/hour/minute time stamp as the file name.
- A schedule timer lets you set start times and duration for unattended operation.
- A user-specified scans-per-minute (SPM) option allows you to capture images having nonstandard SPM rates.
- Mirror-image selection corrects for wire-service photos that are received as mirrored images.
- Enhanced printer and file support permits printing and saving images that are zoomed 50%. This permits printing more of the image and reduces file size.

Version 3.0 software is being supplied at no charge with the purchase of WEATHERFAX adapter cards in kit or assembled form.—*Paul Pagel, N1FB, Associate Technical Editor*

[7]J. Dahl, "A Weather-Facsimile Package for the IBM PC—*Part 1*, *QST*, Apr 1990, pp 15-24; —*Part 2*, *QST*, May 1990, pp 17-21.
[8]Software upgrade, $30; specify disk size (3½" or 5¼"). Order from OFS Software, 6404 Lakerest Ct, Raleigh, NC 27612, tel 919-847-4545.

SURFACE-MOUNT SOLDERING

□ Surface-mount devices and boards are a great invention and a joy to work with once you get comfortable handling and soldering the tiny devices. My soldering routine is slightly different from that suggested by Bryan Bergeron, NU1N.[9]

Tinning both pads may lead to an installation in which the device is not flat and close to the board. Or, worse, a fragile chip device may be left physically stressed. I prefer this routine:

- Tin only *one* of the pads, and let it cool.
- Set the device in place. While pressing the device very slightly with a toothpick, reheat the tinned pad until the device sinks flat to the board. Allow the connection to cool.
- Solder the second terminal, touching the iron only to the pad.
- After the device has again cooled, touch up the first solder joint as necessary.
- Use silver solder.

With this method, I get a 100% success rate of devices that are flat, straight and well-soldered.

Finding silver solder can be a problem in some locations. I have a good stock of Kester 60/37/3 (tin/lead/silver) solder. This solder contains flux and works easily with low-wattage irons. I can supply a one-ounce coil of solder for $2.50 plus an SASE. (Radio Shack carries 62/36/2 solder [RS 64-013], 1.5 oz for $2.99.—*Ed.*)—*Paul D. Husby, WØUC, 1462 Midway Pkwy, St Paul, MN 55108*

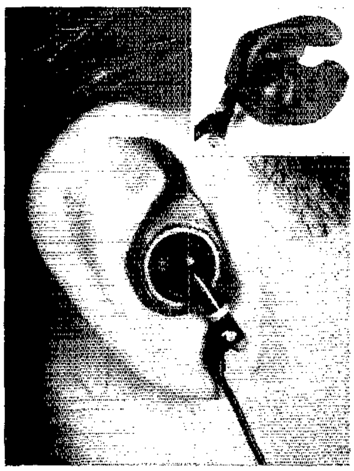
[9]B. Bergeron, "A Surface-Mount Technology Primer—*Part 2*," *QST*, Jan 1991, pp 27-30; see p 29, Fig 12.

Note: All correspondence addressed to this column should bear the name, call sign and complete address of the sender. Please include a day-time telephone number at which you can be reached if necessary. (The ARRL and *QST* in no way warrant offers of products or services presented herein by correspondents.)

New Products

CUSTOM EARSETS

□ The Radio Partner Custom Earset is a high-fidelity inside-ear transducer that eliminates headbands and allows you to listen to audio from transceivers, broadcast receivers, tape decks and CD players while bicycling, jogging or engaging in other physical activities. The individually made Earsets are crafted to your ears' shape from the special impression forms supplied (you ship them back for use as a template). The Earsets come in red, blue or yellow and are fitted with Sony 414 ($69), 565 ($109) or 484 ($149) Turbo speakers ($4 p/h additional). The unconventional design keeps the audio from disturbing others and reduces the need for high audio power by channeling more sound into the ear canal. Radio Partner Inc, 132 W 21st St, New York, NY 10011, tel 212-924-1124.



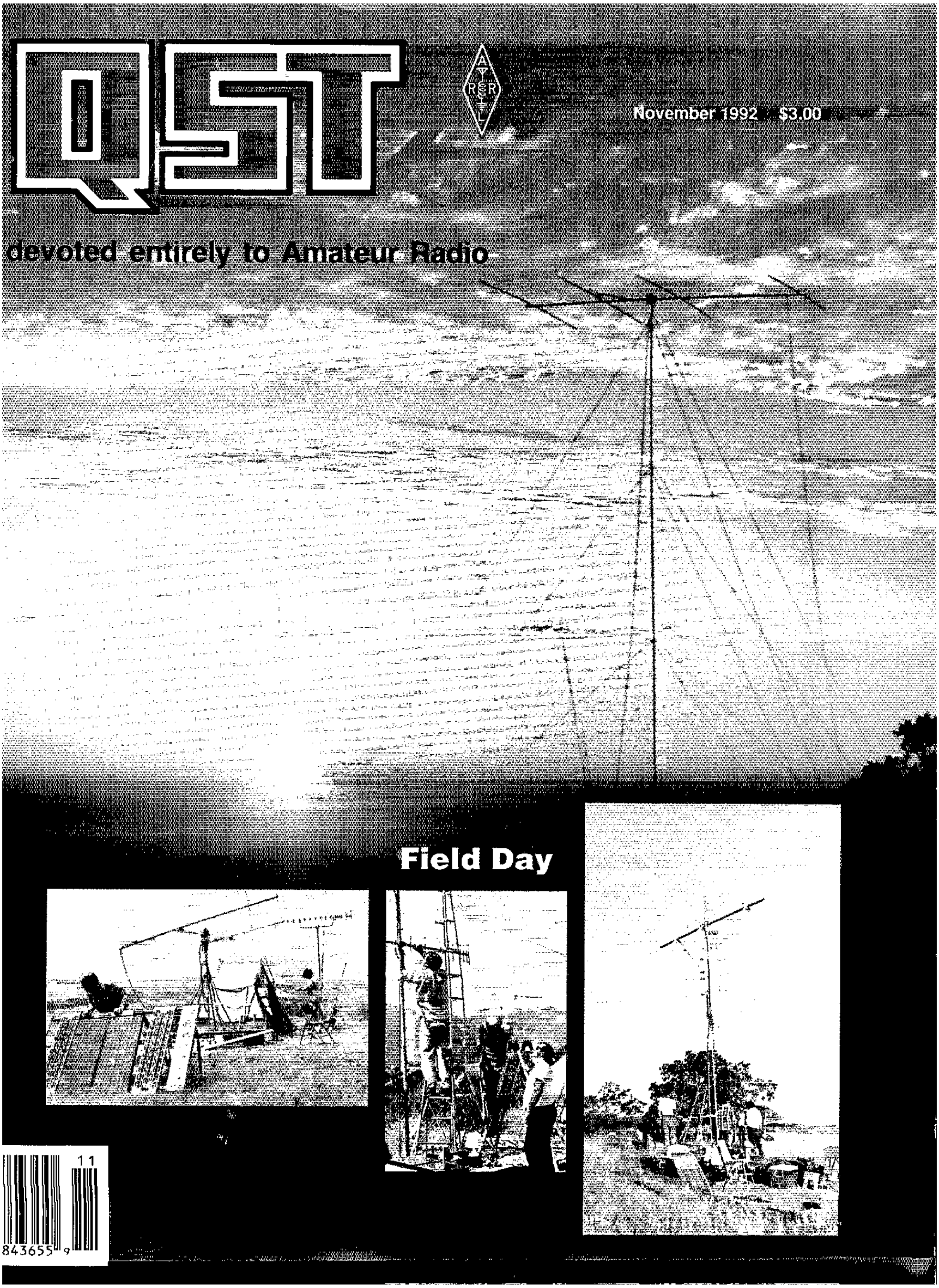
New Books

VIBROPLEX GUIDE

□ *The Vibroplex Collector's Guide* by Tom French, W1IMQ, covers details on these unique telegraph keys. It contains the complete text and drawings from all the major patents beginning with Horace Martin's 1903 Autoplex patent. There are also original advertisements, historical notes, a list of collectors' magazines, tips on dating the bugs, making adjustments, variations in models over the years and more. It's an 8½- × 11-inch 87-pp soft-cover book with black & white illustrations that sells for $14.95 plus $2 s/h from Artifax Books, PO Box 88, Maynard, MA 01754.

Feedback

□ Emil Pocock, W3EP, points out an error in Fig 8 of his April 1991 *QST* article, "Midrange Forecasts of Solar and Geomagnetic Activity." See page 27. In the figure, the horizontal-axis labels should each be shifted one bar to the left; the tallest bar should be labled 0, the one to its left −1, and so forth.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Foreign remittances should be by international postal or express money order or bank draft negotiable in the US and for an equivalent amount in US funds. Canadians apply to CRRL address; see page 9.

Second-class postage paid at Hartford, CT and at additional mailing offices. Postmaster: Form 3579 requested. Send change of address to: American Radio Relay League, 225 Main St, Newington, CT 06111.

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Indexed by Applied Science and Technology Index, Library of Congress Catalog Card No: 21-9421.

OUR COVER

The antennas at the San Jose State University ARC's Field Day station, W6YL, overlook a beautiful Pacific Ocean sunset. Varied sights—and sites—included (inset, l-r) the East Bay ARC's solar-powered OSCAR station, at W6CUS; members of the Conejo Valley ARC install 70-cm antennas at K6CAB in the Santa Barbara Section; W6YL used this 3-element quad in the 2A category. Field Day 1992 drew more than 37,000 participants June 27-28. See Up Front in *QST* for more photos and read the complete results on page 118.

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TECHNICAL

NEWS AND FEATURES

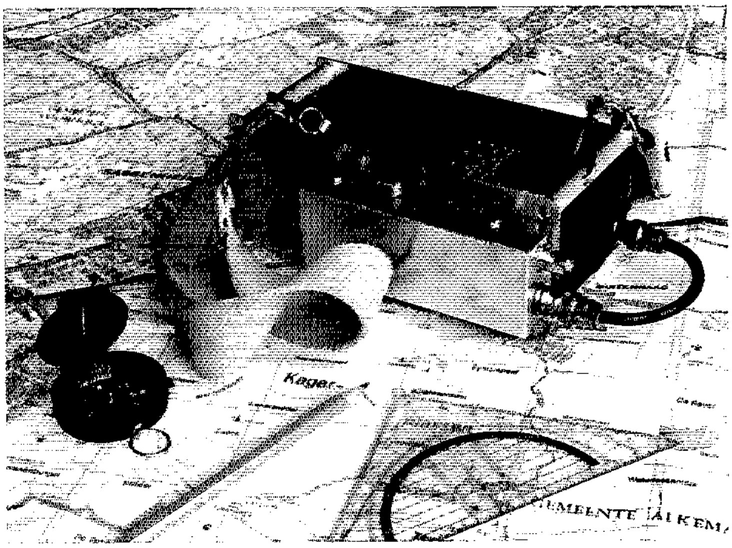
OPERATING

DEPARTMENTS

An Active Attenuator for Transmitter Hunting

Here's an innovative approach to transmitter hunting that eliminates the use of traditional passive attenuators to control the strength of the received signal. With this *active* attenuator, you'll be able to home in on your target with greater precision!

By Anjo Eenhoorn, PA0ZR
Frankenhorst 12
2171 VE Sassenheim
The Netherlands



During a transmitter hunt, the strength of the received signal can vary from roughly −120 dBm at the starting point, to 0 dBm when you're very close to the transmitter. To find the transmitter, your receiver must be capable of providing accurate signal-strength readings throughout the hunt. Most hand-held transceivers provide a signal-strength indicator (either a meter or an LCD bar graph) with a usable range of −120 to −90 dBm. Although this may be fine for normal operating, it's totally inadequate for transmitter hunting!

Inserting a passive attenuator between the antenna and the receiver reduces the received-signal strength. By selecting various levels of attenuation, you'll see peak signal readings as you search for your target. More precise readings and greater ease of use would result if the attenuation was *continuously variable*. However, the usefulness of a variable attenuator is limited by how well the receiver is shielded. Modern hand-held transceivers often lack adequate shielding, allowing strong signals to effectively "leak around" the attenuator. This can result in significant directional errors.

I've designed an active attenuator that achieves continuously variable attenuation by mixing the received signal with a signal from a simple oscillator circuit. This process creates mixing products above and below the input frequency. The spacing of the closest products from the input frequency is equal to the local oscillator frequency. If the input signal is at 146.52 MHz, for example, and the oscillator is running at 500 kHz, the closest mixing products will appear at 147.02 and 146.02 MHz. By increasing or decreasing the oscillator signal, the strength of the mixing product signals decreases or increases according to the *conversion loss* of the diode mixer.

By monitoring the mixing products, you can obtain accurate headings even in the presence of a strong received signal. As a result, any hand-held transceiver—regardless of how poor its shielding may be—can be used for transmitter hunting.

Varying the level of the oscillator signal provides the extra advantage of controlling the strength of the input signal as it passes through the mixer. So as you close in on your target, you have the choice of monitoring and controlling the level of the input signal or the product signals—whichever provides the best results. (Although I used 2-meter frequencies in the previous example, the attenuator will function elsewhere in the VHF or UHF range.)

Circuit Description

The heart of the oscillator circuit is Q1, a 2N2222A transistor (see Fig 1). Trimmer capacitor C1 adjusts the oscillator's operating frequency. Oscillator frequency stability is only a minor concern; a few kilohertz of drift is tolerable.

Q1's output is fed to an emitter-follower buffer comprised of Q2, a 2N3904 transistor. R6—a linear-taper potentiometer—controls the oscillator signal level present at the cathode of our mixing diode, D1. D1 and coupling capacitor C7 are in series with the signal path from the antenna input to the attenuator output.

I must admit that my oscillator/mixer design may seem unorthodox. In my initial attempts to design an active attenuator, I tried the conventional approach using a doubly balanced mixer with the prescribed 5-mW local oscillator drive, matching pads, filters and so on. My conclusion was that this simple circuit has all the necessary performance features, is easy

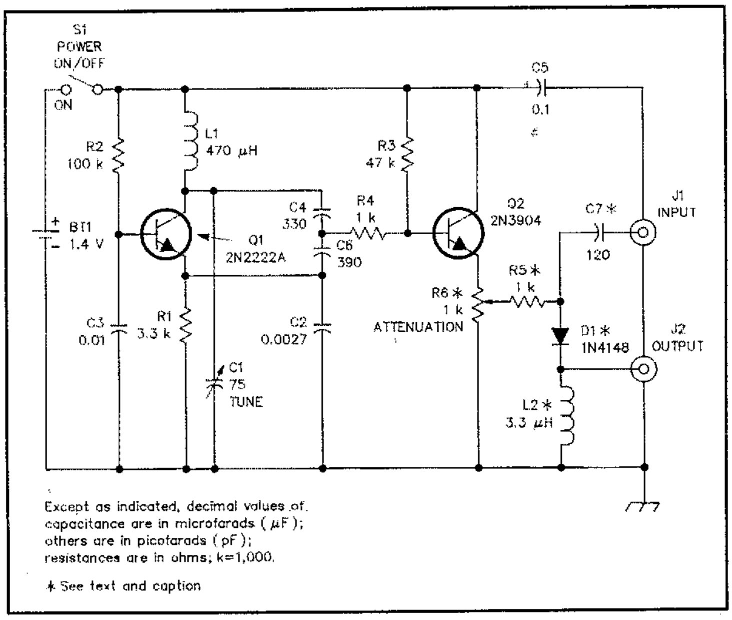


Fig 1—Schematic of the active attenuator. Resistors are ¼-W, 5%-tolerance carbon-composition or film. R6 is mounted on the wall of the metal enclosure. (The author used a slide control at R6; a rotary control is also suitable.) R5, C7, D1 and L2 are connected between the input/output connectors, ground and R6.

BT1—Alkaline hearing-aid battery. Duracell SP675 or equivalent.
C1—75-pF miniature foil trimmer.
J1, J2—BNC female connectors.
L1—470 μH-RF choke.
L2—3.3 μH-RF choke.
R6—1 kΩ, 1-watt, linear taper (slide or rotary).
S1—SPST toggle.

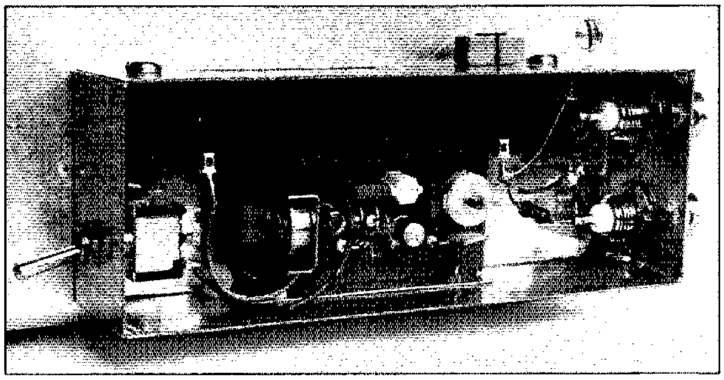


Fig 2—An interior view of the active attenuator. Note how C7, D1 and L2 are mounted between the BNC connectors. R5 (not visible in this photograph) is connected to the wiper of slide pot R6.

to build and consumes little power. In fact, its power source is a tiny 1.4-volt hearing-aid battery!

Construction

I've designed a small PC board for the oscillator and buffer circuits. The etching template and parts overlay are available from ARRL Headquarters.[1] To further simplify assembly, a circuit board is available from FAR Circuits.[2]

I mounted the PC board within a tin-plated enclosure using female BNC connectors for the input and output (see Fig 2). My enclosure was designed to accommodate a slide potentiometer, R6. Other potentiometers and enclosures can be used as well. C7, D1, L2 and R5 are installed with point-to-point wiring between the BNC connectors and the potentiometer. S1, an SPST switch, is mounted on the rear wall of the enclosure.

BT1 is held in place by a piece of U-shaped tin plate (see Fig 3). This plate is the positive terminal and it's soldered to the PC board with four pieces of #18 wire. The negative terminal consists of a piece of spring bronze that's soldered to the underside of the PC board. When the battery is inserted into the holder, the spring clip holds it in place.

To make the entire system as portable as possible, I bolted the attenuator box to the side of a U-shaped aluminum carrying case in which the transceiver is mounted face up. Two bars are attached to the case and holes were drilled in the middle of each bar. The holes serve as attachment points for a camera belt. These belts are generally available in photographic supply shops.

Tuning the Attenuator

The example at the beginning of the article assumed that the oscillator was operating at 500 kHz. This would place the closest mixing products 500 kHz above and below the true transmitter frequency. Most hams will find that this is a convenient arrangement, but the oscillator can be tuned to other frequencies as well. The frequency you choose will depend on local operating conditions. If VHF/UHF activity is high in your area, it may be to your advantage to choose an oscillator frequency that will create products in clear portions of the band.

You can tune the oscillator with a frequency counter, or with the help of a strong signal of known frequency (it helps to enlist the aid of a friend for this procedure). Connect a short piece of wire to J1 and connect your hand-held transceiver to J2. Select a simplex receive frequency that matches the frequency of your friend's transmitter. Ask your friend to make sure the transmitter is operating at its lowest power output setting. (Better yet, attach the transmitter to a dummy antenna.)

With the attenuator on, adjust R6 to obtain a midscale reading. Now switch your receive frequency to one of the mixing product frequencies. Carefully tune C1 and adjust R6 until you hear the mixing product. Watch your signal-strength meter and tune C1 for maximum reading. If the circuit is performing normally, you should be able to switch to the other mixing product frequency and hear a signal there as well.

Using the Active Attenuator

If your receiver or transceiver features memory functions for frequency selection,

[1]Notes appear on page 95.

What's Transmitter Hunting?

Some call it fox hunting, radio direction finding, DFing, bunny hunting or T-hunting. Regardless of which label you choose, the objective is simple—find the hidden transmitter!

A person selected to play the role of the fox takes a transmitter to an undisclosed location. The hiding place could be very close to the starting point, or it could be many miles away. The fox may go to great lengths to disguise the transmitter. It might be buried in a weed-choked field, or hanging from the branches of a tree. A particularly clever fox will use a directional antenna to bounce the signal off a building, hill or mountain. This will send the hunters on a wild goose chase until they discover the true direction of the signal.

The hunters usually gather at the starting point and carefully check their equipment as they wait for the chase to begin. At the appointed time, the fox activates the transmitter and the hunt is on! Everyone takes their first bearings on the signal and heads off in that direction, taking new bearings frequently as they go.

If the fox is very close by, the entire hunt can be conducted on foot. Many hamfests feature such localized hunts as one of their main attractions. Other hunts cover greater distances, with teams of hunters traveling by car. Some groups conduct marathon hunts that cover more than a hundred miles and last several days!

Transmitter hunting isn't all fun and games, though. By participating in these hunts, you're sharpening your skills for some very practical applications. For example, your transmitter hunting experience can make a life or death difference when you're assisting in the search for a missing aircraft. Most aircraft carry emergency locator transmitters—ELTs—that emit a continuous beacon in the event of a crash. Your skills and equipment may play a vital role in determining an ELT's location.

In recent years, amateurs have launched electronics packages (many of which include ATV equipment) in rockets and high-altitude balloons. Experienced transmitter hunters are essential to the safe recovery of these devices. Thanks to the skills of amateur transmitter hunters, the recovery rate has exceeded 90%.

Transmitter hunting also comes in handy when a signal jams your local repeater. The jamming could be malicious, or it could be an innocent amateur with a microphone PTT switch locked on.

Most transmitter hunts take place at VHF frequencies. The equipment requirements are simple. All you need is a receiver, a highly directional antenna and a signal attenuator such as the one designed by PAØZR. The *ARRL Handbook* suggests designs for effective transmitter-hunting antennas. Another excellent reference is *Transmitter Hunting: Radio Direction Finding Simplified*, by Joseph Moell, KØOV, and Thomas Curlee, WB6UZZ. Both books are available from your local dealer, or direct from ARRL Headquarters. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

Transmitter hunting is pure excitement—whether you're the hunter or the fox! It only takes two hams to start a hunt, but it's even more fun when you involve a large group. Transmitter hunting is an excellent activity for clubs. You can challenge your members to join the hunt and offer prizes for the winners.—*WB8IMY*

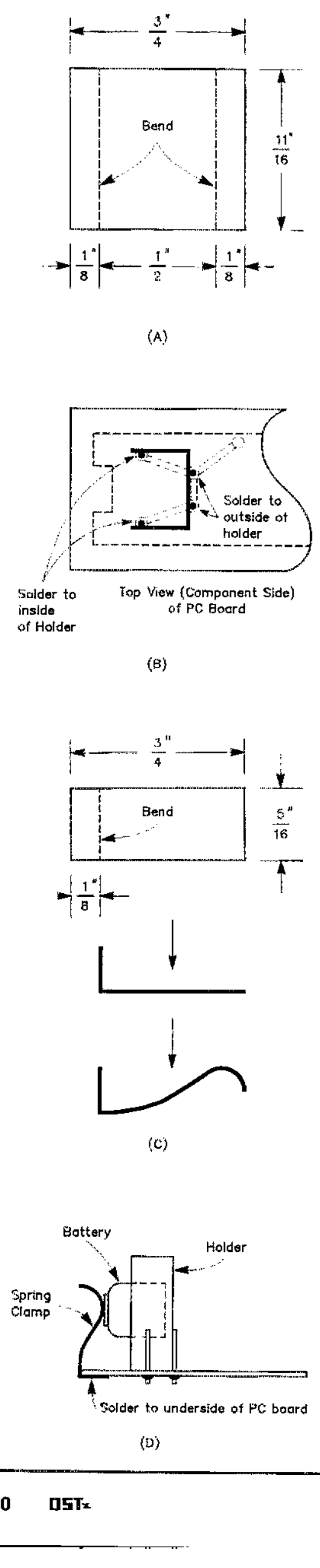


Fig 3—The positive terminal of the battery holder is fashioned from a piece of 3/4- × 11/16-inch tin plate, approximately 0.02 inches thick. Bend the plate as shown at A and make certain that the hearing-aid battery fits inside it. Solder four #18 bare wires to the circuit board pads shown at B. Position the holder on the component side of the board as indicated and solder the wires to it. The battery clip is made from a 5/16- × 3/4-inch piece of spring bronze. Bend the clip as shown at C. Slip the flat end of the clip around the edge of the PC board and solder it to the foil side as shown at D. If you're using a larger enclosure for the attenuator, you can omit the hearing-aid battery and use a standard AA-cell battery holder mounted away from the PC board.

enter the frequency of the fox along with both mixing-product frequencies before the hunt starts. This allows you to jump from one to the other at the press of a button.

When the hunt begins, listen to the input frequency with the attenuator switched on. Adjust R6 until you obtain a peak reading. If the signal is too weak, connect your antenna directly to your transceiver and use the S meter without the attenuator until the signal becomes stronger.

As you get closer to the transmitter, the attenuator may not be able to reduce the signal enough to provide a usable signal-meter peak. Switch to one of the mixing-product frequencies. At the mixing-product frequencies, the attenuator's range is greater than 100 dB. As you approach the

(continued on page 95)

Remote Control Using Your H-T

Remote control of ac power is easy using your DTMF-equipped rig and this handy control box.

By Bill Caruso, NØBLD
4020 Evans Ave
Boulder, CO 80302

Most radio amateurs are aware of the low-power, 27- and 49-MHz wireless transmission systems used for garage door openers and remote-control toys. Your ham ticket permits you to legally transmit remote-control signals at much higher power levels than those permitted on 27 and 49 MHz, allowing for longer-range remote-control applications. Because there are several amateur rigs on the market with built-in dual-tone, multi-frequency (DTMF) generators, remote-control systems that use DTMF coding are the easiest to implement for most of us.

This simple circuit uses popular and inexpensive CMOS logic ICs and power triacs to switch 120-V ac power, allowing you to turn on and off equipment or appliances (up to a maximum load of 1250 watts) from distant locations. With this circuit, you can ready your radio or computer, have a fresh cup of coffee waiting for you when you arrive home, or turn lights on and off in your home as extra security when you're away. The potential applications of this project are quite broad, and I've made it easy to modify so that it can be used universally. It's easy to build, too, using the PC board available from FAR Circuits.[1,2] See Table 1 for a list of parts sources.

Circuit Description

Refer to Fig 1. Power for the circuit is supplied by a transformer/diode-bridge combination followed by Zener diode D7 and a low-current, 5-V regulator, U1. Receiver audio is sent via J1 to the DTMF detector, U2. S1, an 8-pole DIP switch, is used as a coding device. Four poles of the switch are used in each of two comparator positions at U4 and U5. By setting the individual switch poles, you customize the circuit to your individual DTMF codes.

Three DTMF tones are used to control the output circuit; the first two are part of a security code. If the first received tone is the same as that represented by the settings of the first four positions of S1 ahead of the first comparator (U4), one flip-flop in U10 is set, thereby enabling the second comparator, U5. On receipt of the second tone matching the setting of the last four positions of S1, comparator U5 sets a second flip-flop in U10. The third tone contains the information needed by the circuit to ascertain which particular output circuit will be switched, and whether the voltage is to be applied to, or removed from, the respective output-circuit socket. As shown here, the circuit is wired so that the third tone controls the output circuits as shown in Table 2. Upon receiving the third tone, U7 decodes the 4-bit word sent from U2 and activates a single output pin that sets or resets one of the flip-flops in U8 or U9.

Within three seconds of any tone transmission, U6 resets all the flip-flops in U10. If you accidentally press the wrong button on the DTMF pad, you simply wait about three seconds for the circuit to reset then start your transmissions over again. Of course, this also means that you can't expect the circuit to do what you want unless you press three buttons in less than three seconds apiece.

The first two DTMF tones are used as an uncomplicated security code to prevent unauthorized access to the circuit by others transmitting DTMF signals that the controller receives. Although other on-frequency signals may or may not have malicious intent, some sort of barrier must be maintained so that only authorized access is honored.

If, for whatever reason, you need to override these security codes, you can choose to modify the circuit by breaking the connection between pin 11 of U10 and pin 23 of U7 and tying high pin 23 of U7. The DTMF signal can then be transmitted directly to the circuit; command execution occurs about three seconds later.

Note that although only one output circuit is shown in the schematic, you can include any number of output circuits, up to a maximum of 7. Each output circuit consists of a 2N2222A bipolar transistor (Q1, 3, 5, 7, 9, 11, 13), an MOC3010 optoisolator (U11-U17,); an associated MAC210A6FP triac (Q2, 4, 6, 8, 10, 12, 14); four resistors (R14-38, R15-37, R16-40 and R17-41) and a capacitor (C13-19) for each circuit. For example, adding a second output circuit would involve installing Q3

Table 1
Parts Availability

The components for this project were chosen for their low cost and ready availability from several sources, some of which are listed below. PC boards can be obtained from FAR Circuits (see Note 1). The ac sockets are available inexpensively from All Electronics and Ocean State Electronics; you may be able to find them at your local hardware store. With everything purchased new, the parts cost for this project is about $95. Of this, I paid $20 for the enclosure and $10 for the transformer. Buy parts inexpensively (at a ham fest or surplus outlet), or scrounge them, and you can considerably reduce the overall cost.

Part sources

All Electronics Corp, PO Box 567, Van Nuys, CA 91408-0567, tel 800-826-5432, 818-997-1806, fax 818-781-2653.

Digi-Key Corp, 701 Brooks Ave S, PO Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4539, 218-681-6674, fax 218-681-3880.

FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269.

Newark Electronics (many locations throughout the US; check your telephone book for a branch near you). Main office: 4801 N Ravenswood Ave, Chicago, IL 06040-4496, tel 312-784-5100, fax 312-784-5100, ext 3107.

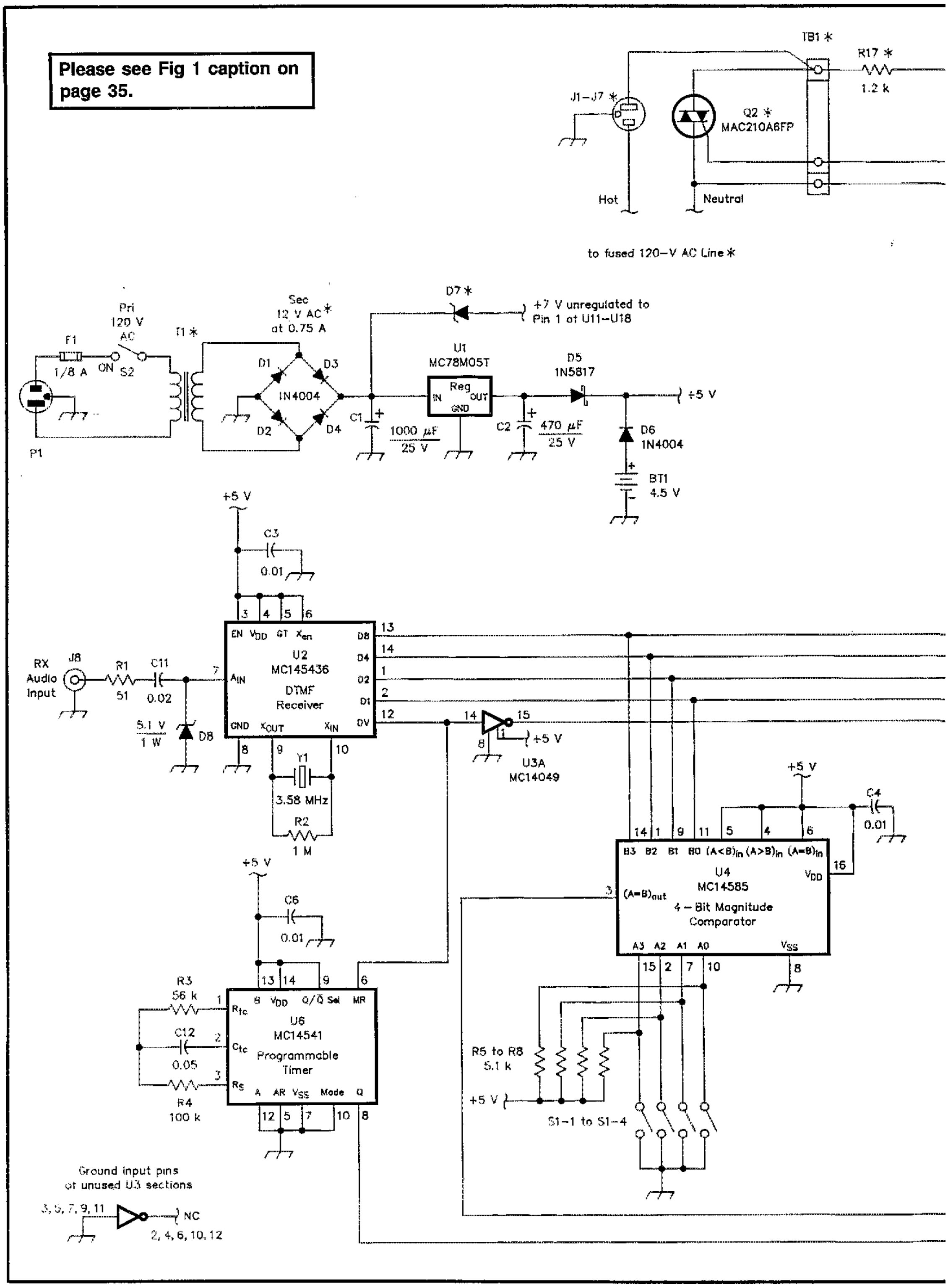
Ocean State Electronics, PO Box 1458, Westerly, RI 02891, tel 800-866-6626 (orders only), 401-596-3080, fax 401-596-3590.

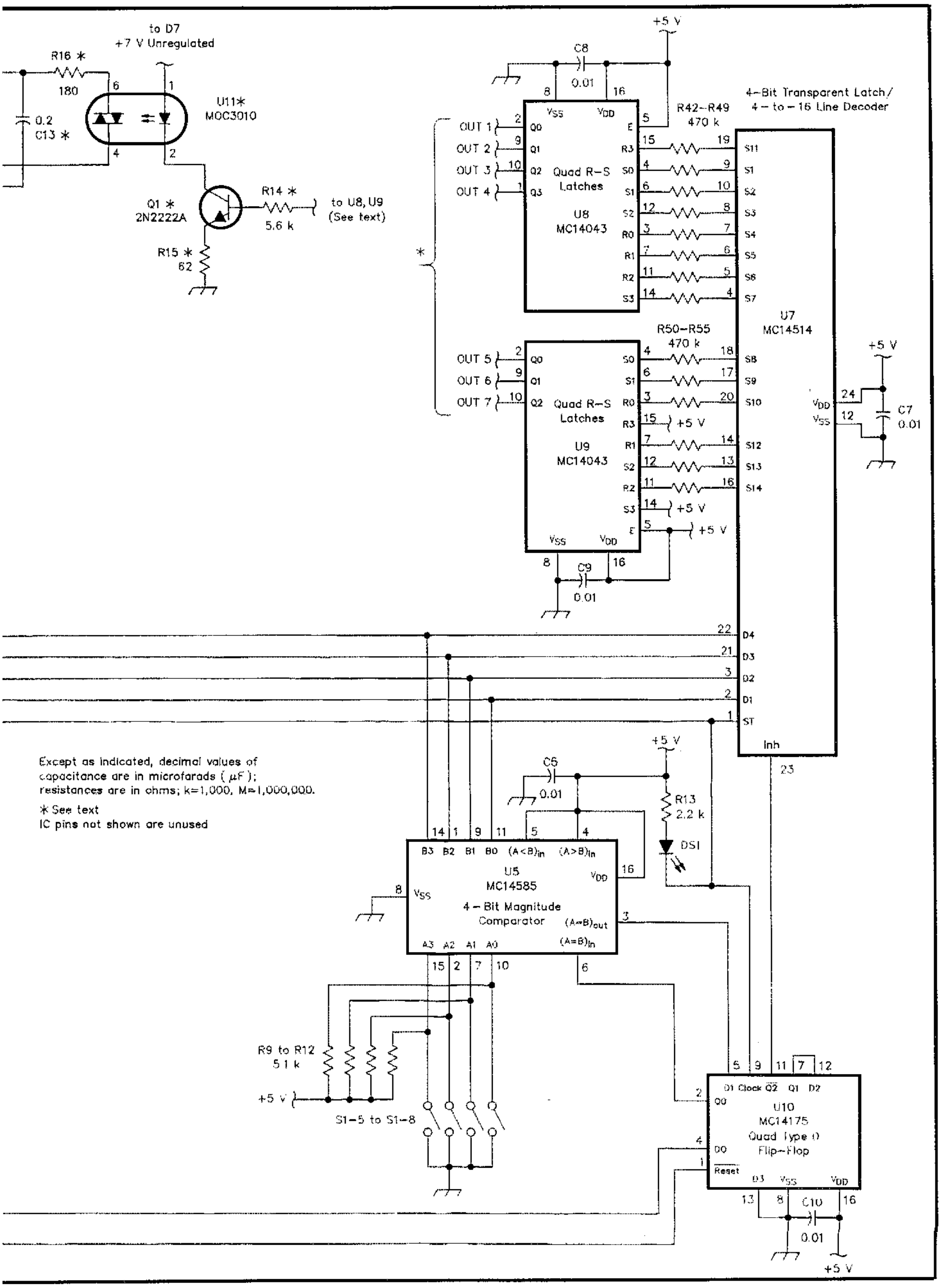
Table 2
DTMF Keystrokes and Resulting Action

Key Pressed	Resulting Action	Key Pressed	Resulting Action
1	1 turns on	8	5 turns on
2	2 turns on	9	6 turns on
3	3 turns on	*	4 turns off
4	1 turns off	0	5 turns off
5	2 turns off	#	6 turns off
6	3 turns off	A	7 turns on
7	4 turns on	B	7 turns off

[1]Notes appear on page 35.

Please see Fig 1 caption on page 35.





to D7
+7 V Unregulated
R16 *
180
0.2
C13 *
U11*
MOC3010
Q1 *
2N2222A
R14 *
5.6 k
to U8, U9
(See text)
R15 *
62
+5 V
C8
0.01
R42–R49
470 k
4-Bit Transparent Latch/
4 – to – 16 Line Decoder
OUT 1
OUT 2
OUT 3
OUT 4
Quad R–S
Latches
U8
MC14043
U7
MC14514
R50–R55
470 k
OUT 5
OUT 6
OUT 7
Quad R–S
Latches
U9
MC14043
C9
0.01
C7
0.01
Except as indicated, decimal values of capacitance are in microfarads (μF); resistances are in ohms; k=1,000, M=1,000,000.
* See text
IC pins not shown are unused
C5
0.01
R13
2.2 k
DS1
U5
MC14585
4 – Bit Magnitude
Comparator
R9 to R12
51 k
S1–5 to S1–8
U10
MC14175
Quad Type D
Flip–Flop
C10
0.01

(2N2222A), Q4 (MAC210A6FP), U12 (MOC3010), R18 (5.6 kΩ), R19 (62 Ω), R20 (180 Ω), R21 (1.2 kΩ), C14 (0.22 μF) and J2. With this approach, all components are sequentially numbered for each output circuit.

Circuit Protection and Isolation

The input circuit employs a peak clipper (D8) to prevent destructive overloading of the DTMF-receiver input. When the incoming signal is clipped, the DTMF receiver won't recognize the signal. Decreasing the radio's audio output will remedy this.

The optoisolators prevent destruction of the CMOS chips and the output of the receiver to which this project is connected. Without the optoisolators, triac failure could destroy these associated components.

The MAC210A6FP triac is capable of passing 10 A with proper heat sinking, allowing each channel to handle loads of up to 1250 W at 125 V ac. The resistors and capacitors between the triacs and their associated drivers are necessary when driving inductive loads such as motors. When driving purely resistive loads, the capacitors and resistors can be omitted, *with the exception of the 180-Ω resistor*, which is necessary to limit the triac's gate current.

Table 3

D7 Choices Versus T1 Voltage

(Equivalent diodes can be substituted.)

T1 Peak Secondary Voltage	*Diode Choice*
7.5	Use direct connection
10	1N5333A
12	1N5338A
12.6	1N5339A
14	1N5342A
15	1N5343A
16	1N5344A
18	1N5348A
20	1N5352A
24	1N5354A
25	1N5355A

A MAC210A6FP triac looks like a TO-220 package that slipped into a vat of molten plastic. Essentially, that's what the TO-221 package is! This makes mounting the triac easy. There's no need to use mica insulators and plastic shoulder washers when installing this package because it's already electrically insulated from its surroundings. Of course, this doesn't preclude you from using heat-sink compound, as the heat from the triac's package must still be transferred to the heat sink. Because the triacs in this project are cooled through natural convection—and because there's a lot of power dissipated by these triacs—use a chassis that permits generous spacing between triac mountings: A space of about 2.5 inches between each triac should provide sufficient breathing room.

On power-up, the circuit *usually* switches off all ac outputs. Be aware, however, that when you power up the circuit, some channels *may* turn on. Here's where BT1 comes in. Battery backup BT1 ensures that all logic states are maintained in the event of a temporary power failure. Once the battery is installed, the output channels should always retain the state they were in when ac power was removed from the circuit.

For safety, fuse each load properly and independently.

Construction

I built my controller in a 12 × 7 × 3-inch box (see Fig 2). A sheet of aluminum, with a number of ventilation holes drilled in it, acts as the cover. The enclosure size you use will probably depend primarily on how many controlled outlets you're going to include. (The PC board measures 7-7/8 × 4-3/4 inches.) Stick-on rubber feet are placed at each corner of the outside bottom of the box. You can make the holes for the snap-in ac outlets by using a nibbling tool (Radio Shack sells one: #64-823) and file. Practically every other hole can be made simply with a hand drill and an appropriately sized bit, file and/or tapered reamer.

For T1, use any transformer that delivers a secondary current of at least 500 mA and a secondary voltage of between 7.5 and 25. The diode used at D7 must be chosen appropriately for T1's secondary voltage. Table 3 provides a list of suitable diodes to use with several T1 secondary voltages.

On the inside chassis bottom, I mounted two double-row barrier terminal strips. (My surplus strips had 17 terminals each.) These are used to make the interconnections between the PC board and the off-board components. One-inch standoffs support the PC board above the chassis bottom and terminal strips.

Modifications

For controlling lower-voltage projects, you may prefer to tap the output from the 2N2222A directly: The transistor can deliver a maximum of about 50 mA. You may want to connect the input of the controller to the input to your telephone answering-machine speaker (or rig the answering machine and radio in parallel). That allows you to remotely control, via the telephone lines, the equipment attached to the controller box. In such an application, it may be safe to disable the security code as you probably won't have callers randomly pressing DTMF buttons on their telephones.

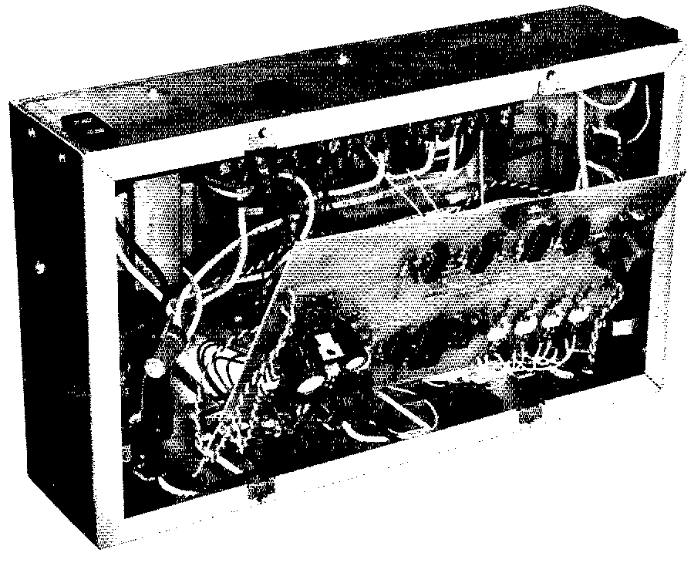


Fig 2—An inside view of the controller with the PC board partially removed. An early version of the FAR Circuits board is used in this prototype. Beneath the line-cord entry point at the lower-left corner of the chassis is a battery holder containing three AA cells (BT1). T1 is above that. The ac outlets (J1-J7) are mounted around the perimeter of the enclosure. The larger two of these are three-terminal sockets (equipped with a safety ground); the others are two-terminal sockets. (I used these because I had them on hand.) Between the outlets, secured to the inside wall of the case, are the triacs. One of the two double-row barrier terminal strips used for making interconnections between the PC board and the off-board components can be seen above the PC board. In position, the board is supported by 1-inch standoffs.

Fig 1—Schematic of the remote-control circuit. Equivalent parts can be substituted. Unless otherwise specified, resistors are ¼-W, 5- or 10%- tolerance carbon-composition or film units. See Table 1 for a list of parts sources.

BT1—Three AA alkaline cells.
C1—1000 μF, 25 V.
C2—470 μF, 25 V.
C3-C10—0.01 μF.
C11—0.022 μF.
C12—0.047 μF.
C13-C19—0.22 μF.
D1-D4, D6—1N4004.
D5—1N5817, 20-V, 1-A Schottky diode.
D7—5-W Zener; see Table 3.
D8—1N4734A, 5.6-V, 1-W Zener.
DS1—LED.
F1—3AG, fast-acting, 0.125-A, 250-V fuse (Littelfuse 312.125).
J1-J7—120-V ac receptacles (All Electronics #ACS).
J8—Phono jack or single-circuit jack.
P1—120-V ac polarized wall plug.
Q1, Q3, Q5, Q7, Q9, Q11, Q13—2N2222A.
Q2, Q4, Q6, Q8, Q10, Q12, Q14—MAC210A6FP triac.
R14, 18, 22, 26, 30, 34, 38—5.6 kΩ.
R15, 19, 23, 27, 31, 35, 37—62 Ω.
R16, 20, 24, 28, 32, 36, 40—180 Ω.
R17, 21, 25, 29, 33, 37, 41—1.2 kΩ.
R42-R55—470 kΩ.
S1—8-position DIP.
S2—SPST toggle.
T1—7.5- to 25-V, 500-mA (minimum) secondary, 120-V primary transformer; see text and Table 3.
TB1—Part of an 18-position double row barrier terminal strip (Beau 76018); see text and Fig 2 caption.
U1—MC78M05CT, 5-V, 500-mA voltage regulator.
U2—MC145436P DTMF receiver.
U3—MC14049BCP hex inverting buffer.
U4, U5—MC14585BCP 4-bit magnitude comparator.
U6—MC14541BCP programmable timer.
U7—MC14514BCP 4-bit transparent latch/4- to 16-line decoder.
U8-U9, incl—MC14043BCP quad R-S latch.
U10—MC14175BCP quad type D flip-flop.
U11-U17—MOC3010 optoisolator.
Y1—3.58-MHz color-burst crystal.

Misc: PC board (see Note 1), enclosure, fuse holder (Littelfuse 150145), #14 AWG three-conductor line cord, 8 feet of #14 AWG, 10 feet of #20 or #22 hookup wire, 4 rubber feet, machine screws, nuts, standoffs, 1 cable strain relief, cable ties, etc.

Hookup and Operation

The controller connects directly to the audio output of your rig. Because the input range of the MC145436 DTMF receiver is quite broad, it's easy to find the optimal audio-gain adjustment simply by transmitting a weak RF signal to the receiver and turning the receiver's volume knob until DS1 illuminates every time a DTMF signal is sent. You can obtain the required weak RF signal by transmitting into a dummy antenna or inserting an attenuator between a transmitter and its antenna. Too much RF can cause IF interference that makes preliminary adjustment difficult.

FCC rules allow using amateur transmissions for remote control. Proper operating procedures and good sense dictate that you don't use repeaters for this purpose, and that you use minimum power and identify yourself before and after transmitting the DTMF tones when using any frequency. Try to use a relatively unpopulated part of the spectrum intended for simplex communication in your area. On 2 meters, I suggest a frequency from 145.5 to 145.8 MHz.

Instead of tying up an entire receiver—an expensive proposition for the simple task of receiving DTMF transmissions—you could build your own receiver using inexpensive ICs, such as the MC3362 radio-on-a-chip. A well-written application note, AN-980, on the use of this chip for 2-meter use, is available from Motorola.[3, 4]

Summary

I've used a prototype of this controller for about three years to switch lights and stereos on and off while I was on vacation. This was done to deter would-be burglars. You can turn on your radio gear, coffee maker, provide a means of feeding pets while you're on vacation, or hook it to the speaker of your telephone answering machine while you're on vacation.

I'm sure you'll enjoy not only building this controller, but finding applications for it. If you discover any unusual applications for it, please let me know about them! Have fun!

Notes

1PC boards are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118; price $19.50, plus $1.50 shipping and handling. This 7½ × 4¾ inch (approximately), double-sided PC board has provisions for seven output circuits.

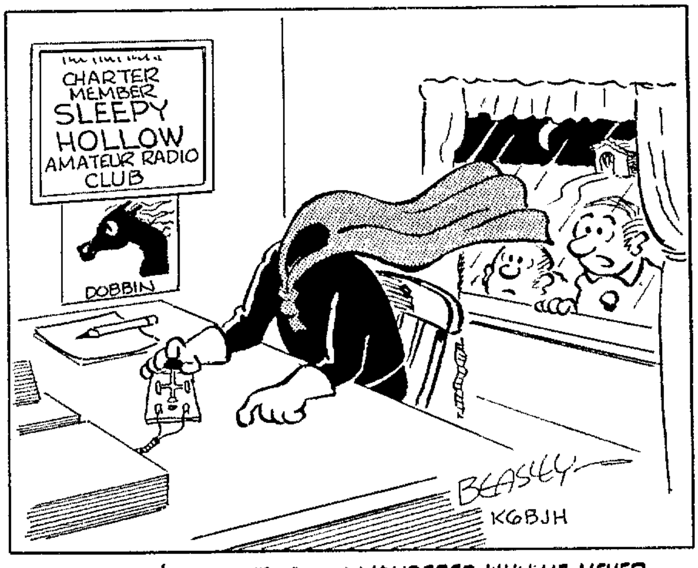
2A PC-board template and part-overlay drawing are available from ARRL HQ. (This is a *double-sided* PC board.) Please send a business-size SASE and address your request for the CARUSO REMOTE CONTROLLER PC-BOARD TEMPLATE to the Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111.

3Contact Motorola at 1-800-441-2447.

4S. Powell, "The W2CXM 2-Meter Cube Receiver and Scanner," *QST*, June 1987, pp 15-21. See also Feedback, *QST*, Aug 1987, p 39.

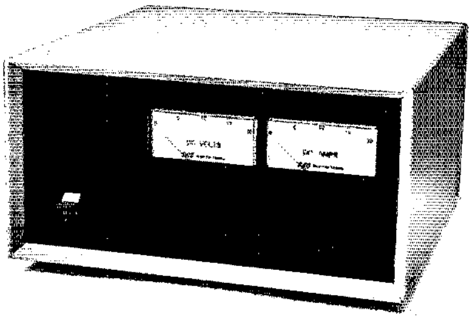
After working as an RF/analog designer for several companies, Bill got his Amateur Radio license in 1989, while pursuing graduate studies in telecommunications at the University of Colorado. He is presently working on his code speed and plans to upgrade to an Advanced class license. Bill is a Design Engineer for RELA, Inc. When he wrote this article, he was a Field Applications Engineer for Motorola Semiconductor in Agoura Hills, California.

Bill enjoys operating a packet-radio station and plays with optical and RF remote-control projects whenever he can. Besides Amateur Radio, he enjoys skiing, whitewater kayaking, fishing, backpacking and scuba diving.



SO THAT'S WHO HE IS--- I WONDERED WHY HE NEVER WORKS ANYTHING BUT C.W.

A 12-V, 15-A Power Supply



This husky and attractive power supply is easy to build and is an ideal power platform for your solid-state transceiver or workbench.

By Ed Oscarson, WA1TWX
70 Behrens Rd
New Hartford, CT 06057

Most amateurs have seen low-voltage, high-current regulated supplies, from the switching supplies (*switchers*) used in computers to three-terminal linear regulators (*linears*) used in many pieces of ham gear. Although switching technology is in vogue today, switchers generally produce lots of RF noise and exhibit limited dynamic load regulation. On the other hand, linear regulators offer good dynamic load regulation and generate little RF noise. Linears are usually heavier and less efficient than switchers, however. For amateur use, weight—in most cases—is not an issue, and the loss of efficiency, which translates to higher dissipated power, can be tolerated. Therefore, the linear regulator is still the most common design in amateur use.

This supply is a linear 12-V, 15-A design with adjustable output voltage and current limiting. Supply regulation is excellent, typically exhibiting a change of less than 20 mV from no load to 15 A. This basic design, with heftier components and additional pass transistors, can deliver over 30 A.

Circuit Description

Fig 1 is the supply's schematic. The ac-line input is fused by F1, switched on and off by S1 and filtered by FL1. For safety, F1 and S1 are mandatory. F1 and S1 are rated at about one-fourth of the output current requirement (for 15-A output, use a 4- or 5-A slow-blow fuse or a similarly rated circuit breaker). FL1 prevents any RF from the secondary or load from coupling into the power line and prevents RF on the power line from disturbing supply operation. If your ac power line is clean, and you experience no RF problems, you can eliminate FL1, but it's inexpensive insurance.

When discharged, filter capacitor C1 looks like a short circuit across the output of rectifier U2 when ac power is applied. That usually subjects the rectifier and capacitor to a large inrush current, which can damage them. Fortunately, a simple and inexpensive means of inrush-current limiting is available. Keystone Carbon Company (and others) market a line of inrush-current limiters (thermistors) for this purpose. The device (RT1) is placed in series with one of the transformer primary leads. RT1 has a current rating of 6 A,[1] and a cold resistance of 5 ohms. When it's hot, RT1's resistance drops to 0.11 ohm. Such a low resistance has a negligible effect on supply operation. Thermistors run *HOT!*[2] They must be mounted in free air, and away from anything that can be damaged by heat.

The largest and most important part in the power supply is the transformer (T1). If purchased new, it can also be the most costly. Fortunately, a number of surplus dealers (see Table 1) offer power transformers that can be used in this supply.

Two parameters important to the power-

[1]Notes appear on page 41.

Fig 1—Schematic of the power-supply. Equivalent parts can be substituted. Unless otherwise specified, resistors are ¼-W, 5%- tolerance carbon-composition or film units. The bold lines indicate high-current paths that should use heavy-gauge (#10 or #12) wire. This schematic graphically shows wiring to a single-point ground; see text. The majority of the parts used in this supply are surplus components.

C1—19,000 µF, 40-V computer-grade electrolytic capacitor.
C2—100 µF, 35-V capacitor.
C3—470 pF, 50 V.
C4, C5—0.1 µF, 50-V.
F1—120-V, 4-A, Littlefuse SLO-BLO fuse.
FL1—6-A CORCOM ac line filter (surplus model #6H1 used; new model is #6EH1).
J1, J2—8-position SIP female jack.
J3, J4—Heavy-duty binding posts (one red, one black).
M1—0-to 20-V dc voltmeter (1-mA movement, 1-kΩ coil).
M2—0- to 20-A ammeter (1-mA movement, 1-kΩ coil).
P1, P2—8-position male SIP plug.
P3—3-wire ac plug and line cord.
Q1, Q2, Q3—2N3055 NPN power transistor.
Q4—TIP112 NPN Darlington power transistor.
Q5—S6025L 25-A SCR.
R1, R2, R3—0.05-Ω, 5%-tolerance, 10-W.
R4—0.075 Ω, 5%-tolerance, 50-W.
R5—75-Ω, 5%-tolerance, 20-W.
R6—2.2 kΩ.
R7—3.3 kΩ.
R8—470 Ω.
R9—13 kΩ.
R10—1 kΩ.
R11—330 Ω, ½ W.
R12—1-kΩ multiturn trimmer potentiometer.
R13—500-Ω multiturn trimmer potentiometer.
R14—500-Ω multiturn trimmer potentiometer.
R15—10-kΩ multiturn trimmer potentiometer.
R16—500-Ω multiturn trimmer potentiometer.
RT1—Thermistor, 5-Ω no-load resistance, 0.11-Ω I_{max} resistance, 6-A I_{max} (Digi-Key KC004L-ND; KC003L-ND can be substituted).
S1—DPDT toggle.
U1—LM723C voltage regulator (14-pin DIP).
U2—50-V, 25-A bridge rectifier.
Misc: Enclosure (Hammond Manufacturing #1426Q used here), fuse holder, 14-pin DIP socket, PC board (see Note 10).

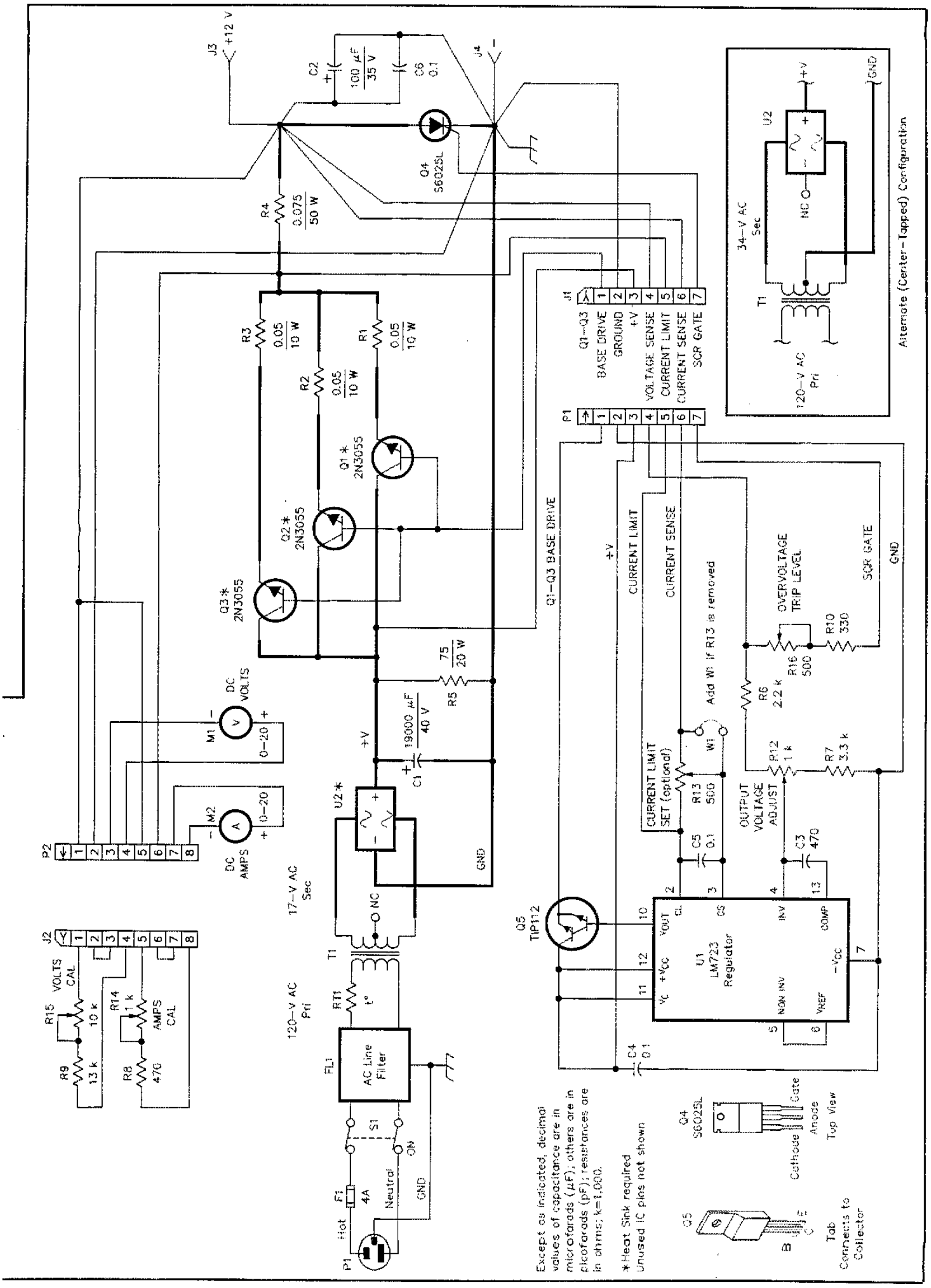

J3 +12 V
C2 100 µF 35 V
C6 0.1
J4 −
Q4 S6025L
R4 0.075 50 W
R3 0.05 10 W
R2 0.05 10 W
R1 0.05 10 W
Q3* 2N3055
Q2* 2N3055
Q1* 2N3055
R5 75 20 W
C1 19000 µF 40 V
+V
U2*
GND
M1 DC VOLTS 0–20
M2 DC AMPS 0–20
P2
J2
R15 VOLTS CAL 10 k
R9 13 k
R14 1 k AMPS CAL
R8 470
T1
17–V AC Sec
120–V AC Pri
NC
RT1
FL1 AC Line Filter
S1
F1 4A
P1 Hot Neutral GND ON
J1
P1
BASE DRIVE
GROUND
+V
VOLTAGE SENSE
CURRENT LIMIT
CURRENT SENSE
SCR GATE
Q1–Q3 BASE DRIVE
CURRENT LIMIT
CURRENT SENSE
OVERVOLTAGE TRIP LEVEL
SCR GATE
GND
Add W1 if R13 is removed
R6 2.2 k
R16 500
R10 330
W1
CURRENT LIMIT SET (optional)
R13 500
R12 1 k
R7 3.3 k
OUTPUT VOLTAGE ADJUST
C5 0.1
C3 470
Q5 TIP112
U1 LM723 Regulator
C4 0.1
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms; k=1,000.
*Heat Sink required
Unused IC pins not shown
Q4 S6025L
Cathode Anode Gate
Top View
Q5
Tab Connects to Collector
34–V AC Sec
U2
Alternate (Center-Tapped) Configuration

Table 1
Parts Sources

A&A Engineering 2521 W La Palma Ave, Unit K Anaheim, CA 92801 Tel: 714-952-2114 Fax: 714-952-3280	Transformers, power transistors, bridge rectifiers, heat sinks, capacitors, cabinets.
All Electronics Corp PO Box 567 Van Nuys, CA 91408-0567 Tel: 800-826-5432, 818-997-1806 Fax: 818-781-2653	Transformers, power transistors, bridge rectifiers, heat sinks.
Digi-Key 701 Brooks Ave South PO Box 677 Thief River Falls, MN 56701-0677 Tel: 800-344-4539, 218-681-6674 Fax: 218-681-3380	Thermistors, SCRs, transistors, and most other small parts.
R&D Electronics 1224 Prospect Ave Cleveland, OH 44115 Tel: 800-642-1123, 216-621-1121 Fax: 216-621-8628	Transformers, power transistors, bridge rectifiers, heat sinks.

supply design are the transformer secondary's voltage and current capability. For a 12-V supply, a secondary voltage of about 15 to 17 V ac under load is adequate. If a center-tapped transformer is used (you have to alter the rectifier connection and ground the center tap; see the inset of Fig 1), the secondary has to deliver twice that (30 to 34 V CT). Transformers with higher secondary voltages can be used, but the power dissipated (wasted) in the pass transistors (Q1-Q3) increases proportionally. If you're fortunate, you may find a transformer that has an additional secondary winding—or a tapped primary winding—that offers the ability to fine-tune the secondary voltage. For intermittent duty (such as SSB or CW), the secondary winding's current rating should be at least equal to the required output current. If continuous duty is required of the supply (such as in FM or RTTY service), increase the secondary current rating requirement by about 25%.

T1 produces 17 V ac at 20 A; the center tap is not used. Bridge rectifier U2 provides full-wave rectification. Full-wave rectification produces a low ripple component on the filtered dc, which results in dissipating little power in the filter capacitor. U2's voltage rating should be at least 50 V, and its current rating about 25% higher than the normal load requirement; a 25-A bridge rectifier will do. U2 is secured to the chassis (or a heat sink) because it dissipates heat.[3]

C1 is a computer-grade electrolytic. Any capacitor value from 15,000 to 30,000 μF will suffice. I use a 19,000-μF, 40-V capacitor in my supply. The capacitor's voltage rating should be at least 50% higher than the expected no-load rectified dc voltage. In my supply, that voltage is 25, and a 40-V capacitor provides enough margin.

As mentioned earlier, C1 dissipates power proportional to the ripple voltage. With a 15-A load and a measured ripple voltage of 1.5, that amounts to 32 W.[4] Therefore, the *physical* size of the capacitor is important, too. A physically larger capacitor is better able to dissipate the power.

R5, a 75-ohm, 20-W bleeder resistor, is connected across C1's terminals to discharge the supply when no load is attached or one is removed. Any resistance value from 50 ohms to 200 ohms is fine; adjust the resistor's wattage rating appropriately.

At the terminals of C1, we have a dc voltage, but it varies widely with the load applied. When keying a CW transmitter or switching a rig from receive to full output, 5-V swings can result. The dc voltage also has an ac ripple component of up to 1.5 V under full load. Adding a solid-state regulator (U1) provides a stable output voltage even with a varying input and load. The LM723 used at U1 is an older chip that provides voltage regulation and current limiting with few external components. Additional components can be added to provide output metering. U1 has a built-in voltage reference and sense amplifier, and a 150-mA drive output for a pass-transistor array.

U1's voltage reference provides a stable point of comparison for the internal regulator circuitry. In this supply, it's connected to the noninverting input of the voltage-sense op amp. The reference is set internally to 7.15 V, but the absolute value is not critical because an output-voltage adjustment (R12) is provided. What *is* important is that the voltage is stable, with a specified variation of 0.05% per 1000 hours of operation. This is more than adequate for the supply.

For the regulator to work properly, its ground reference must be at the same point as the output ground terminal. The best way to ensure this is to use the output **GROUND** terminal (J4) as a *single-point ground for all of the supply grounds.* Run wires to J4 from each component requiring a ground connection. Fig 1 attempts to show this graphically.

The output pass-transistor array consists of a TIP112 Darlington transistor (Q5) driving three 2N3055 power transistors (Q1-Q3). This two-stage design is less efficient than connecting the power transistors directly to the LM723, but Q5 can provide considerably more base current to the 2N3055s than the 150-mA maximum rating of the LM723. You can place additional 2N3055s in parallel to increase the output-current capacity of the supply.

This design is not fussy about the pass transistors or the Darlington transistor used. Just ensure all of these devices have voltage ratings of at least 40. Q5 must have a 5-A (or greater) collector-current rating and a beta of over 100. The pass transistors should be rated for collector currents of 10 A or more, and have a beta of at least 10.[5]

When unmatched transistors are simply connected in parallel, they usually don't equally share the current.[6] By placing a low-value resistor in each transistor's emitter lead (*emitter-ballasting resistors,* R1-R3), equal current sharing is ensured. When a transistor with a lower voltage drop tries to pass more current, its emitter resistor's voltage drop increases, allowing the other transistors to provide more current. Because the voltage-sense point is on the load side of the resistors, the transistors are forced to dynamically share the load current.

With a 5-A emitter current, 0.25 V develops across each 0.05-Ω resistor, producing 1.25 W of heat. Ideally, a resistor's power rating should be at least *twice* the power it's called upon to dissipate. To help the resistors dissipate the heat, mount them on a heat sink, or secure them to a metal chassis (as shown in Fig 2). I used 10-W resistors because that's what I had available. You can use any resistor with a value between 0.065 and 0.1 Ω, but remember that the power dissipated is higher with higher-value resistors.

At the high output currents provided by this supply, the pass transistors dissipate considerable power. With a current of 5 A through each transistor—and assuming a 9-V drop across the transistor—each device dissipates 45 W. Because the 2N3055's rating is 115 W when used with a properly sized heat sink, this dissipation level shouldn't present a problem.

The output-voltage sense is connected through a resistive divider to the negative input of U1. U1 uses the difference between its negative and positive inputs to control the pass transistors that in turn provide the output current. C3, a compensation capacitor, is connected between this input and a dedicated compensation pin to prevent oscillation. The output voltage is adjusted by potentiometer R12 and two fixed-value resistors, R6 and R7.[7] The voltage-sense input is connected to the supply's positive output terminal, J3.

Current sensing is done through R4, a 0.075-Ω, 50-W resistor connected between the emitter-ballasting resistors and J3. R4's power dissipation is much higher than that of R1, R2 or R3 because it sees the *total* output current. At 15 A, R4 dissipates 17 W. At 20 A, the dissipated power increases to 30 W.

U1 provides current limiting via two sense inputs connected across R4. Limiting takes place when the voltage across the sense inputs is greater than 0.65.[8] For a 15-A maximum output-current limit, this requires a 0.043-Ω resistor. By using a larger-value sense resistor and a potentiometer, you can vary the current limit. Connecting potentiometer R13 across R4 provides a current-limiting range from full limit voltage (8.7 A limit) to no limit voltage. This allows the current limit to be fine-tuned, if needed, and also permits readily available resistor values (such as my 0.075-Ω resistors) to be used. I normally set the current limit at 20 A because that's the top end of the ammeter scale.

Voltmeter M1 is a surplus meter. R8 and potentiometer R15 provide for voltmeter calibration. If the correct fixed-value resistor is available, R15 can be omitted. The combined value of the resistor and potentiometer is determined by the full-scale current requirement of the meter used.[9]

Ammeter M2 is actually a voltmeter (also surplus) that measures the potential across R4. The positive side of M2 connects to the high side of R4. R8 and potentiometer R14 connect between the positive output terminal (J3) and the negative side of M2 to provide calibration adjustment. The values of R8 and R14 are determined by the coil-current requirements of the meter used.

The supply output is connected to the outside world by two heavy-duty banana jacks, J3 and J4. C2, a 100-µF capacitor, is soldered directly across the terminals to prevent low-frequency oscillation. C6, a 0.1-µF capacitor, is included to shunt RF energy to ground. Heavy-gauge wire must be used for the connections between the pass transistors and J3 and between chassis ground and J4. The voltage-sense wire must connect *directly* to J3 and U2's ground pin must connect directly to J4 (see Fig 1). This provides the best output-voltage regulation.

An over-voltage crowbar circuit prevents the output voltage from exceeding a preset limit. If that limit is exceeded, the output is shunted to ground until power is removed. If the current-limiting circuitry in the supply is working properly, the supply current-limits to the preset value. If the current limiting is not functioning, the crowbar causes the ac-line fuse to blow. Therefore, it's important to use the correct fuse size: 4 to 5 A for a 15-A supply.

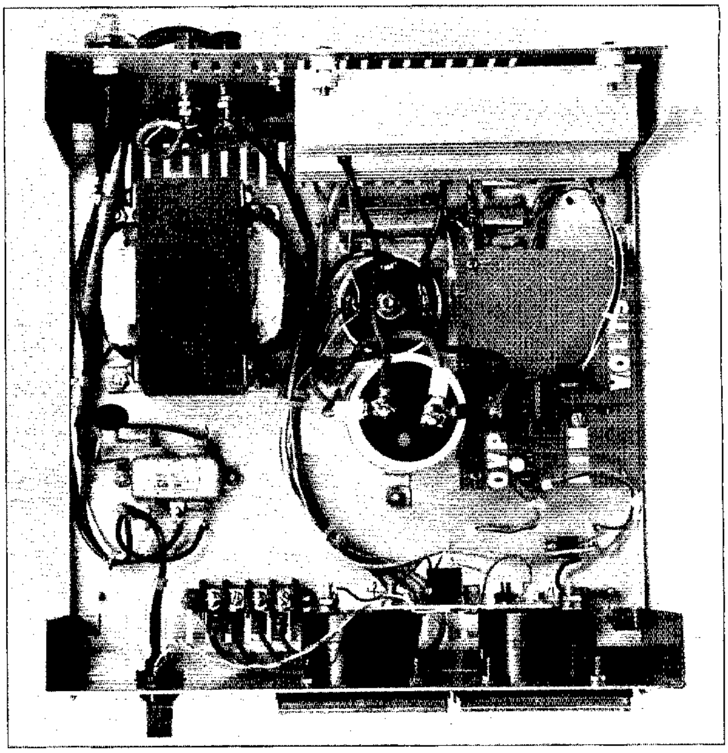


Fig 2—An inside view of the neatly constructed 12-V, 15-A power supply. There's plenty of room in this cabinet to accept the components comfortably and allow hands and tools to get at them. Vents in the bottom and rear of the cabinet provide some measure of convection cooling. For safety, all exposed ac-line leads and connections are insulated with shrink tubing. Wire bunches are secured with plastic cable ties. The terminal block at the lower left serves only to provide a resting place for unused transformer secondary-winding leads. Along the left of the cabinet are the ac-line filter, thermistor (it looks like a large, black ceramic capacitor) and power transformer. The fuse holder and line cord are behind the transformer, as are the dc output terminals J3 and J4. The black objects across the terminals are C2 and C6. Pass transistors Q1-Q3 are hidden by the heat sink fins. Note the insulated standoffs supporting the heat sink. The metal-cased power resistors are secured to the enclosure bottom beneath the heat sink. Bridge rectifier U2 is between the heat sink and C1. The parts mounted on the perfboard secured to the chassis near U2 and C1, and the perfboard mounted behind the meters, are now contained on one PC board (see Note 10). The small three-terminal device between the perf board and front panel is the SCR, Q4. Bleeder resistor R5 is secured to the chassis beneath M2.

The crowbar circuit is a simple design based on an SCR's ability to latch and conduct until the voltage source is removed. The SCR (Q4) is connected across output terminals J3 and J4. R10 and potentiometer R16 in series with the Q4's gate provide a means of adjusting the trip voltage. I set the crowbar in my supply to conduct at 15 volts. The S6025L SCR is rated at 25 A and should be mounted on a metal chassis or heat sink. (Note: Some SCRs are isolated from their mounting tabs, others are not. The S6025L and the 65-ampere S4065J are isolated types. If the SCR you use is not isolated, use a mica washer to insulate it from the chassis or heat sink.)

The bold lines in Fig 1 indicate high-current paths that should use heavy-gauge (#10 or #12) wire. Traces that are connected to the output terminals in the schematic by individual lines should be connected directly to the terminals by individual wires. This establishes a 4-wire measurement, where the heavy wires carry the current (and have voltage drops) and the sense wires carry almost no current and therefore do not have errors caused by voltage drops in the wiring. If desired, the sense wires can be carried out to the load, but that may introduce noise into the sense feedback circuit, so use caution if that is done.

Construction

Fig 2 shows the inside of the prototype supply. The larger components are chassis mounted; two perfboards contain the majority of the low-power parts of the supply. This includes the potentiometers for the regulator, meters and over-voltage adjustments. A PC board is available that contains all of the parts mounted on the two perf boards.[10,11]

Start construction by selecting a cabinet or chassis adequate to contain the components. Not only must the chassis have sufficient room inside, it must also be sturdy enough to support the weight of the components without deforming. I used an attractive Hammond Manufacturing #1426Q cabinet that measures 5.5 × 11 × 11.7 inches (HWD).

Once the chassis is selected, lay out the front panel. Drill and punch the necessary holes, apply the appropriate labels and coat the panel with clear acrylic paint.

I placed the transformer on the left side of the chassis for best access to the power switch. Wires from an unused secondary winding and the center tap are routed to an out-of-the-way location on the chassis and connected to a terminal strip, isolating them from each other and the surrounding components. On the chassis bottom, U2 is positioned near T1, as are C1 and R5. Identify the position of the regulator PC board. Don't locate components too near the rear of the chassis because the heat sink and/or circuit wiring need clearance.

Q1, Q2 and Q3 must be mounted on a heat sink. The one I used measures 1-1/4 × 6 × 3-5/8 inches (HWD). It's the minimum size I'd recommend using. If you can find a heat sink with vertically oriented fins, so much the better. Use a small amount of heat-sink compound between the transistors and the heat sink. Because the transistor collectors are at a potential of +25 V, they must be insulated from the heat sink, or, as in my supply, the entire heat sink can be isolated from the chassis. If there is adequate ventilation, you can mount the heat sink inside the chassis. The three emitter-ballasting resistors and the sense resistor can be secured to the chassis rear or bottom, but they should be located near the transistors to which they are connected. Orient the components so that they can be easily soldered to the common output connections.

Also mounted on the back panel are a line-cord strain relief and fuse holder. Use a strain relief to prevent the cord from being pulled out of the chassis. Mount the fuse holder directly above the line cord. The output terminals, J3 and J4, are placed in the same area; use heavy-duty banana jacks or terminal blocks. If FL1 is used, mount it on the chassis. Install an insulated terminal strip near the filter to hold the inrush-current limiter.

Once all of the major components are installed, some of the wiring can be done. Wire the line cord to the fuse with the black (hot) lead at the center, and the outer ring connected to the power switch. It's important to connect the green (ground) line-cord wire to the chassis for safety.

Connect the transformer secondary *directly* to the bridge rectifier. Use #12 wire to connect the rectifier output to the filter capacitor. Use crimp-on or solder-on terminal lugs as needed, as at the filter-capacitor connections. Connect C1's negative lead directly to the output **GROUND** terminal, J4. Connect a length of #12 wire from J4 (or C1) to the chassis. J4 is the single-point ground for the rest of the system. The positive connection will be made later. Attach bleeder resistor R5 to C1.

At this point, you should test the basic dc supply. When ac power is applied, about 20 to 28 V dc should be present across C1's terminals. This potential is dependent on the transformer used, but should not exceed 30 V dc. Turn off the supply.

Next, wire the output pass transistors. If the transistors are insulated from the heat sink, use #10 wire to connect together the collectors. Leave an 8- to 10-inch pigtail for later connection to C1's positive terminal. If the transistors are mounted directly to the heat sink, the pigtail can be connected to the heat sink.

Use #20 wire to connect together the transistor base leads, and provide a pigtail for attachment to U1. Using #12 wire, connect the emitters of Q1-Q3 to their respective emitter-balancing resistors. Solder together the remaining emitter-resistor leads and use #10 wire to connect them to R4. Solder the other side of R4 to J3, the positive output terminal.

Next, attach the 100-μF (C2) and 0.1-μF capacitors (C6) across the output terminals. Keep the leads as short as possible, especially those of C6.

Once the regulator board is wired, attach its mating connector to the appropriate points on the chassis. The voltage-sense wire and ground wires must connect directly to the appropriate output terminals. Use #20 or #22 wire for the voltage-sense wire and #18 for the ground.

Attach the current-limit and current-sense wires directly to R4. This is essential for proper regulation and current limiting. There is little current in the wires, so use #20 or #22 wire here and for the power, SCR gate and base-drive connections.

Q4 connects across J3 and J4. Q4's gate is attached to the PC board SCR GATE connection at J1, pin 7. Set potentiometer R16 to its maximum resistance or disconnect the SCR's gate prior to testing the supply.

Testing

Initial testing is done without a load. Use a 2-A fuse at F1 to protect the components in case of problems. If any of the steps do not produce the expected results, check the circuit wiring.

Connect a voltmeter to the output terminals. Turn on the supply. The voltmeter should read between 8 and 15 V. Adjust R12 to bring the output voltage to 12. Adjust R15 for a 12-V reading on the meter. Turn off the supply.

Connect a 12-Ω, 20-W resistor to J3 and attach the other end through an ammeter to J4. (The ammeter must be capable of reading a current flow of more than 1 A.) Turn on the supply and measure the output current, which should be 1 A. Adjust R14 until ammeter M3 displays 1 A. Turn off the supply.

The next test requires a 0.5-Ω load resistor. Use a high-power-dissipation resistor. To provide additional cooling, immerse the resistor in a plastic container (I use a discarded margarine container) of water. Connect the resistor to the supply in place of the 12-Ω load resistor previously used. If the ammeter is left in series with the load, it must be capable of reading a current flow of at least 10 A. The front-panel ammeter may also be used to measure the current. Adjust the **CURRENT LIMIT SET** potentiometer (R13) to the position where the wiper is at the same end of the potentiometer as the terminal that is connected to the output side of R4. This sets the current limit to 8.7 A (if R4 is a 0.075-Ω resistor).[12] Turn on the supply. The ammeter should indicate about 9 A. If it doesn't, immediately turn off the supply. Check the wiring of the current-limiting circuit, including R13.

If the ammeter reading was okay, remove the series-connected ammeter and connect the 0.50-Ω load resistor across the output terminals. Turn on the supply and adjust **CURRENT LIMIT SET** pot R13 for a 20-A current indication (or the desired limit point). Turn off the supply.

At this point, the output voltage and the current limit are set. You can recalibrate M2 with a 5- or 10-A load to get better meter resolution when adjusting R14.

The following sequence assumes that the desired output voltage is 12, and the over-voltage trip point is 15. Using R12, set the output voltage to 15. Decrease the resistance of R16 until the SCR trips. When this happens, turn off the power. With the power off, adjust R12 to decrease the voltage. Turn on the supply and readjust R12 for 12 volts.

Now, regulation needs to be checked. Connect a voltmeter across the output terminals with no load connected to the supply. Turn on the supply and record the output voltage. Connect a 10- or 15-A load to the supply and record the voltage. Turn off the supply. The difference between the no-load and 10- or 15-A load voltages should be less than 50 mV. (It is typically less than 20 mV on my prototype.) Higher voltage differences could be caused by the current limit being activated (if near the limit point), or by problems in the sense or single-point ground wiring.

Summary

This supply was originally designed to power a 100-W, solid-state amplifier for 10-meter FM operation. It operated fine in that application for a number of years. At that time, I used only two of the three pass transistors in the supply and was able to get 100 W output from the amplifier without overtaxing the supply. I added the third pass transistor to increase the output current to meet the requirements of some of the newer HF rigs.

The supply now powers VHF equipment in my shack and doubles as a lab bench supply. For applications that need less current, you can build the supply using a single pass transistor. This should prove capable of powering even the newer VHF rigs, many of which now provide 40 to 50 W output. I've had no problems powering a 25-W, 2-meter rig from the supply; with only two pass transistors installed, it doesn't even get warm. I've not experienced any significant RF problems with the supply. The 100-μF and 0.1-μF capacitors across the output terminals shunt any RF on the power lines to ground before it gets inside the supply. If RF problems do arise, better grounding of the equipment in the shack—or better antenna matching—is probably called for.

As presented here, the supply is as modular as possible. This allows you to add (or delete) some parts as cost or needs warrant. The transformer size, number of pass transistors, current limiting, over-voltage protection and metering circuits can all be modified to support your requirements. With a little ingenuity, the core of this supply could find its way into many useful applications in the shack. You might want to modify the supply to provide a 5-V output for a logic supply, or change the voltage-adjust circuit to provide a variable output for use as a bench supply. Whatever the application, this supply can provide you with a reliable power source for years to come.

Notes

[1]Limiters with higher current ratings are available.

[2]ARRL Lab measurements show the surface temperature of the thermistor to be about 100 °C.

[3]U2's heat dissipation is calculated by:

$$P_{(watts)} = 0.7 \times I \times 2 = 21 \qquad \text{(Eq 1)}$$

where I is the maximum delivered current (15 A), 0.7 is a typical diode voltage drop, and 2 is for the two diodes in the bridge that are simultaneously conducting.

[4]In order to determine the power, we also need either the ripple current, or the impedance of the capacitor. The impedance of a 19,000-μF (0.019-F) capacitor at the 120-Hz ripple frequency (120 Hz because of full-wave rectification) is:

$$Z = \frac{1}{(2\pi \times 120\ \text{Hz} \times 0.019\ \text{F})} = 0.07\ \Omega \qquad \text{(Eq 2)}$$

Plugging the 0.07-Ω impedance into the power equation with the measured 1.5 ripple voltage and a 15-A load yields

$$P_{watts} = \frac{V^2}{Z} = \frac{(1.5)^2}{0.07\ \Omega} = 32 \qquad \text{(Eq 3)}$$

Thirty-two watts is a lot of power, so you can see the physical size of the capacitor is important. The larger the capacitor, the better it can dissipate that power.

[5]Simply dividing the maximum required output current (15 A) by the transistor beta, you can determine the drive requirement of the LM723. If we assume betas of 10 for the 2N3055s and 100 for the Darlington, the drive current is required from the LM723 is:

$$I = \frac{\left(\frac{15\ \text{A}}{\beta_{2N3055}}\right)}{\beta_{TIP112}} = \frac{\left(\frac{15}{10}\right)}{100} = 0.015\ \text{A} \qquad \text{(Eq 4)}$$

or 150 mA.

[6]This is caused by manufacturing-process variations in the transistor die that result in different voltage drops across the part. These differences are very small, but can result in large variations in current flow among devices.

[7]The voltage range is determined by the equations:

$$V_{out}\ \text{Upper} = V_{ref}\left(\frac{(3.3 + 1 + 2.2)}{3.3}\right) \qquad \text{(Eq 5)}$$

$$V_{out}\ \text{Lower} = V_{ref}\left(\frac{(3.3 + 1 + 2.2)}{(3.3 + 1)}\right) \qquad \text{(Eq 6)}$$

where 3.3 is the 3.3-kΩ resistance of R7, 2.2 is the 2.2-kΩ resistance of R6 and 1 is the 1-kΩ resistance of R12. U1's reference voltage (V_{ref}) is nominally 7.15 This results in an output-voltage range of 10.8 to 14.1 V dc. The range can be increased by increasing the value of R12. (For example, a 2.5-kΩ potentiometer yields 9.8 to 17.3 V.)

[8]Therefore, the value of the current-limiting resistor for a fixed output is

$$R_{limit} = \frac{0.65\ \text{V}}{I_{out}} \qquad \text{(Eq 7)}$$

[9]For a 1-mA meter movement and 20-V full-scale reading, the resistance should be:

$$R = \frac{20\ \text{V}}{1\ \text{mA}} - R_{meter} \qquad \text{(Eq 8)}$$

where R_{meter} is the dc resistance of the meter movement. See the Test Equipment and Measurements chapter of The *Handbook* for information on how to determine the meter's internal resistance. In recent editions, this is Chapter 25.

[10]Bare PC boards ($15), assembled PC boards ($30) and kits of parts containing the PC board and board-mounted parts ($25) are available from Single Chip Solutions, PO Box 680, New Hartford, CT 06057. Please add $3.50 for shipping and handling charges; Connecticut residents add sales tax.

[11]A PC-board template package is available free of charge from the ARRL. Please address your request for the OSCARSON 12-V, 15-A POWER SUPPLY PC-BOARD TEMPLATE to the Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111. Please include a business-size SASE.

[12]If the sense resistor you use has a value other than 0.075 Ω, the minimum-current limit is calculated by

$$I_{limit} = \frac{0.65\ \text{V}}{R_{sense}} \qquad \text{(Eq 9)}$$

where R_{sense} is the value of the sense resistor in ohms.

New Books

AERIALS

By Kurt N. Sterba and Lil Paddle.

Published by Worldradio, *2120 28th St, Sacramento, CA 95818; tel 916-457-3655. Softcover. 96 pp. 8½ × 10½ inches. $10.*

Reviewed By Brian Battles, WS1O

QST *Features Editor*

It's fun to dream, but sometimes I get fed up with hearing about the ham who's got 16 200-foot towers with stacked 10-element monobanders for every band above 80 meters, or the contest crew that's built a full-size 7-element Yagi for 160 meters. Sometimes I just like to read about practical antenna designs and ideas that I can implement while waiting for my Publisher's Clearinghouse check to arrive. *Aerials* is my kind of book. This is an amusing collection of the earliest such columns from *Worldradio*, spanning the late 1970s-mid 1980s. The husband-and-wife team of "Kurt and Lil" claim to have adopted these conspicuous pseudonyms to preserve their personal privacy and to give them freedom to write whatever they want and express what may be arguable opinions.

And express they do. Their debunking of common myths and pronouncements of fact—most of which are right on the mark—will make many readers cringe, writhe and quiver with outrage. As we all learned as children, anyone who has the nerve to point out that the splendidly dressed emperor is naked is bound to upset the admirers of His Royal Rawness. Kurt and Lil make no bones about exposing conventional nonwisdom. They poke holes in theories espoused by celebrated experts and published in hallowed tomes—including such scriptures as ARRL *Handbooks* and *Antenna Books*.

If you like to straight talk that cuts through pseudoscientific jargon and phony academic treatises, you'll appreciate seeing Kurt and Lil slash away at the waist-deep barrage of "conventional wisdom" with their machete-sharp pens. They're direct, on target and almost entirely correct—or at least practical. Whether you laugh at, learn from or loathe their writing, you'll find *Aerials* hard to put down.

Calibrating the Signal Generator in the Sky

Amateurs have long used sun noise as a system-performance indicator on the VHF, UHF and microwave bands. Correlating sun noise to other factors can make this giant signal generator an even more useful crystal ball.

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The received amplitude of solar radiation, a standard indicator of performance for sensitive microwave receiving stations, is known to exhibit significant temporal fluctuations as a function of solar activity. Using sun noise collected at 2304 MHz at Paul (W4HHK) Wilson's station and daily solar activity indexes broadcast on WWV, we have used statistical methods to generate a model for predicting sun noise. Over a period of months, the model has proved accurate to within about half a decibel. We plan future studies to attempt to generalize the model for use at other stations and frequencies.

Sun Noise: Fact and Fallacy

Microwave experimenters have long calibrated the performance of radiotelescopes, satellite-tracking facilities and advanced Amateur Radio stations by measuring the intensity of emissions received from our nearest stellar neighbor, the sun. It's amusing, at technical conferences across the country, to hear boastful comparisons of system performance: "My EME station gets 15 dB of sun noise." "That's nothing; mine gets 17 dB!" Or perhaps an experimenter will use sun-noise measurements to justify a supposed design improvement: "I switched to Barry's feedhorn design, and my sun noise came up three quarters of a dB." In fact, unless the measurements were made at the same time, on the same day, at the same frequency, any conclusions drawn from such comparisons are specious.

The sun, like all stars, is a powerful fusion reactor. It is also a powerful generator of broadband electromagnetic radiation, much of which we see as sunlight, and some of which we hear in radio receivers as sun noise. The problem is, the sun is a poorly regulated signal generator. Daily and seasonal fluctuations in microwave radiation intensity of several decibels are the rule, not the exception.

Fig 1—Paul Wilson, W4HHK, holds a 2304-MHz feed for his 17-foot Kennedy dish (background).

Fortunately, we need not leave these fluctuations unquantified. The US National Institute of Standards and Technology (formerly National Bureau of Standards) broadcasts over its standard frequency and time stations (WWV and WWVH) three daily indicators of solar activity: 10.7-cm solar flux, A index and K index. The exact meanings of these indexes may be known to astrophysicists, but not to us! And although the literature contains ample recent material dealing with the interpretation of WWV solar activity data,[1,2,3,4] we have adopted a more pragmatic approach to understanding solar noise: direct observation and statistical correlation.

Structuring the Experiment

The 2304-MHz station at W4HHK, involved in the first two-way EME contact on that band in 1970, is depicted in Fig 1. It consists of a 5.5-meter parabolic reflector with a 0.41 focal length-to-diameter (f/D) ratio on an azimuth-elevation mount. This system has been in regular operation since 1964. A circularly polarized 0.7-λ ID cylindrical waveguide feed horn with a choke ring yields a net antenna gain on the order of +39.5 dBic (decibels with respect to a circularly polarized isotropic source). An antenna-mounted GaAsFET preamplifier and low-loss feed line set the receiving system noise figure at 0.85 dB.

Since June of 1991, this station has been used to make daily measurements of sun noise by integrating audio noise in a 2.2-kHz receiver bandwidth from a linear CW detector, with AGC disabled. The antenna was pointed alternately at the sun and a cold point in the sky with an expected noise temperature of 25 Kelvins. The difference in received noise was then observed by averaging seven to ten readings on a digital rms voltmeter.

[1]Notes appear on page 44.

Several dozen such sun-noise measurements were made over a period of months so as to account for seasonal variations in solar activity. Concurrent with each observation, the 10.7-cm solar flux and mean geomagnetic field measurements (A and K indexes) were recorded from WWV. We hoped that these three solar activity indicators provided by NIST would serve as useful predictors of observed sun noise.

Statistical Analysis

W4HHK noticed some time ago, and reported at the 1991 Central States VHF Conference in Cedar Rapids, Iowa, a direct correlation between the WWV 10.7-cm solar flux and the sun noise he observed at 2.3 GHz. The WWV solar flux is based on sun noise received at local noon in Ottawa, Ontario, measured at a frequency of 2.8 GHz.[5] Since the frequencies of observation are reasonably close, the longitudes of the two observers are separated by less than one terrestrial time zone, and W4HHK's measurements were often made near midday, this correlation is not particularly surprising. As a first-order approximation, W4HHK hypothesized for his station the following relationship between sun noise and the WWV solar flux number:

$$\text{Sun Noise (dB)} = \sqrt{\text{WWV flux}} + 1 \quad \text{(Eq 1)}$$

This approximation, appealing in its simplicity, appeared to hold reasonably well for sun-noise measurements in the range of 15 to 16 dB, with errors increasing for higher and lower sun-noise levels. Fig 2 is a scatter diagram of the predictions from this model, as compared to measured sun noise, for a sample of three weeks' daily observations. Note the concentration of data points above the regression line for low values of sun noise, and below it for higher sun-noise values. Although a correlation coefficient of 0.916 was achieved, the obvious disparities between prediction and observation led us to believe that a better model could be built with additional independent variables (predictors), of which WWV gave us two candidates: the A and K indexes.

Adding the A and K Indexes to the Model

For this same preliminary sample, correlation was sought between the WWV solar flux index, A index and K index (*predictors*) and W4HHK's observed sun noise (the *response variable*). We expected the sun noise to follow the WWV flux index rather well, and it did, as seen in the scatter diagram of Fig 3A. As Fig 3B indicates, the relationship between A index and sun noise is not nearly as strong. And Fig 3C shows almost no correlation between sun noise and the K index. Thus, we conclude that the K index is the weakest predictor of sun noise, and exclude it from our further analysis.

Turning his attention to WWV 2.8-GHz solar flux and the A index, N6TX employed multiple linear regression analysis on a microcomputer to come up with the following refined predictive model from W4HHK's preliminary sample:

$$\text{Sun Noise (dB)} = 11.3 + (\text{WWV flux} \div 51) + (\text{A index} \div 141) \quad \text{(Eq 2)}$$

Agreement between observed and predicted values of sun noise, employing Eq 2, yielded only a negligible improvement (to 0.920) in correlation coefficient over the initial model. However, the resulting scatter diagram (Fig 4) shows that data points fall noticeably closer to the regression line than they did initially.

Satisfied that we had a working strategy, we next sought to refine our predictions by amassing a much larger data base of observations covering several months, and exploring various possible transformations of the regression model. One that gave us acceptable agreement between observation and prediction was:

$$\text{Sun Noise (dB)} = 12 + (\text{WWV flux} \div 59.5) + (\text{A index} \div 97.1) \quad \text{(Eq 3)}$$

which is merely a fine-tuning of Eq 2. Although further improvement in fit is doubtless possible, we submit this as our final model of the present study, and will explore its predictive validity below.

Testing the Predictive Model

Prior to generating the final predictive model, a holdout sample was randomly drawn without replacement from the sun noise and solar activity data base. Statistical tests were performed to assure that this sample constituted an unbiased representation of the underlying population. The size of the sample was tested to assure that it would produce statistically significant results. The pertinent WWV data were applied to Eq 3 to generate sun-noise predictions for the holdout sample, and these predicted values were compared to measured sun noise. They lined up well, as Fig 5 shows.

The resulting correlation coefficient of 0.927 represents a slight but noticeable improvement over Eq 2. It achieves significance well beyond the 0.05 level, which indicates excellent agreement between observation and prediction. Discrepancies we detected were random rather than systematic. That is, the correlation between the predictive errors and measured sun noise was insignificant ($r = -0.37$).

More importantly, the differences between prediction and observation averaged 0.17 dB, and never exceeded 0.44 dB, suggesting that our predictions are limited only by the inherent accuracy of the method we use to measure sun noise. We suggest that Eq 3 accurately predicts sun noise for the 2.3-GHz station at W4HHK, and will discuss a process for generalizing these results to other stations and frequencies.

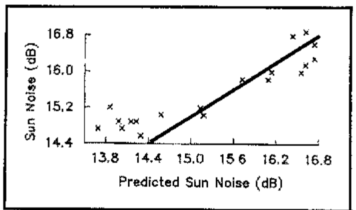

Fig 2—Scatter diagram of predicted versus observed sun noise, W4HHK model.

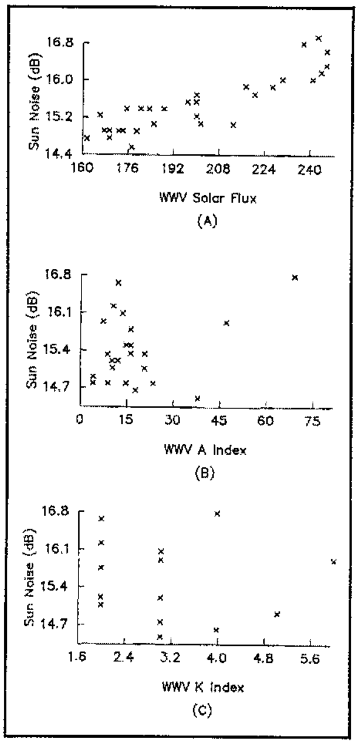

Fig 3—WWV solar flux (A), A index (B), and K index (C) as predictors of sun noise measured at W4HHK.

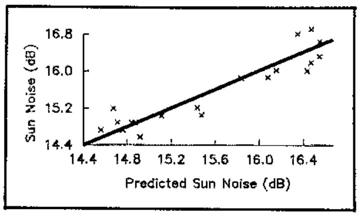

Fig 4—Scatter diagram of predicted versus observed sun noise at W4HHK, N6TX model 1.

The beauty of these results lies in the fact that, with sun-noise predictions accurate to within half a decibel, you can easily see what changes in your system noise temperature (and thus noise figure) are attributable to station improvements!

An Explanatory Hypothesis

The scientific method, as espoused at institutions of higher learning, requires that the investigator first formulate a hypothesis; design experiments to test that hypothesis; conduct those experiments to gather data; and perform statistical analysis to ascertain whether the data supports or rejects the hypothesis. We admit to having sidestepped established procedures somewhat, in that we first gathered data experimentally, then designed a statistical analysis procedure to sift through that data. We shall now totally subvert (and pervert) the scientific method, by utilizing that analysis to formulate a hypothesis!

Some call this the needle-in-a-haystack approach to science: "I don't know what I'm looking for, but I'm sure it's in there somewhere." Our most powerful analytical tool is the *interoccular trauma* test: "When a relationship is so overwhelming that it hits me between the eyes, I'll know I've found something significant."

What hit us between the eyes here is that the sun is supposed to be a thermal *black body*, radiating differently at different frequencies, as determined by its 5800-K surface temperature (see Fig 6, after Jespersen and Fitz-Randolph, 1990.) But microwave radiation from the quiet, or undisturbed sun (Fig 7), seems to fit a Planck radiation curve for a significantly warmer black body.[6]

Perhaps our receivers are responding not to the sun's surface temperature at all, but rather to its somewhat warmer (20,000 K) chromosphere, or even its amazingly hot (100,000 K) corona. Since, for example, solar flares are known to extend well into the sun's upper atmosphere, one could well expect the effective temperature *around* the sun to vary with solar activity—the very activity that the WWV data captures, and our statistics analyze.

Generalizing the Results

Note in Fig 7 that, at least over the range encompassing the amateur 902- through 5650-MHz bands, solar flux appears relatively linear with frequency. (Fig 7 is a log-log plot, so the region between 0.9 and 5.6 GHz will still appear as roughly a straight line on a linear graph). Such a line may be described in terms of its slope and y-intercept. In our general predictive model, solar flux will relate to the intercept, and slope can be expected to be indicative of geomagnetic activity.

If we accept the WWV solar flux and the A index as our predictors and observed sun noise as our criterion measure, then an appropriate model for sun noise at a particular frequency, measured by a particular station, will be of the general form:

$$\text{Sun Noise (dB)} = \alpha + \beta\,(\text{flux number}) + \delta\,(\text{A index}) \qquad \text{(Eq 4)}$$

where α is a constant unique to the particular station (encompassing G/T and operating frequency), and β and δ weigh the contributions to measured sun noise of solar flux and geomagnetic activity, respectively. We have already estimated α, β and δ for the 2.3-GHz station at W4HHK. It now remains for us to determine such constants for other stations, at other frequencies.

Further Study

Thus far, all of our computations have been based upon sun-noise measurements taken by one station, at one frequency. A long term objective of our efforts, however, is to generate a predictive model of sun noise for *any* observer, given pertinent station parameters and WWV solar indexes. Toward this end, it will be necessary to accumulate a sizable data base of sun-noise observations from numerous stations operating in the various microwave bands. We believe that from such a data base, we can derive an equation that predicts sun noise for any station, given that station's antenna gain, system noise temperature, frequency of operation, and the pertinent WWV solar-activity data. The cooperation and assistance of the world's microwave radio amateurs is thus hereby solicited.

There are probably several hundred stations worldwide with EME, satellite and radioastronomy capabilities in the 420-MHz through 24-GHz Amateur Radio bands. We invite those capable of observing sun noise to participate in our research. Experimenters possessing such stations can make a significant contribution to knowledge by periodically measuring sun noise, along with the corresponding WWV A and K indexes and 10.7-cm flux readings. We ask that those desiring to participate in this research send logs of such readings monthly, along with as detailed a station description as they are able to supply, to N6TX at his byline address.

If we receive sufficient data, the statistical techniques outlined herein will be applied to the broader problem of developing a general sun-noise model. The results will be published in the Amateur Radio press and the scientific literature, and all participants will be gratefully acknowledged.

The present investigation is only a start. We look forward to including your data in this more ambitious study. If we hear from enough of you, you will most certainly hear more from us! Thanks in advance for your contribution to the radio art and science.

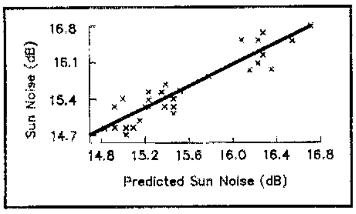

Fig 5—Scatter diagram of predicted versus observed sun noise at W4HHK, N6TX model 2.

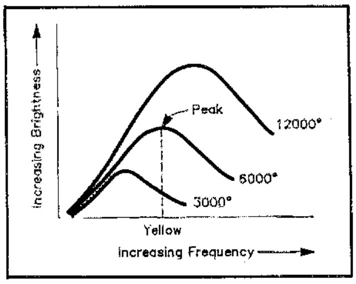

Fig 6—Heat signature varies with the temperature of the radiating body.[7]

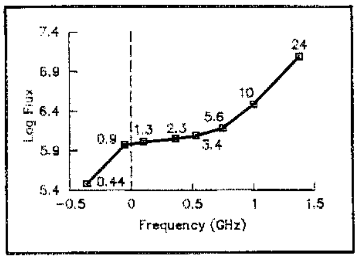

Fig 7—Microwave radiation from the sun seems to fit a far warmer black-body curve than we had expected the sun's temperature to produce. *(After Shaffer,* The ARRL UHF/Microwave Experimenter's Manual, *ARRL, 1990)*

Notes

[1] W. Atchison, "Calculating System Performance Using Solar Flux Data," *Proceedings of Microwave Update '91* (Newington: ARRL, 1991), pp 61-69.

[2] R. Healy, "Propagation Broadcasts and Forecasts Demystified," *QST*, Nov 1991, pp 20-24.

[3] E. Pocock and B. Blake, "Midrange Forecasts of Solar and Geomagnetic Activity," *QST*, Apr 1991, pp 22-27, 30.

[4] R. Beehler and M. Lombardi, *NIST Time and Frequency Services*, NIST Special Publication 432 (Boulder, CO: National Institute of Standards and Technology, June 1991).

[5] D. Rosenthal and J. Hirman, *A Radio Frequency User's Guide to the Space Environment Services Center Geophysical Alert Broadcasts*, NOAA Technical Memorandum ERL SEL-80, NOAA Space Environment Laboratory, Boulder, CO, Jun 1990. Note: Since June of 1991, WWV solar flux measurements have been made in Penticton, BC (49° N, 120° W).

[6] D. Shaffer, "Microwave System Calibration Using the Sun and Moon," *ARRL UHF/Microwave Experimenter's Manual* (Newington: ARRL, 1990), pp 60-64.

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Recent Advances in Shortwave Receiver Design

Working in conjunction with microprocessor control, strong *analog* hardware still performs the majority of receive signal-processing tasks in today's best MF/HF radios. Here's a look at some of the circuitry you may find in the ham transceivers of tomorrow.

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Extended dynamic range in amateur MF/HF receivers is particularly important today because receivers are frequently operated in hostile environments like contests, or at antenna sites subjected to extremely strong signals. This article explores current trends in receiver design by concentrating mostly on the analog portion of a modern communications receiver. The novel approaches discussed include:

- multilevel, microprocessor-driven menus as operator control interfaces;
- fast, low-phase-noise PLL synthesizers, including digital direct frequency synthesis (DDS);
- analog and digital tracking front-end filters;
- ultra-high-level double-balanced mixers with MOS transistors;
- low-noise, advanced AGC-controlled feedback amplifiers;
- high-isolation IF-filter-switching stages;
- IF amplifiers with low in-band intermodulation-distortion (IMD) properties;
- high-performance sampling product detectors; and
- adaptive squelch circuits.

Some IF signal processing can be implemented digitally, and a few well-known ham transceiver suppliers have begun doing so. Such techniques are becoming increasingly important. For now, however, those in the general ham community who are interested in building their own radio hardware may have more interest in the analog

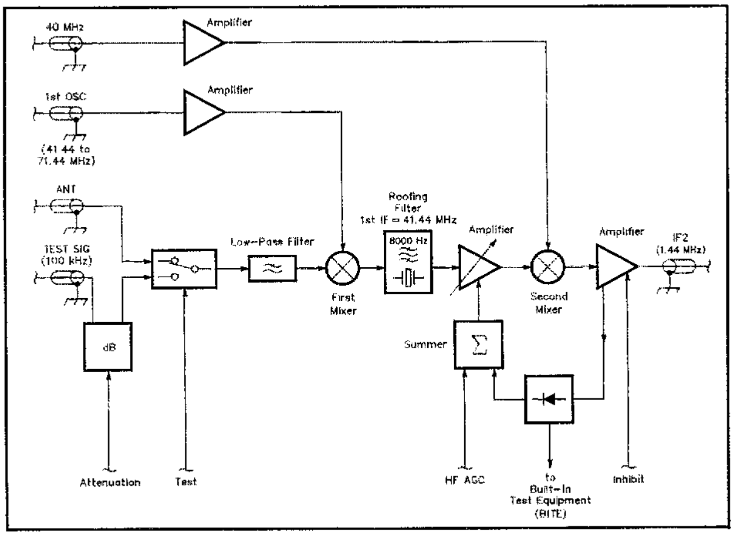


Fig 1A—Block diagram of the input stage of a dual-conversion receiver with the first IF well above the highest frequency of reception. Note the inclusion of built-in test equipment (BITE).

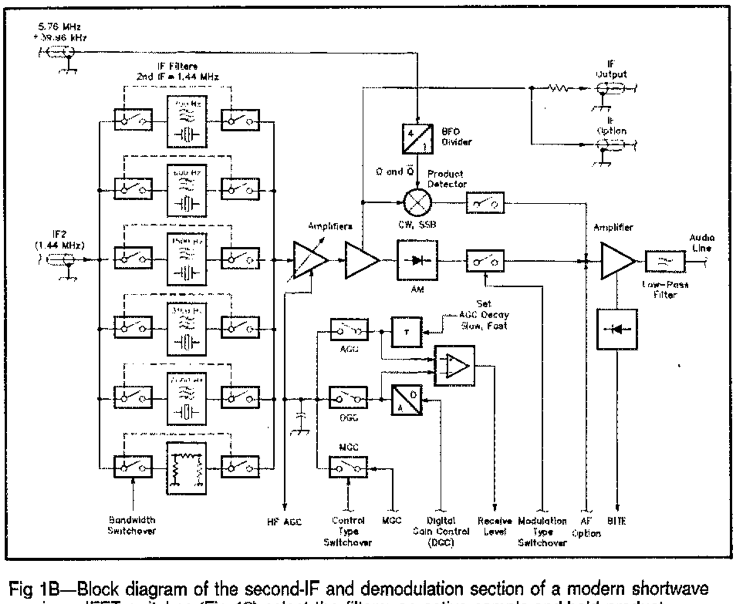


Fig 1B—Block diagram of the second-IF and demodulation section of a modern shortwave receiver. JFET switches (Fig 12) select the filters; an active sample-and-hold product detector (Fig 13) is used. Note the provision for digital AGC (DGC).

circuit details on which this article concentrates.

High Performance Receiver Basics

Modern shortwave (<30 MHz) and UHF/VHF receivers generally follow the traditional block diagram approach shown in Fig 1.[1-9] This can be extended into transceiver applications. Table 1 reflects the large-signal receive performance currently considered to be state-of-the-art for receivers and transceivers. In most cases, VHF/UHF receivers differ from their MF/HF counterparts mainly in that they include more FM demodulation capabilities and almost always use preamplifiers. A preamplifier generally reduces a strong VHF/UHF receiver's third-order input intercept (iP_3) to between 10 and 20 dBm.[10]

In spite of recent advances in shortwave transceiver design, not all the possibilities in improving the dynamic-range/electrical performance have been implemented by commercial manufacturers. Table 1 refers to a current governmental MF/HF transceiver which reflects the state of the art today. To maximize their capabilities, modern high-performance receivers and transceivers usually use one or more microprocessors. Up to 1000 memory channels are provided to allow the storage of frequencies, operating modes and other relevant data for scanning and later recall. Smart use of software can ease hardware requirements, provide multilevel control menus and allow full remote-control capability. Built-in test equipment (BITE) is also commonly available.[11-23]

Another important point I have noticed in recent designs is the trade-off between coherent analog (phase-locked-loop [PLL]) and digital frequency synthesis. Switching speed and synthesizer signal purity work against each other. The faster a PLL synthesizer must switch, the wider its loop bandwidth must be. It will thereby be "noisier." Direct digital synthesis is relatively easy, but it must be implemented properly to retain its advantages over traditional PLL approaches.[24-32]

Finally, the widespread use of some approaches, like diode switching of input filters and IF filters, has caused more headaches than it has solved. While the concept of having suboctave input filters is laudable and the filters are necessary, the use of such filters has led to problems because the switching diodes usually used introduce intermodulation distortion that the filters they select cannot cure! Of course, there is an easy fix: Replace all the front-end-filter-switching diodes in a transceiver with Hewlett-Packard 5082-3080 or -3081 PIN diodes. Changing 15 or more such diodes at a cost of $3 per diode makes this proposal less than exciting. But installing these diodes can reduce the intermodulation distortion products traceable to the replaced diodes by 18 dB or increase the receiver's input-intercept point by 6 dB.

Table 1

Specifications of a High-Performance 1992 Receiver/Transceiver

Data Common to Transceiver Transmitter and Receiver	
Transmitter frequency range	1.5 to 29.99999 MHz
receiver	0.4 to 29.99999 MHz
Frequency resolution	1-Hz steps
Frequency error within one day	$\leq 3 \times 10^{-8}$
within rated temperature range.	$\leq 3 \times 10^{-7}$
Time required for frequency changes	$\leq$100 ms, typically 50 ms
RX/TX switchover	<10 ms
Programmable channels	1000 (transmit and receive frequencies separately programmable for half-duplex operation)
Classes of emission	A1A (A1), J3E (A3J) (switch-selected USB and LSB), H3E (A3H), J7B (A7J) (data transmission)
Recommended extras	
ISB modem	B3E (A3B)
FSK modem	F1B (F1) with three frequency shifts: ±42.5 Hz/max, 100 Bd; ±85 Hz/max, 200 Bd; ±425 Hz/max, 200 Bd
Selectivity characteristics (input/output)	
Digitally tuned filter (alternative configuration)	
Frequency range	1.5 to 30 MHz
Selectivity ($\Delta f/f \geq 0.15$ in the range 1.5 to 12 MHz)	>15 dB
Selectivity ($\Delta f/f \geq$ 0.2.5 in the range 12 to 30 MHz)	$\geq$15 dB
(Band-pass filter in the range 0.4 to 1.5 MHz)	
Tuning time	approximately 20 ms
Motor-tuned filter (alternative configuration)	
Frequency range	1 to 30 MHz
Selectivity ($\Delta f/f \approx 0.05$)	$\geq$25 dB, typically 30 dB
($\Delta f/f \approx 0.1$)	$\geq$40 dB, typically 45 dB
(Low-pass filter <1 MHz)	
Tuning time	approximately 2 s
Transmitter Data	
Output power into 50 Ω (with 26.5-V supply)	>100 W CW, 150 W PEP
Power reduction	according to mismatch, but does not reduce power to zero even for very high SWRs
Intermodulation products (with two-tone modulation, referred to PEP) during	$\geq$46 dB down (100 W PEP, 1.5 to 16 MHz)
data transmission	$\geq$42 dB down (100 W PEP, 16 to 30 MHz)
during voice operation	$\geq$42 dB down (150 W PEP, 1.5 to 30 MHz)
Transmitter S/N ratio	
referred to 1-Hz test bandwidth 50-kHz spacing	>142 dB
500-kHz spacing	>155 dB
with digitally tuned filter (alternative configuration) and frequency spacing $\geq$25%	>165 dB
With motor-tuned filter (alternative configuration) and frequency spacing $\geq$5%	>165 dB
Weighted S/N Ratio (weighted with psophometer filter to CCIR for H3E (A3H)	>50 dB referred to PEP
Carrier suppression for J3E (A3J)	>50 dB referred to PEP (>40 dB with voice compressor switched on)
Suppression of unwanted sideband	>50 dB referred to PEP
Voice compressor (IF clipper)	built-in, disconnectable
Increase of average transmitter power for radiotelephony	3 dB

Another common approach that works against receiver dynamic range is the use of transmit-only antenna tuners. Check your transceiver's schematic carefully, and you may discover that its automatic antenna tuner is switched out during receive. If an antenna tuner is necessary to match a transceiver to a feed line, it should be used in transmit *and receive* to add to the transceiver's receiver-front-end selectivity.

Fig 2 shows an experimental transceiver which incorporates most of the techniques mentioned in this article. We will now concentrate on the important circuits outlined in the introduction.

Practical Software and Hardware

Software Menus

The transceiver microprocessor is responsible for all housekeeping activities. These include driving the radio's display; memory management (including BFO and passband tuning, frequency and channel scanning; data bus to RS-232 conversion; scanning the tuning knob and keypad

[1]Notes appear on page 54.

Table 1
(continued)

Receiver Data			
Antenna Input		50 Ω	
Maximum input voltage			
0.4 to 30 MHz		100 V EMF into 50 Ω	
30 to 400 MHz		50 V EMF into 50 Ω	
Oscillator reradiation		≤ 0.5 μV at antenna input with 50-Ω termination	
Sensitivity (1.5 to 30 MHz) for A1A (A1)		≤0.4 μV EMF for S+N/N = 10 dB, IF BW = 300 Hz	
J3E (A3J), J7B (A7J), H3E (A3J)		≤0.65 μV, typically 0.9 μV EMF for S+N/N = 10 dB, IF BW = 2.4 kHz	
Receiving Bandwidths			
Class of emission	*CCIR designation*	*3-dB Bandwidth*	*60-dB Bandwidth*
CW	A1A, A1B	±150 Hz	±375 Hz
AM equivalent	H2A, H2B, H3E	−100 to +2300 Hz	−700 to +2900 Hz
USB (and AM equivalent in receive and transmit)	J3E, R3E	+300 to +2700 Hz	−300 to +3300 Hz
LSB		−300 to −2700 Hz	+300 to −3300 Hz
FSK narrow	F1A, F1B	±150 Hz	±375 Hz
FSK medium		±150 Hz	±375 Hz
FSK wide		±1200 Hz	±1800 Hz
Interference immunity, nonlinearities			
Intermodulation (Δf >30 kHz, f = 1.5 to 30 MHz		≥85 dB down with motor-tuned filter (alternative configuration), interfering signals 2 × 100 mV EMF)	
Blocking		≤3 dB signal attenuation, desired signal 2 mV EMF, interfering signal 4 V EMF, f ≥30 kHz	
Cross-modulation		≤10% modulation transfer, wanted signal 1 mV EMF, interfering signal 500 mV EMF, modulation = 30% at 1 kHz, f ≥30 kHz	
Inherent spurious signals		≤0.4 μV equivalent EMF	
Weighted S/N ratio		≥46 dB for 1 mV EMF	
Image rejection		≥80 dB	
IF rejection		≥80 dB	
Spurious responses		≥80 dB down at Δf ≥30 kHz	
Automatic gain control (RF)			
AGC error		<4 dB 1 μV to 3 V EMF)	
Attack time for +60 dB jump in input signal		≤10 ms	
Decay time		50 ms or 500 ms (depending on class of emission)	
BFO		variable over ±3 kHz in 100-Hz steps in CW; can be used for passband tuning	

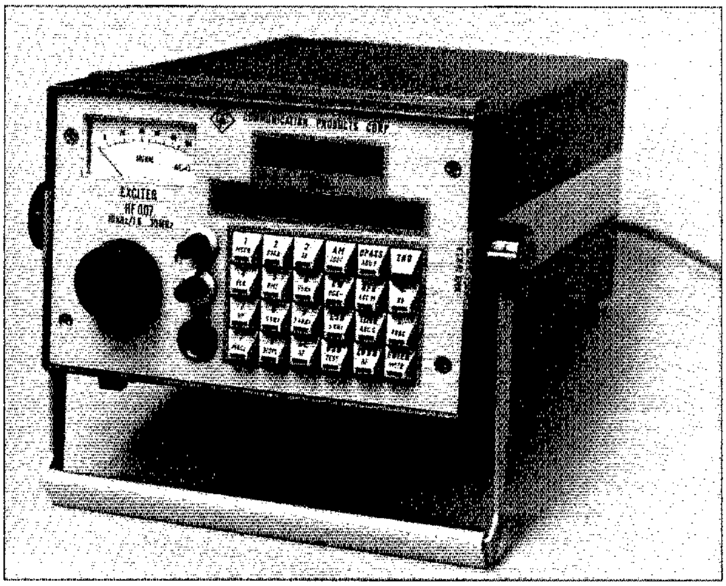


Fig 2—Photograph of experimental exciter that includes a receiver and uses advanced adaptive capabilities. The S meter is calibrated in decibels relative to a microvolt (dBμV).

matrix for input; and detecting service requests or commands for remote control). Among these, those most apparent to the user are the effects of the keypad and tuning knob on different transceiver functions. Several key points must be observed.

1) Keypad and tuning-knob scanning must not generate any switching noises the receiver can pick up.

2) All possible combination of functionalities between frequency steps, operating modes, BFO frequency offset and passband tuning must be freely and independently programmable *and* storable as one data string in memory. See Fig 3A and B.

3) Multilevel menus should be provided for easy use and display of all functions. See Fig 3C. This includes not only modes (USB, LSB, CW and so on), but also AGC attack and decay times. All these parameters must be freely accessible and independently selectable.[33]

Input Filters

Three types of input filters are typically found in current MF/HF receivers and transceivers. The first is the inexpensive and somewhat more traditional combination of fixed-tuned, band-pass filters as implemented in most shortwave transceivers.

The next approach uses filtering tuned by ganged (tracking) capacitors with a post-filter amplifier to overcome tuned-circuit losses (Fig 4). To some degree, wide frequency excursions with such a system are slow—up to two seconds—but the technique is otherwise highly effective. The feedback amplifier sets the system's in-band IMD characteristics. In cases where the filter insertion loss (approximately 6 dB) can be tolerated, the amplifier can be bypassed. This feedback approach, with the three-winding transformer (T1), raises the circuit's intercept point to approximately 30 dBm. This, together with the filter's 6-dB insertion loss, produces an intercept point of 36 dBm. The neon lamp at the input provides overvoltage protection. (Sometimes, the lamp in such a circuit is kept turned on during normal operation. This produces a path to ground that stands ready to instantly act as a short circuit should the lamp's breakdown voltage be exceeded.) Fig 4 shows the proper implementation of a filter used for both transmit and receive.

Fig 5, a digitally switched filter, is a good compromise between the motor-tuned assembly and suboctave band-pass filters. This filter has a microprocessor-controlled matrix which selects BCD-coded capacitance and inductance to cover 1.5 to 30 MHz. Its worst-case switching time is 20 milliseconds. Table 1 shows the differences in the phase-noise performance obtained with the motor-tuned and digitally switched filters. Reed relays work well in this application, and their lifetime is high (more than 1 million switching cycles); latching reed relays can be used to minimize power consumption. The use of PIN switching diodes specified for transmit applications would allow a faster (and more expensive) implementation suitable for frequency hopping.

In the case of transceivers, particularly in manpack applications where electrically short antennas are used, it is a good idea to combine input selectivity with the antenna tuner. A variety of antenna tuners have been published, most of which use the standard Collins (pi-network) or T-network filter (three tuning elements—C-L-C). The ARRL *Handbook* includes an antenna tuner which is a combination of C-L-C and high-pass filters.[34] There are some drawbacks to this, particularly the fact that it may not attenuate, or may even accentuate, harmonics depending on the particular component values used. It also requires that the rotors of its three capacitors must float relative to ground. This makes the arrangement expensive. Fig 6 shows a better way to implement antenna tuning in computer-controlled applications.[35-37]

The antenna matching circuit in Fig 7A[38] provides both the huge transformation range and adjustment simplicity needed for short antennas, as in manpack transceivers. The circuit's impedance-matching range covers several decades. The worst-case antenna impedance is a combination of a highly capacitive load with extremely low ground loss—an impedance consisting of about 5 kilohms of capacitive reactance and 6 ohms of resistance. At the other extreme, the load is slightly inductive and about 40 ohms resistive.

In the circuit, a 4:1 transformer steps the tuner's input impedance down from 50 to 12.5 Ω. The transformer consists of two

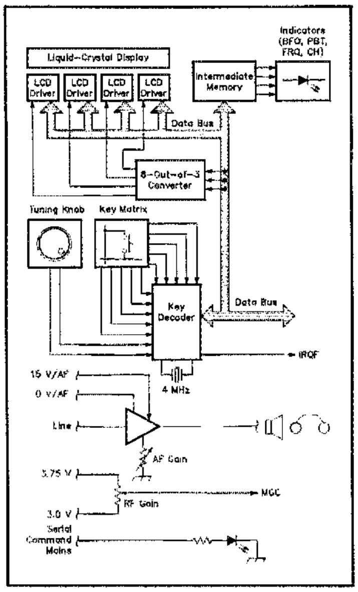


Fig 3A—Block diagram of the bus and control structure of a modern receiver.

parallel 50-Ω lines wound through a ferrite toroid. The ferrite should have a cutoff frequency of 10 MHz and an A_L factor of at least 80 to achieve the Q necessary for wideband performance. The matching circuit that follows it consists of a low-pass, L-section filter paralleled with an inductance

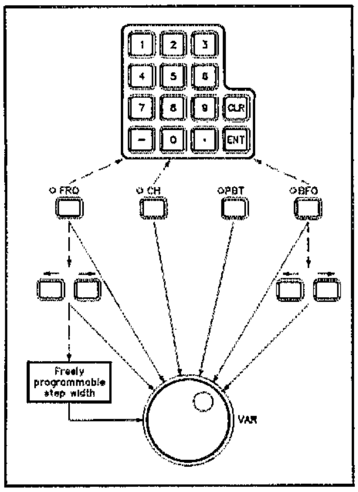
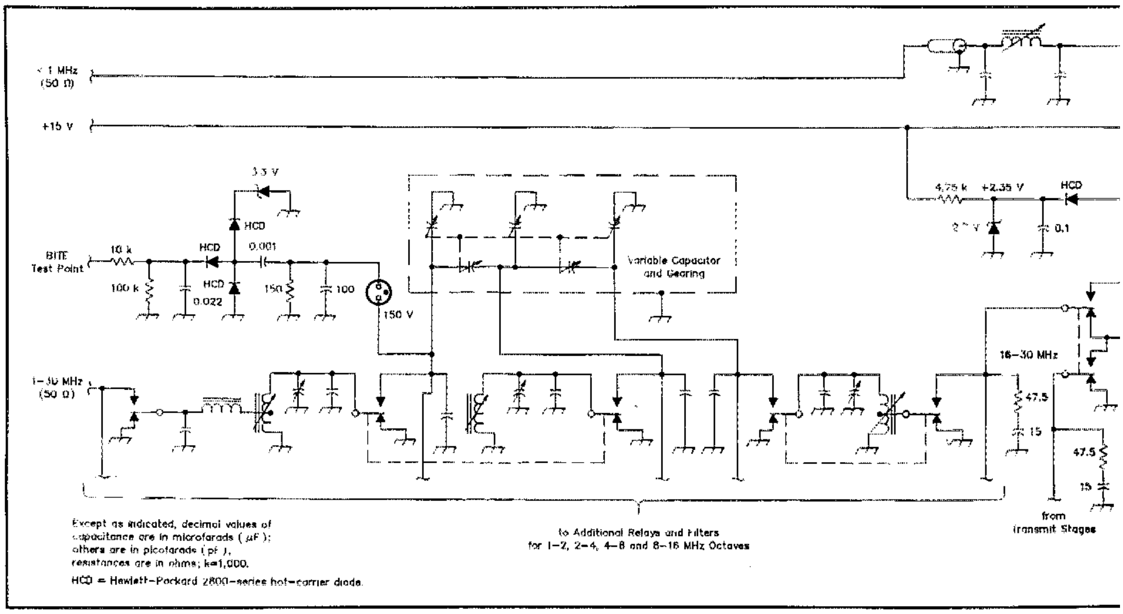


Fig 3B—Enabled by microprocessor control, the keypad and tuning knob interact to allow modification of equipment functions according to multilevel menus (Fig 3C).

of 1 µH, and a 500-pF capacitor in series with the antenna.

The Smith Chart diagram in Fig 7B shows how the 1-µH parallel inductance enables the circuit, at low frequencies, to transform impedances as low as 6 ohms resistive. At high frequencies, this inductor has little influence.

The 500-pF series capacitor allows use of



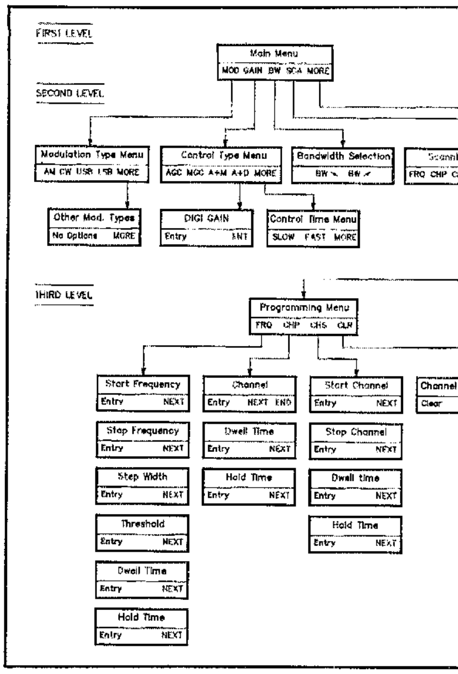


Fig 3C—One example of multilevel menus as implemented in a modern shortwave receiver.

a much smaller shunt capacitor because of its transformation. Without the series capacitor, a shunt capacitor with a maximum value as high as 4000 pF would be required to cover the impedance range. In the circuit, less than half this value does the job.

A whip antenna has a capacitance of approximately 8 pF/m; one popular 7-m military whip exhibits about 56 pF of capacitance. The series 500-pF capacitor of the Fig 7 circuit doesn't appreciably affect the capacitive impedance of such an antenna. The effect of the capacitive or inductive component of long antennas and wideband dipoles is, however, reduced by this series capacitor.

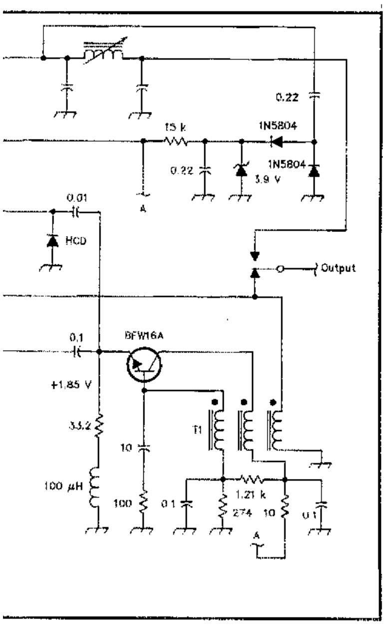


Fig 4—A motorized three-tuned-circuit tracking filter and post-amplifier for use in applications where transmitting and receiving antennas are in close proximity. During receive, the filter's high selectivity increases the receiver's resistance to overload from nearby transmitters; during transmit, the filter band-limits the transmitter's composite-noise output to reduce interference to nearby receivers. T1 is wound trifilarly on one core.

Fig 8 shows a prototype arrangement which can be used with binary stepped component values.

Frequency Synthesizers

The filter shown in Fig 5 is used in a receiver with a first IF of 41.44 MHz. Fig 9 shows the block diagram of a synthesizer which develops the BFO and local-oscillator signals necessary for that receiver's first and second mixers.

This synthesizer uses only one frequency standard, and therefore all of its output frequencies can be traced to this one master standard, which can be either internal or external to the receiver. The synthesizer's BFO output energy is available in Q and $\bar{Q}$ form (the second 180° out of phase with the first) for application to the product detector after division by four. Dividing the signal also reduces the phase jitter of the BFO synthesizer output. In applications where the output frequency is already equal to the BFO frequency, Q and $\bar{Q}$ can be generated by chaining two gates.

The synthesizer's main loop generates first-local-oscillator output in the range 41.44 to 71.44 MHz. This is a two-loop PLL synthesizer that includes direct frequency synthesis. The division ratio in the main loop does not exceed 1000. The reference frequency (100 kHz) provides 100-kHz resolution. This allows a fast-switching PLL design; the phase detectors and filter loop are the limiting factors in its switching time.

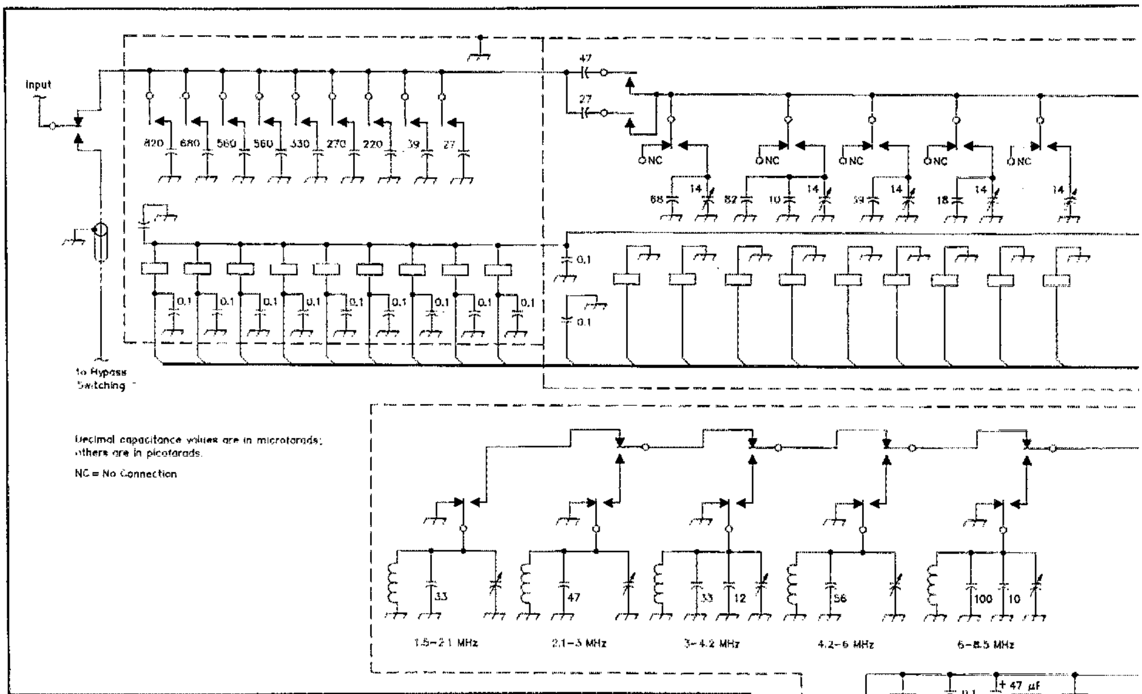
The DDS provides 1-Hz resolution, and the loop bandwidth used to control VCO3 determines the degree of spurious-free operation. VCO3 can also be called a clean-up loop. Typically a switching speed of 5 milliseconds, which translates into a bandwidth of approximately 200 Hz, is to be expected. This has the added benefit of compensating for possible microphonic effects in the VCO circuitry. Although the signal-to-noise ratio of the DDS is quite high, its spurious output limits the phase noise of VCO3. In addition, VCO2 is in a translation loop and its noise sidebands therefore contribute to the system's overall noise performance. As can been seen in Table 1, however, the system's overall phase-noise characteristics are very good.[39]

Input Mixers

Many articles have been written on how to improve a receiver's input intercept point. The design of low-noise, double-balanced diode mixers (particularly using hot-carrier diodes) and ring arrangements of FETs and bipolar transistors has generated a lot of speculation, technical publications and, at times, emotional reaction regarding actual performance. The four leading contestants are:

1) Double-balanced mixers using high-level hot-carrier diodes. The highest achieved iP_3 values for this topology are about 30 dBm, accompanied by 6 dB of insertion loss.

2) Active FET ring modulators using four symmetrical FETs, such as in the U350 quad manufactured by Siliconix. For reasons of cost, and because these mixers are more sensitive than diodes to changes in termination (more to changes in reactance than resistance) at the output for third-order intermodulation distortion (IMD_3), they have not become very popular. A more popular version of this is a push-pull arrangement with N-junction FETs or dual-gate MOSFETs. Both provide similar performance. The dual-gate MOSFETs have slightly more conversion gain, higher intercept points and higher isolation, but most



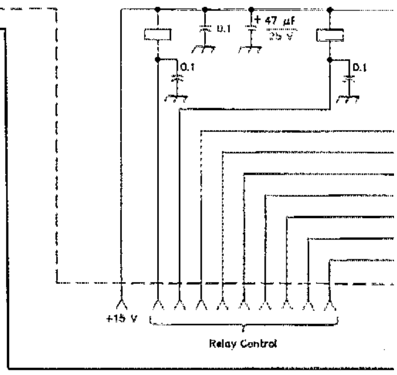


Fig 5—Digital (BCD-code) implementation of single-tuned input filter intended for transmitting and receiving. All of the variable capacitors in this circuit are preset trimmers. The fixed values shown provide sufficient tuning resolution without additional variable inductors or capacitors.

Japanese receiver/transceiver manufacturers prefer the single-gate combinations.

3) High-level ring-type mixer arrangements using bipolar transistors as published by this author[40] and implemented by Plessey in the SL6440 IC. Because of its high dc supply requirement, this approach has not been implemented in many designs.[41]

4) Use of DMOS switches like the Siliconix SD210. This approach, with wideband termination, has been implemented in commercial radios from AEG TELEFUNKEN and Rohde & Schwarz as shown in Fig 10. Third-order intercept points up to 45 dBm have been measured in such circuits. The intercept point depends somewhat on the manufacturing quality of the devices and, of course, their termination. It is important to note that this mixer acts as a switch and exhibits an insertion loss of 6 to 10 dB—much as with the high-level diode mixers. Because of its different switching mechanism, however, it provides a higher intercept point than the diode approach. The gate signal level required to switch these transistors (several volts) translates into approximately 1 watt of local-oscillator power. This method cannot be extended above the VHF range because the trifilar transformers it entails do not provide sufficient symmetry at VHF for the design to outperform diode mixers. At frequencies above 100 MHz, diode-based high-level (Class III) double-balanced mixers are still the best choice. In cases where the first IF is fairly high, recent depletion-layer dual-gate GaAsFETs have provided excellent results. The flicker (1/f) noise component in such arrangements is fairly high, however.

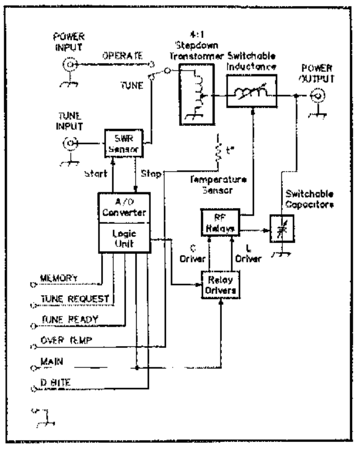
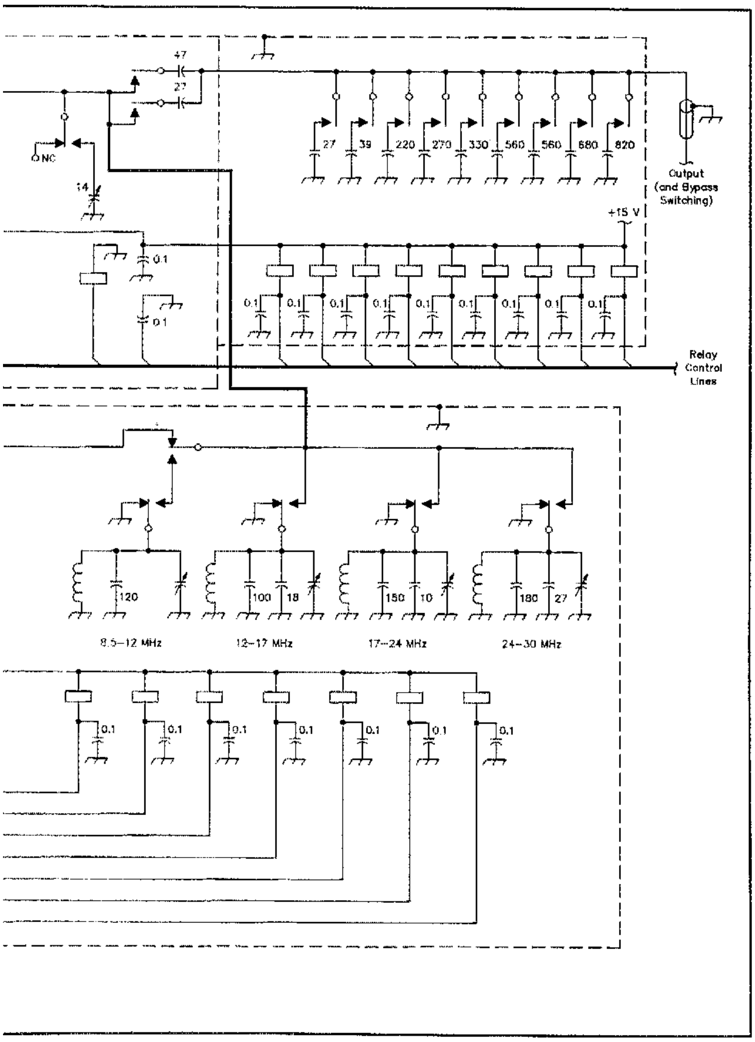


Fig 6—Block diagram of a computer-controlled, wide-impedance-range antenna tuner.

Low-Noise AGC Amplifiers

Modern high-frequency circuit design tries to maintain a 50-Ω impedance level throughout the entire signal chain. Crystal filters and double-balanced mixers are specified for this impedance. It is therefore necessary to design amplifiers with 50-Ω input and output impedances. They must combine low noise figure, high intercept point, and good AGC range. Some of these requirements are almost contradictions in themselves.

The feedback amplifier shown in Fig 11 fulfills these needs. It is used as a termination for the input crystal filter at



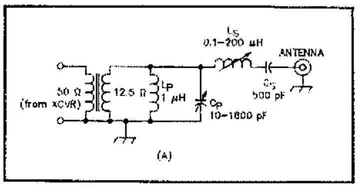


Fig 7A—Simplified circuit of the digitally implemented wideband antenna tuner (analog section). Only two of its components need be variable.

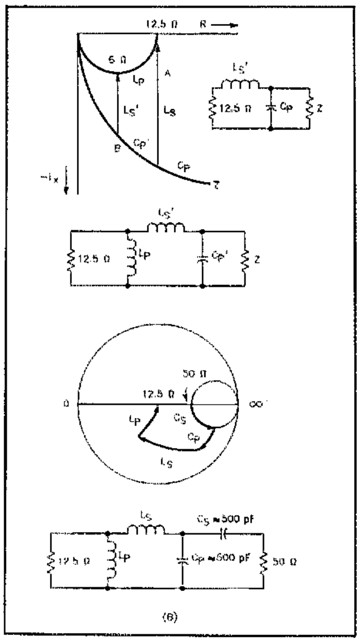


Fig 7B—The antenna tuner first transforms the antenna impedance to 12.5 Ω and then back up to 50 Ω for connection to the transceiver or receiver. Transforming to this intermediate impedance does away with the need for extreme matching-network values.

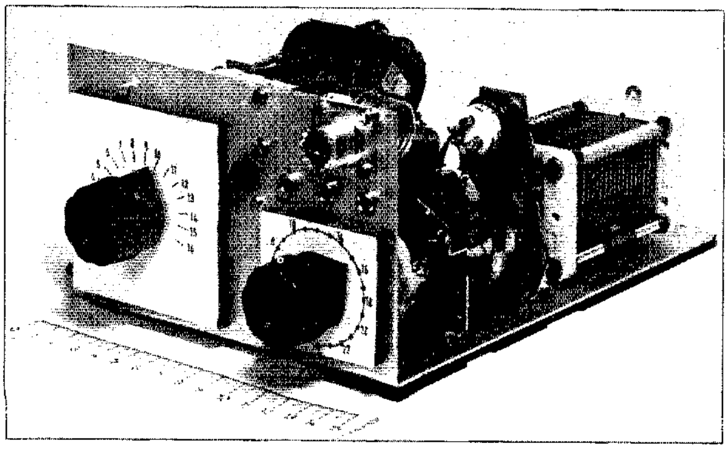
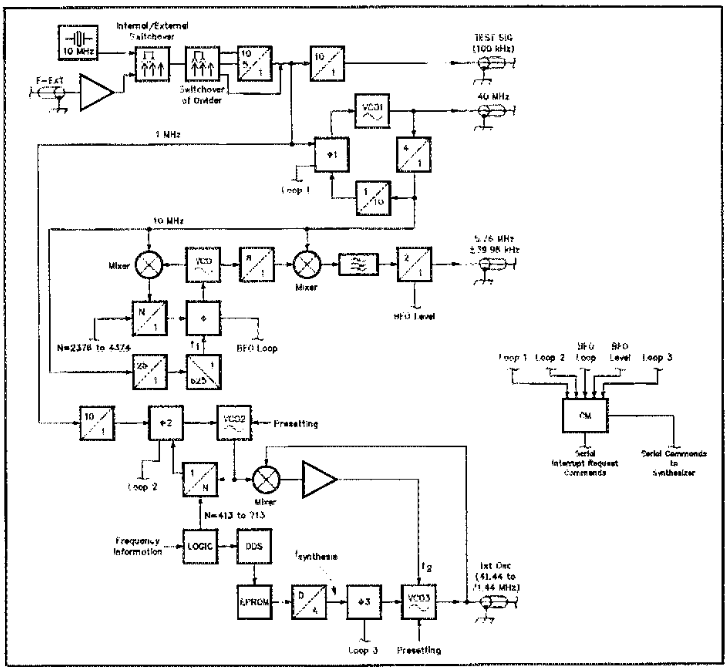


Fig 8—Experimental version of the antenna tuner shown in Fig 7.

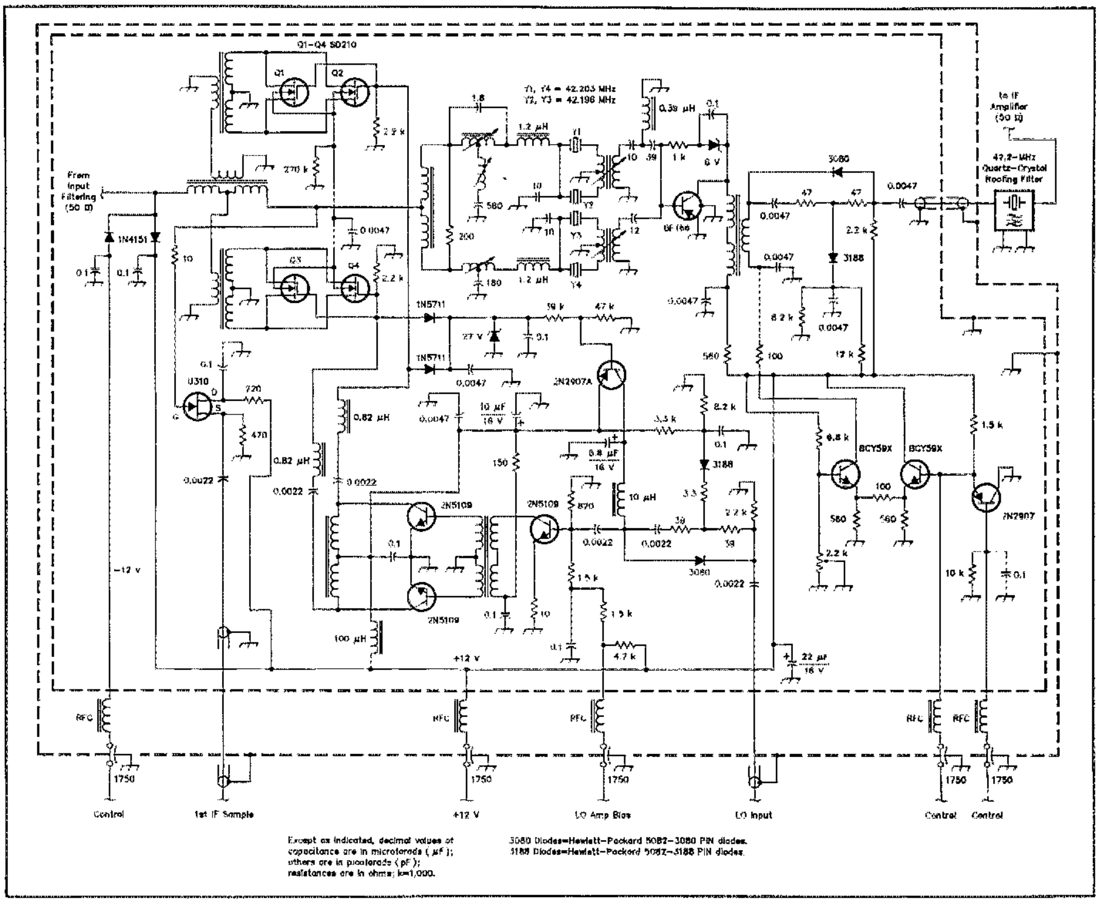
41.44 MHz. This patented approach generates an electronic input impedance of 50 Ω based on the 1:4 feedback transformer (T1) between collector and emitter. The "cold" side of the output winding is terminated by two VHF transistors (BFR96s) which have an input impedance of about 3 Ω. For all practical purposes, the cold side of the output winding is terminated by this low impedance. Therefore, the resistor (182 Ω) in parallel with the output winding is responsible for generating the lossless feedback input impedance of 50 Ω.



Modern bipolar transistors for CATV applications have noise figures of roughly 1 dB up to 500 MHz. The cascode arrangement, with the differential amplifier as the second stage of the cascode, allows the maintenance of a constant impedance or constant termination for the output of the first transistor even as RF gain varies. The cutoff frequency of this type of feedback is essentially determined by the transformer. These transformers are broadband (100 kHz-100 MHz). This unique AGC low-noise amplifier design combines all the necessary features outlined above. It is used between the first crystal filter and the second mixer.

Fig 9—Block diagram of a synthesizer for a dual-conversion shortwave receiver with IFs at 41.44 and 1.44 MHz, including DDS (direct digital synthesis).

Fig 10—Input stage of an ultra-high-dynamic-range receiver (the AEG TELEFUNKEN E1800). The first mixer consists of paralleled pairs of Siliconix SD210 DMOS switching FETs operated in push-pull.



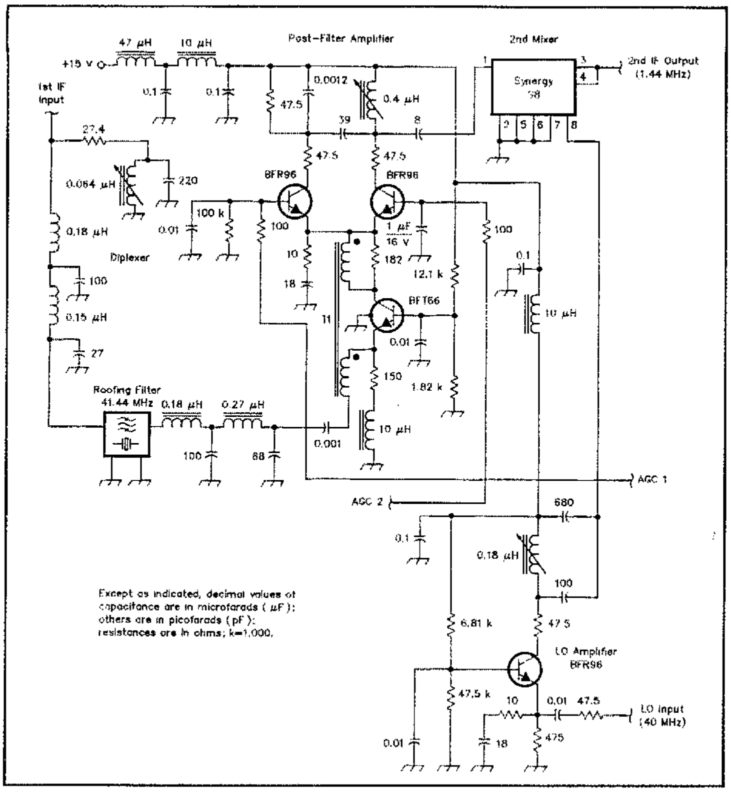


Fig 11—Input diplexer, crystal roofing filter, high-performance AGC-controlled IF-amplifier stage and second mixer of a high-performance receiver (Rohde & Schwarz EK0890). The amplifier has two gain-control inputs, AGC1 (relatively wideband [roofing-filter limited] AGC for large-signal protection, derived from stages immediately following the second mixer) and AGC2 (driven by the receiver's main AGC line). T1 is a bifilar transformer (impedance ratio, 1:4) wound on a single core. The Synergy S8 is a double-balanced diode mixer.

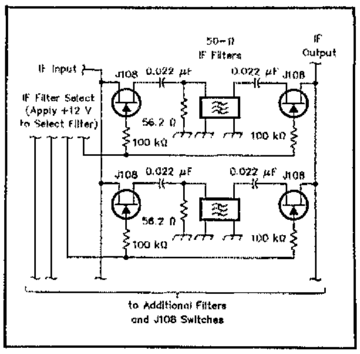


Fig 12—Switching 50-Ω IF filters with JFETs. This method provides more than 90 dB of isolation.

Any other resistive feedback method would result in much higher noise figures. The standard Norton feedback amplifier does not have any useful resonance impedance. The approach described here has extremely high isolation between input and output. An AGC stage could be used *ahead* of a feedback amplifier, but this would result in a noise figure the same as the attenuation provided, and the receiver's overall noise figure would not be as good. A PIN-diode attenuator followed by an amplifier is a good example of this "noisy" technique.

IF Filters and Filter Switching

Most IF filters operate at fairly high impedances—500 Ω to 100 kΩ. By using JFET switches (Fig 12) to select filters with 50-Ω I/O impedances, 90 dB of isolation is possible at frequencies below 2 MHz. The temperature stability and quality factors of crystals are also much better at these lower frequencies. That is why the design shown in Fig 12 uses a second IF of 1.44 MHz. It is much more difficult to build stable, narrowband CW filters with low insertion loss at frequencies between 8 and 12 MHz.

Product Detectors

Product detectors are similar to the mixers used in receiver front ends. Passive diode and active transistor mixers have dominated product-detector designs. Although they are usually somewhat protected from overload by AGC-controlled stages and narrowband IF filtering, their IMD performance and signal-to-noise ratio are important because they contribute directly to the receiver's sound.

A novel and unique product detector (Fig 13) uses two sample-and-hold demodulators based on two CD4066 CMOS analog switches. The Q and Q information they require can be obtained by processing a standard sinusoidal BFO with a CMOS Schmitt trigger and a CMOS inverter operating at 12 V. This simultaneously increases the peak BFO voltage to the drive level

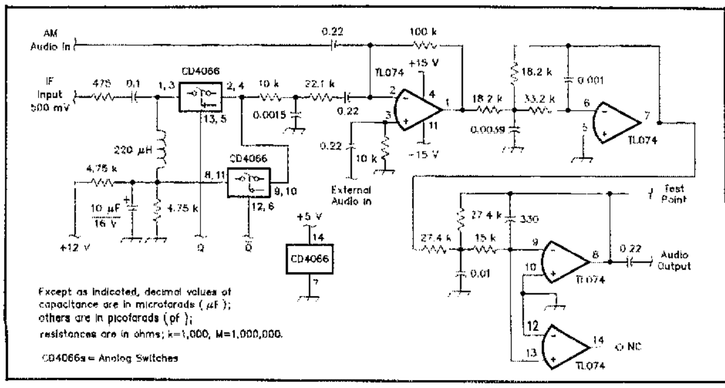


Fig 13—Using CMOS analog switches in a sample-and-hold circuit produces a product detector with 25 dB more dynamic range than conventional designs. Active low-pass audio filtering improves signal-to-noise ratio by band-limiting the detector's detected-IF-noise output.

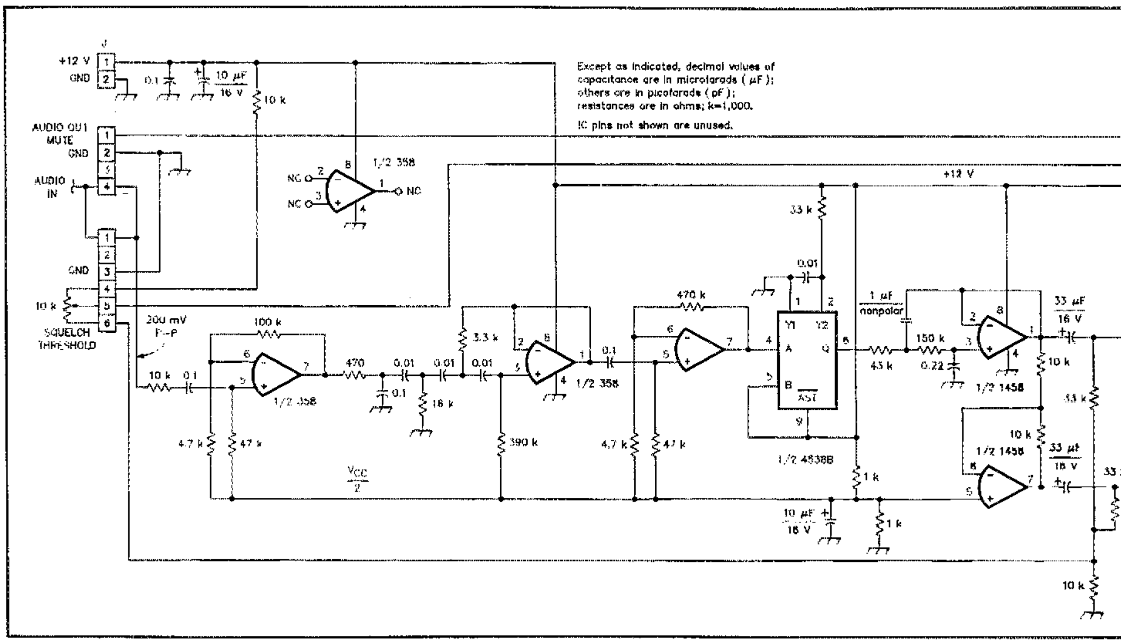


Fig 14—An audio-controlled SSB squelch that senses the presence of syllabic-rate energy to avoid false triggering on steady carriers and noise. This circuit practically acts like an analog computer.

required by the 4066s while producing the necessary two 180° out of phase outputs with sufficiently fast rise and fall times. Because the sampling voltage is at least 10 times larger than normally found, the signal-to-noise ratio possible with this type of product detector is at least 20 dB better than that of standard designs. My experiences are that this type of product detector a S/N ratio of more than 60 dB—much higher than any conventional product detector offers.

A two-stage, low-pass audio filter follows the detector in Fig 13. It has a cutoff frequency of 3 kHz. It may be desirable to use two different low-pass filters, one for CW (with a 1-kHz cutoff frequency) and one for SSB (3 kHz). Active analog filters with band-pass characteristics and a Q of 10 tend to ring and show a severe trade-off between selectivity and time-domain response. In applications where a specific time-domain response is important (in reception of high-speed data signals, for example), such filters can be implemented digitally with switched-capacitor filters or DSP. Some of these techniques may be beyond the reach of most who build their own radio hardware, however.

High-Performance SSB Squelch

The SSB squelch circuit shown in Fig 14 uses a radically different method to control the receiver-audio muting. Whereas conventional squelch circuits compare the received signal level to a preset level, the SSB squelch ignores differences in signal level and instead looks for low-frequency variations in the pitch of the received audio. This method allows the squelch to completely ignore static and impulse-type noise while retaining the ability to open immediately on voice signals.

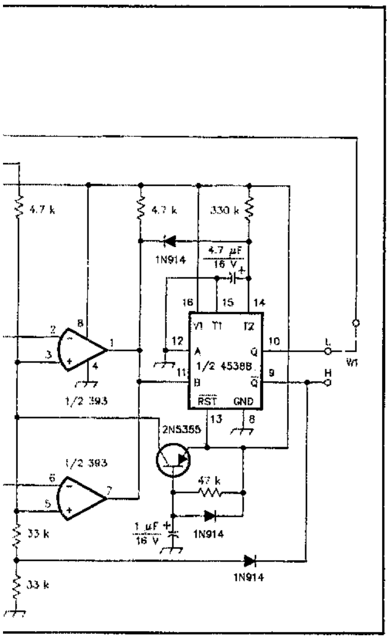
The circuit's audio input is taken directly from the demodulators and fed through a 300-Hz high-pass filter to the squelch circuit. This prevents low-pitched audio tones from falsely triggering the squelch. The signal is then limited to remove amplitude variations and fed to a discriminator centered at 1500 Hz. Any variations in audio pitch show up as variations in the discriminator's dc output. This dc is fed through a low-pass filter that removes ripple above 3.25 Hz. Variations in the pitch of voices fall below this frequency and are coupled to the comparator circuit through blocking capacitors. The comparator (U2) triggers the gate one-shot (U1B) whenever the variations exceed a variable threshold in either a positive or negative direction. The gate one-shot, when triggered, opens the audio channel for a fixed period of time (about 2 seconds). A feedback signal from the gate one-shot is applied to the comparator to lower its threshold when the squelch gate is open. This hysteresis reduces the incidence of false triggering and minimizes drop-out on desired signals.

Summary

This review article has outlined a variety of important new techniques available for improving the performance of communication receivers. I hope that both amateurs and the designers of commercial equipment will incorporate these techniques. As mentioned, some of these techniques may be patented, and therefore it is also prudent to look at this angle.

Notes

[1] U. Rohde and T. Bucher, *Communications Receivers—Principles & Design* (New York: McGraw-Hill, 1987).
[2] E. Gosling, ed, *Radio Receivers*, IEE Telecommunications Series 15 (ISBN: 0-86341-056-1).
[3] M. Larimore, "Digital Receiver Technology," presented to the Association of Old Crows, November 12, 1991.
[4] C. Hutchinson and J. Kleinman, eds, *The ARRL Handbook for Radio Amateurs*, 1992 ed (Newington: ARRL, 1991).
[5] D. DeMaw and W. Hayward, *Solid-State Design for the Radio Amateur*, 2nd printing (Newington: ARRL, 1986).
[6] W. Sabin and E. Schoenike, *Single-Sideband Systems and Circuits* (Englewood Cliffs, NJ: McGraw-Hill, 1987).
[7] W. Hayward, "A Competition-Grade CW Receiver," Part 1, *QST*, Mar 1974, pp 16-30; Part 2, *QST*, Apr 1974, pp 34-39.
[8] D. DeMaw, "His Eminence: The Receiver," Part 1, *QST*, Jun 1976, pp 24-30; Part 2, *QST*, Jul 1976, pp 14-17.
[9] J. Rusgrove, "Human-Engineering the Station Receiver," *QST*, Jan 1979, pp 21-25.
[10] One may argue whether or not the dynamic range required of a receiver covering 140-174 MHz, or 420-480 MHz, is higher than on shortwave frequencies (1.5 to 30 MHz). Con-



sidering my location, where I have line-of-sight exposure to New York City and its many large antennas, I think the dynamic range required for UHF/VHF receivers is higher.

[11]See Note 5.

[12]U. Rohde, "Stand der Technik bei Amateurfunkgeraeten im Kurzwellengebiet," 1. Teil ("State of the Art of Shortwave Radio Amateur Equipment," Part 1), *Funkschau*, 1972, Issue 24.

[13]U. Rohde, "Stand der Technik bei Amateurfunkgeraeten im Kurzwellengebiet," 2. Teil ("State of the Art of Shortwave Radio Amateur Equipment," Part 2), *Funkschau*, 1973, Issue 1.

[14]U. Rohde, "Stand der Technik bei Amateurfunkgeraeten im Kurzwellengebiet," 3. Teil ("State of the Art of Shortwave Radio Amateur Equipment," Part 3), *Funkschau*, 1973, Issue 2.

[15]U. Rohde, "High Dynamic Range Receiver Input Stages," *ham radio*, Oct 1975, pp 26-31.

[16]U. Rohde, "Eight Ways to Better Receiver Design," *Electronics*, Feb 20, 1975.

[17]U. Rohde, "Optimum Design for High-Frequency Communications Receivers," *ham radio*, Oct 1976, pp 10-25.

[18]U. Rohde, "Recent Developments in Shortwave Communication Receiver Circuits," National Telecommunications Conference, Nov 1979.

[19]U. Rohde, "Communication Receivers for the Year 2000," Part 1, *ham radio*, Nov 1981, pp 24, 26, 28, 29.

[20]U. Rohde, "Communication Receivers for the Year 2000," Part 2, *ham radio*, Dec 1981, pp 36-44.

[21]U. Rohde, "Digital HF Radio: A Sampling of Techniques," presented at the Third International Conference on HF Communication Systems and Techniques, London, England, Feb 26-28, 1985.

[22]U. Rohde, "Digital HF Radio: A Sampling of Techniques," *ham radio*, Apr 1985, pp 18, 19, 21-24, 27, 29-31, 33-35, 37-39, 41, 42.

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[26]U. Rohde, "Evaluating Noise Sideband Performance in Oscillators," *ham radio*, Oct 1978, pp 51-57.

[27]U. Rohde, "Low-Noise Frequency Synthesizers: Fractional N Phase-Locked Loops," SOUTHCON/81, Jan 1981.

[28]U. Rohde, *Digital PLL Frequency Synthesizers—Theory and Design* (Englewood Cliffs, NJ: Prentice-Hall, 1983). Available from Compact Software, 483 McLean Blvd, Paterson, NJ 07504.

[29]See Note 22.

[30]U. Rohde, "Noise Prediction in Oscillators," *Proceedings*, RF Technology EXPO 87, Feb 11-13, 1987, Anaheim, CA.

[31]W. Robins, *Phase Noise in Signal Sources*, IEE Telecommunications Series 9, ISBN 0-86341-026-X.

[32]R. Stirling, *Microwave Frequency Synthesizers*, (Englewood Cliffs, NJ: Prentice-Hall), ISBN 0-13-582016-2 025.

[33]Service manual for shortwave receiver EK0890, Rohde & Schwarz.

[34]C. Hutchinson and J. Kleinman, eds, *The ARRL Handbook*, 1992 ed (Newington: ARRL, 1991), pp 34-17 to 34-19.

[35]U. Rohde, "Die Anpassung von kurzen Stabantennen fuer KW-Sender" "Matching of Short Rod Antennas for Shortwave Transmitters", *Funkschau* 1974, Issue 7.

[36]U. Rohde, "Die Planung von leichten, tragbarne KW-Sende-empfaegern" "Design of Shortwave Man-pack Transceivers", *Funkschau* 1975, Issue 3.

[37]U. Rohde, "Match Antenna Over 1.5 to 30 MHz with Only Two Adjustable Elements," *Electronic Design 19*, Sep 13, 1975.

[38]See Note 37.

[39]See Note 33.

[40]U. Rohde, "Performance Capability of Active Mixers," WESCON/81, Sep 1981, San Francisco, CA. (Also see the paper by Plessy in the same volume.)

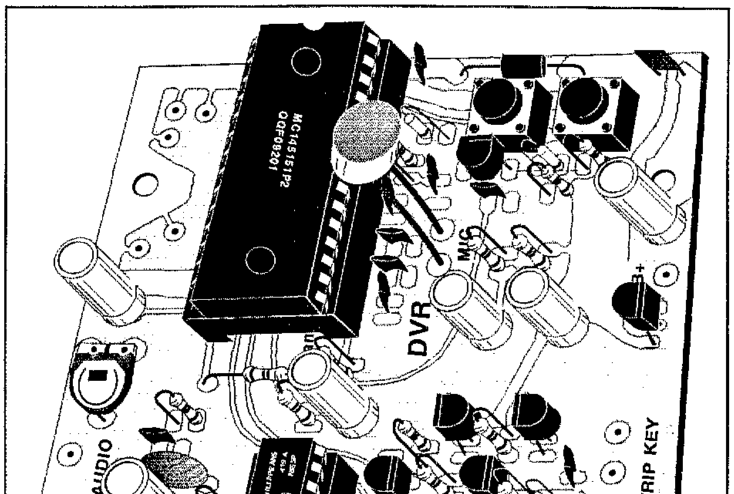
[41]U. Rohde, "Required Dynamic Range and Design Guides for EMI/RFI Test Receivers," presented at ELECTRO/82, May 1982, Boston, MA.

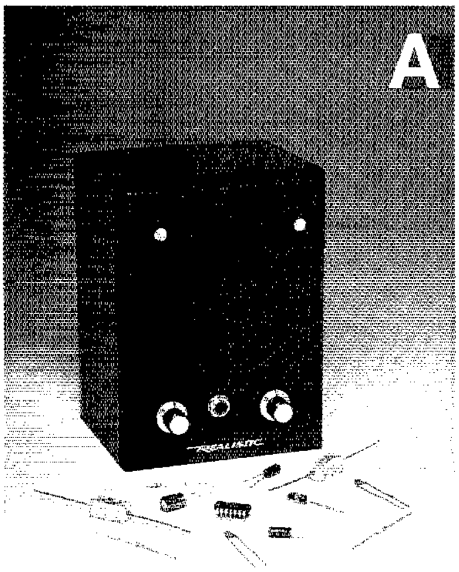
Ulrich L. Rohde is president of Compact Software, chairman of Synergy Microwave Corp and a partner of Rohde & Schwarz, Munich, Germany, a multinational company specializing in advanced test and radio communications systems. Having studied electrical engineering and radio communications at the universities of Munich and Darmstadt, he holds a PhD in electrical engineering and an ScD (hon) in radio communications. Dr Rohde has published more than 50 scientific papers in professional journals, as well as four books. His memberships include the ETA KAPPA NU Honor Society; the Executive Association of the Graduate School of Business, Columbia University, New York; the Armed Forces Communications and Electronics Association; the IEEE (senior member); the Radio Club of America (fellow) and the American Radio Relay League (life member). He holds an Extra Class US amateur license (KA2WEU, 1991) and is an ARRL-accredited VE. He is known for his German call sign DJ2LR (1956) and Swiss call sign HB9AWE (1973)

New Products

DIGITAL VOICE RECORDER

☐ Repeater owners, DXers and contesters will find a multitude of uses for the DVR-1, a versatile PC board module that can be used as a voice IDer for repeaters, a contest CQ caller or an "audio notepad" to record brief received transmissions. You can make recordings with the built-in mike or an external mike. The unit records up to 20 seconds of audio, which can be broken up into several smaller messages. The playback audio output connects directly to any transmitter's mike input or to a small external speaker. The kit is $89, and a wired and tested unit is $139. Hamtronics Inc, 65-E Moul Rd, Hilton, NY 14468-9535; tel 716-392-9430, fax 716-392-9420.





A Dual-Radio Speaker

With an inexpensive speaker and a handful of parts, you can monitor two radios separately—or together—at the flick of a switch.

By Neil Ramhorst, KL7JGS and Fred Cady, KE7X
PO Box 4424
Bozeman, MT 59772
1316 Arrowleaf Hills Rd
Bozeman, MT 59772

We're among several members of our local club who enjoy home-brewing. In an effort to infect new amateurs with our enthusiasm, we searched for a useful project that would be easy to build. Our inspiration came while participating in an emergency preparedness drill.

During the drill we were confronted with the need to monitor two radios simultaneously. However, high background noise in the command center prevented us from simply using the internal speakers in the rigs. Someone suggested headphones, but they could only be plugged into one radio at a time. They also limited the ability of others to easily monitor the communications. What we really needed was a versatile headphone/speaker audio mixer!

A multichannel headphone mixer is described in the *ARRL Handbook*,[1] but it lacks a speaker to allow monitoring by more than one person—and it mixes all inputs to both ears. We were looking for a circuit that would permit us to monitor one or two different radios, either through a speaker or stereo headphones. The audio channels had to be independently selectable for *both* the speaker and the headphones. This would allow the headphone user to listen to either radio (or both mixed together), with the same option available to those listening to the speaker. With the *Handbook* design as our foundation, we applied a healthy dose of inventive imagination. The result was the dual-radio speaker project!

[1]Notes appear on page 58.

The dual-radio speaker uses inexpensive, easy-to-find parts. It's also simple to construct. It fits into a Radio Shack Minimus 2.5 speaker enclosure, although any small speaker can be used. The only limiting factor is the space required to mount switches and pots.

Our club members have built over 20 dual-radio speakers using various enclosure and control combinations. By purchasing parts in volume, we were able to get the cost per speaker below $30. Compared to the price of a communications speaker, that's a bargain.

These handy speakers have found other uses besides emergency communications. Local DXers use them to monitor VHF DX spotting frequencies while listening to HF. The speakers also provide improved audio quality when used with dual-band radios.

Circuit Description

The circuit (Fig 1) uses a National Semiconductor LM380N audio amplifier (U1) in a standard configuration. Signals from channels A and B are applied across 8.2-ohm load resistors R1 and R2, and through volume controls R3 and R4. Selector switches S1A and S1B control which channels are fed to U1 for speaker monitoring. In position 4, the channels are grounded, disabling the speaker. In position 3, only the right channel is heard. In position 2 both channels are available simultaneously, and in position 1, only the left channel is heard. The signals are fed to the positive input of U1 through a coupling network comprised of C3, C4, R5 and R6. The output is applied to the speaker through coupling capacitor C8.

Headphone audio is picked off just after the load resistors and selected by S2A and S2B. By using stereo headphones, the operator can listen to channel A, channel B or both. Note that R3 and R4 *do not* adjust headphone volume. The operator must set a comfortable listening level using the volume controls on each radio. Once this level is set, those listening to the speaker can independently set the monitoring volume by adjusting either R3 or R4.

If you decide to use the Minimus speaker enclosure, make sure that you select *miniature* pots for R3 and R4. If you have difficulty finding two pole, three- or four-position switches for S1 and S2, several manufacturers supply six-position switches with locking mechanisms to select the desired number of usable positions.[2]

Construction

Begin by removing the grill on the Minimus 2.5 speaker. *Carefully* insert the flat blade of a knife or a small screwdriver between the grill and the edge of the enclosure and gently pry out the grill. Now remove the six front-panel screws and lift the panel free. Disconnect the speaker wires and remove the fiberglass insulation.

Remove the input terminal panel from the back of the enclosure. You won't need it for this project. Replace it with a 2 × 2½-inch piece of aluminum that's been drilled to accept your input jacks and power receptacle. The panel must fit over the hole in the back of the enclosure.

Remove the four screws that secure the speaker to the front panel. Set the speaker aside. Mark and drill three holes in the unused area along the *bottom* of the panel

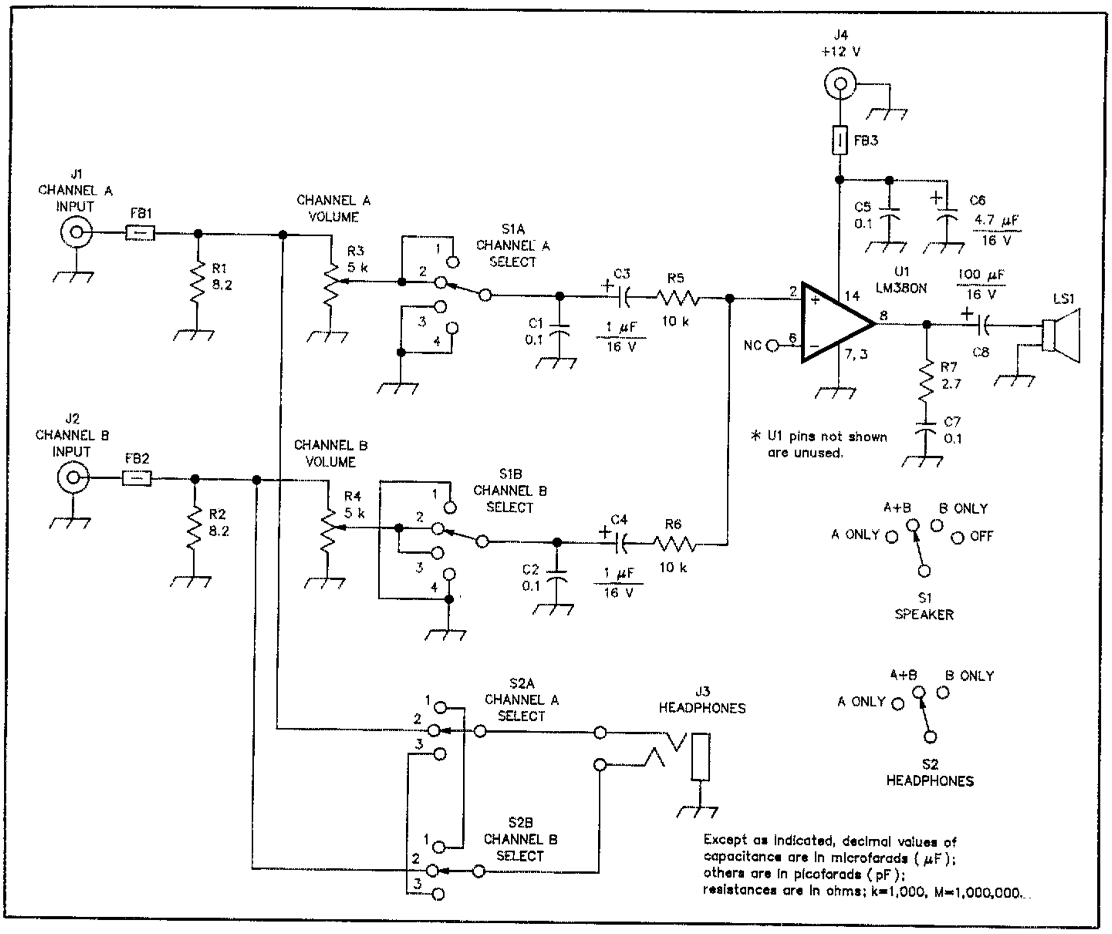


Fig 1—Schematic of the dual-radio speaker. Resistors are ¼-watt, 5%-tolerance carbon-composition or film except as noted below.

C1, C2, C5, C7—0.1-µF ceramic.
C3, C4—1-µF, 16-V electrolytic.
C6—4.7-µF, 16-V electrolytic.
C8—100-µF, 16-V electrolytic.
J1, J2—Miniature phono jacks.
J3—¼-inch stereo headphone jack.
J4—Metal panel-mount dc power jack (Radio Shack 274-1563)
R1, R2—8.2 Ω, 5 W.
R3, R4—5 kΩ, ¼ W, audio taper (All Electronics MLP-5K).
R5, R6—10 kΩ.
R7—2.7 Ω, ¼ W.
S1, S2—two-pole, four-position rotary switch.
U1—LM380N audio amplifier.
Misc: 14-pin IC socket for U1; ferrite beads FB1, FB2 and FB3; Radio Shack Minimus 2.5 speaker.

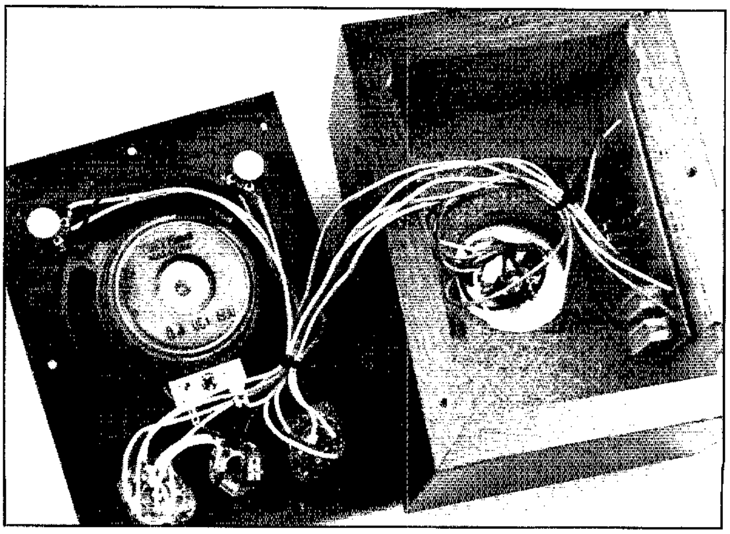


Fig 2—The PC board fits easily inside the speaker enclosure. This board is secured to the interior of the cabinet using Velcro strips. Note the headphone jack, rotary switches and volume controls mounted in the front panel.

for the channel selection switches and the stereo headphone jack. Mount the switches and the jack. Replace the speaker, securing it with the bottom screws *only*. Using a tapered reamer, or a drill bit of the correct size, enlarge the two mounting holes at the *top* of the panel to fit the shafts of the volume potentiometers. The shafts of the pots are mounted in the front panel, *through* the holes in the speaker frame. Their mounting nuts will hold the top of the speaker in place.

The mixer circuitry can be wired on a small piece of perf board. To further simplify assembly, a PC board is available from FAR Circuits.[3] The PC-board design includes a small area to conveniently mount the speaker load resistors. The PC board can be attached to the inside of the enclosure with a small piece of Velcro or double-sided tape (see Fig 2). Ferrite beads have been included to reduce RF interference to the unit. In some cases, additional bypass capacitors (0.01 μF) may be needed at the inputs.

Once everything is wired and tested, the final step is to punch holes through the speaker grill to accommodate the shafts for the switches and volume controls. (Another hole is necessary above the headphone jack.) We used a Rotex rotary punch and created holes slightly smaller than the correct size. (Use a paper template as your guide for the proper hole locations.) The holes were then checked and repunched as necessary. If you don't have a punch handy, a drill can also be used.

Conclusion

During the past year, the dual-radio speakers have been used in two emergency situations and have received positive reviews from operators and local officials. The only complaints we've received came from members who built one speaker and wish they'd built two! If you need a convenient way to monitor two audio sources, or to enhance audio quality in your shack, this project is just the item!

Our thanks to Larry Stanley, KF7XS, who provided photographic assistance for this article.

Notes

1C. Hutchinson and J. Kleinman, eds, *The ARRL Handbook for Radio Amateurs*, 69th ed, (Newington: ARRL, 1991), p 28-7.

2Radio Shack 275-1385 (two poles, six positions, *no stops*). Mouser Electronics, 2401 Highway 287 North, Mansfield, TX 76063 tel 800-346-6873. Model 10WA125 (two poles, six positions, *with stops*).

3A PC board and part overlay are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118; price $3.50 plus $1.50 shipping and handling per order. Check or money order only; credit cards not accepted. The PC-board template and part overlay are available free of charge from the ARRL Technical Department Secretary. With your request for the RAMHORST DUAL-RADIO SPEAKER PC BOARD TEMPLATE PACKAGE, send a #10 SASE.

Neil Ramhorst, KL7JGS, is a wildlife and nature photographer in Bozeman, Montana. He was licensed in 1971 as WBØGLJ. Neil later worked for the Federal Aviation Administration in Alaska, where he received his KL7 call. Neil photographed the scene that appears on the cover of the February 1992 QST. *He holds an Extra Class license and enjoys all phases of Amateur Radio.*

Fred Cady, KE7X, is an Associate Professor in Electrical Engineering at Montana State University. He was first licensed in 1959. He held KC4USM in 1967-68 and ZL3ADY from 1971 to 1980. Fred enjoys DXing, emergency communications and public service. He is also a VE and teaches Amateur Radio license classes. Fred was ARRL Instructor of the Year in 1990.

New Books

THE HIDDEN SIGNALS ON SATELLITE TV, 3RD EDITION

By Thomas P. Harrington, W8OMV. Published by Universal Electronics Inc, 4555 Groves Rd, Suite 13, Columbus OH 43232, tel 614-866-4605. 250 pp, 240 illus. Softcover, 8½ × 11 inches, $19.95 plus $3 s/h.

Reviewed By Bruce S. Hale, KB1MW/7

"This work is published for the commercial field to increase their awareness of the many nonvideo opportunities existing in the satellite communications field. The publisher and its author do not condone any individuals, company or groups misuse of this information in any way."

After that carefully worded disclaimer (on the back of the title page), *The Hidden Signals on Satellite TV* contains a fascinating look at some of the nontelevision services transmitted on geosynchronous communications satellites.

Most people who own satellite TV systems (and there are quite a few these days) are probably not aware of the non-TV services that share transponder space with CNN, TBS and other familiar satellite TV transmissions. Harrington describes many of these services. Chapter Two describes audio subcarriers (which carry a fascinating collection of radio services, such as Southern Gospel Radio, the Tidewater Radio Network, CNN Radio and CBC Stereo).

Other chapters discuss a wealth of other services, such as Teletext, AP, UPI and Reuters small-dish news services, the Zephyr Weather Information service and the Agri-Sat agricultural service. The appendices contain a glossary of satellite terms, a table showing the predicted location of satellites in the "Clarke Belt" in 1995 (Chapter One contains a detailed table of current satellite locations and transponder loading), and a C-band frequency/transponder conversion table. There's no index; an unfortunate omission for a book containing so much information.

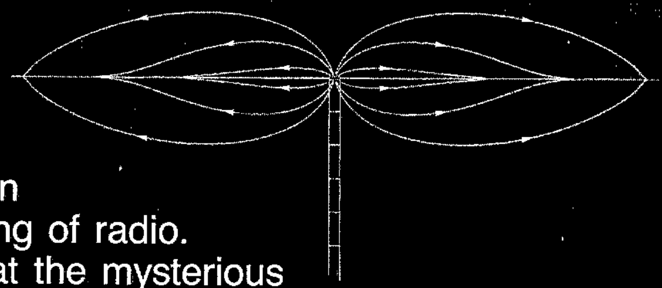
Throughout the book, Harrington describes the equipment required to receive each service; much of this equipment is readily available at satellite-TV dealers (much of it surplus for low cost). Many hams may already have an appropriate receiver for satellite reception (an ICOM R-7000 or Regency M5000 scanner can be used with a dish and 1450-MHz LNB to receive single-carrier-per-channel radio station transmissions).

The book is an interesting collection of technical details. Chapter One assumes almost no technical skill and describes the difference between analog and digital signals, how radio signals are modulated, bandwidth and noise problems, and charts the radio spectrum from 0 to 30,000 MHz. Later chapters introduce terms (such as dB) with no definition or description. Most hams will have no trouble with the technical details, and there are enough diagrams and descriptions to keep others from getting too bogged down.

There are a few typos and inaccuracies, and many of the diagrams and tables are borrowed from other publications. In addition, some figures are several pages away from their text references—this gives the book a slightly less "polished" look than it might have had with a bit more editing and illustration work. This is only a slight distraction from the interesting details, however.

I'd recommend this book to any ham who owns a satellite dish. If you don't already own a dish, this book may be just the incentive you need to go out and buy one.

Why an Antenna Radiates



You don't have to know how an antenna works to use one, but getting a handle on this subject can deepen your understanding of radio. Here's a searching look at the mysterious process by which our antennas hurl energy from Here to There.

By Kenneth Macleish, W7TX
740 E Chula Vista Rd
Tucson, AZ 85718

If antennas didn't radiate, we might be well advised to dispose of our ham gear and take up another hobby. Fortunately, they *do* radiate. Our purpose here is to explore the basic principles underlying this wonderful and little-understood phenomenon.

Before starting, let's try a simple test to see how much you already know about antennas. Don't peek at the answers[1] until you have answered all the questions!

1. In a center-fed, half-wave dipole, electrons surge back and forth from one side of the antenna to the other.

True______ False______

2. It is possible for a perfect insulator to radiate.

True______ False______

3. Unlike ohmic resistance, "radiation resistance" has significance only at the feed point of an antenna or antenna system.

True______ False______

4. The ground around a transmitting antenna radiates.

True______ False______

If you got all the answers right, you probably know more than the writer, and you have permission to skip the rest of this article.

An Imaginary Experiment

Take a pithball about the size of a marble between your thumb and forefinger. If you don't know what a pithball is, or can't find one, a hunk of plastic foam or a ping pong ball will be fine. For lack of a better name we will refer to any of these articles as a pithball. Rub the pithball on your carpet to give it a good electrical charge. Now wave the pithball back and forth in the air over a six-inch distance as fast as you can. The pithball is sending out electromagnetic waves! Let's say you are achieving a rate of 10 cycles of motion per second. If you have placed in the corner of the room a sufficiently sensitive megameter-wave receiver, it will detect a signal when tuned to a frequency of 10 hertz, or to a wavelength of 30 million meters. If you could vibrate your hand fast enough you might even be able to carry on radio communication in this fashion!

We will continue this experiment shortly. Meanwhile let's take a look at what goes on inside an antenna.

Put Your Antenna Under a Microscope

Now, admittedly the average antenna doesn't contain any pithballs. But it does contain hordes of minute, lightweight, electrically charged particles called *electrons*. Many of these are so-called *free* electrons that have broken loose from their parent copper or aluminum atoms and are able to travel more or less freely through the spaces between atoms, under the influence of any electric fields that may be present. The free electrons behave in many ways like tiny pithballs.

We know that an electric current in a conductor is simply a mass migration of free electrons. If the current is alternating, as in an antenna, the free electrons in a given locality move back and forth in unison. Evidently, then, any individual electron moves to and fro around an average position, like the pithball in our experiment. Let's see how far and how fast this electron might travel.

Consider an antenna made of #12 copper wire and operating at 14.1 MHz. Each free electron near the surface of the wire is executing 14.1 million cycles of motion per second. Knowing the number of free electrons per cubic inch of copper, the electric charge on each, and the depth of RF penetration into the wire (the *skin depth*), we can calculate the peak speed of an electron at a place where the RMS antenna current is, say, one ampere. The result comes out to be less than half an inch per second. At that rate the electron doesn't move very far during each half cycle of vibration: its peak-to-peak travel is no more than a hundred-millionth of an inch. In the eyes of an electron this distance is quite respectable, being tens of thousands of times its own diameter. The answer to question 1 above, though, is clearly "False." Not one electron makes it through the feed system from one side of the antenna to the other.

We can compute the electron's deceleration and acceleration, which are greatest when the electron is coming to a stop and then starting up in the other direction. At an antenna current of one ampere, these quantities reach more than 50,000 *g*s! And an accelerating or decelerating charged body, be it an electron or a pithball, is a source of electromagnetic radiation.

A pithball is a pretty good insulator, and so, presumably, is an electron. So the answer to question 2 is "True": a perfect insulator *can* radiate.

Let's return to our imaginary experiment. This time, instead of waving a pithball at 10 hertz, we'll pretend to vibrate a single

[1]Notes appear on page 63.

electron at radio frequency[2] and examine the resulting fields.

Fields of a Vibrating Electron

The detailed structure of an electron is unknown, but for our purposes it doesn't matter; we can assume that our electron is a little round ball with an electrical charge distributed uniformly over its surface. We determine the fields by solving Maxwell's equations[3] at all distances from the electron, right down to its surface. This analysis is not an exercise for the faint-hearted. We'll skip the details and concentrate here on the results.

The Coulomb Field

Grasping the electron in, say, a tiny pair of tweezers, let's start by holding it still. After a while the only field present will be a stationary electric field that points outward[4] in all directions from the electron. The field lines take the form illustrated in Fig 1 for both positive and negative charges. This is called the *coulomb field*. It is always present, regardless of whether the electron is in motion. We'll find later that the coulomb field plays a vital role in the operation of antennas.

With vibratory motion, two new fields make their appearance.

The Magnetic Field

A moving electron constitutes a current, and a current is always surrounded by a *magnetic field*. As if hitchhiking, point the thumb of your right hand in the direction of the electron's motion; then your curled fingers represent the circular lines of the magnetic field around the electron. Point your thumb in the opposite direction and you see that the magnetic field reverses, so a vibrating electron gives rise to an alternating magnetic field. At the electron's surface, the magnetic field is almost exactly in phase with the electron's speed, but as we move away, the phase of the magnetic field begins to lag. Out to a radius of 1/6 wavelength, the phase lag is small. Beyond this radius, the lag starts to increase at a more rapid rate and soon settles at 360 degrees per wavelength of distance.

The Dynamic Electric Field

The second new field is an electric field that results from the electron's acceleration. Because of its dynamic origin—in contrast to the electrostatic nature of the coulomb field—we'll call this field the *dynamic electric field*. It's useful to regard the dynamic electric field as the sum of two separate fields, one of which is in phase with the magnetic field and the other 90 degrees out of phase. We will call the in-phase component the *radiation field* and the out-of-phase component the *induction field*. It is the radiation field that carries energy from an antenna into the surrounding universe.

Fig 2 shows an area the size of a football field in which a lone electron, greatly magnified, is being vibrated at 14.1 MHz. The figure is a snapshot of the electron's radiation field taken at an instant when the electron is at the center of its travel and moving to the right, as indicated by an arrow. The curved arrows show the direction and strength of the radiation field. The dashed circles represent spherical wavecrests on which the field is at a local maximum. As we go outward from a wavecrest, the field decreases to zero, then reverses and rises again to the next wavecrest. Like ripples in a cosmic pond, these spherical waves are expanding outward at the speed of light, 300 million meters per second.

At any one point, the radiation and induction fields vary as sine-wave functions of time. About 1/6 wavelength away from the electron (actually $1/[2\pi]$ wavelength), in a direction at right angles to the line of motion, the two fields are equal in amplitude. As we move farther away, the induction field falls off so much more rapidly than the radiation field that we soon have

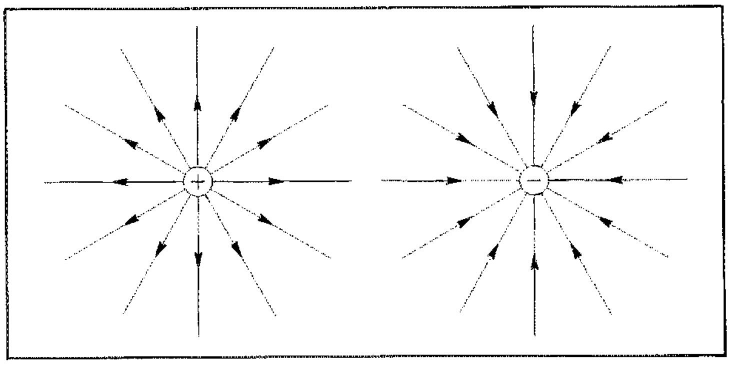


Fig 1—Always present around a charged particle, the coulomb field plays a vital role in energy radiation.

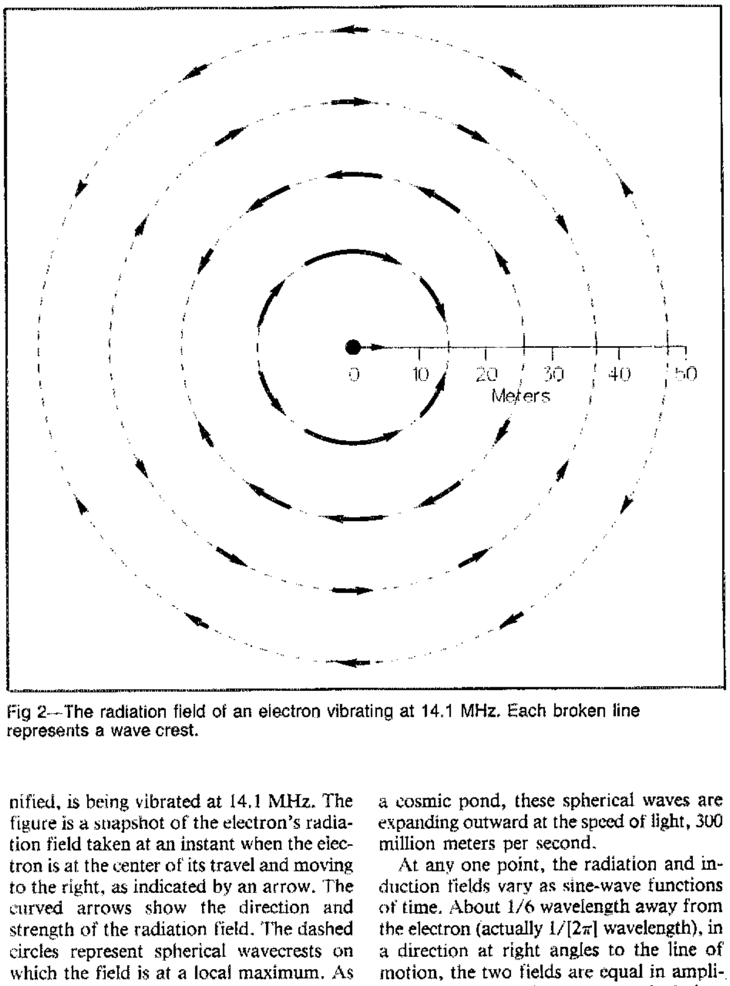


Fig 2—The radiation field of an electron vibrating at 14.1 MHz. Each broken line represents a wave crest.

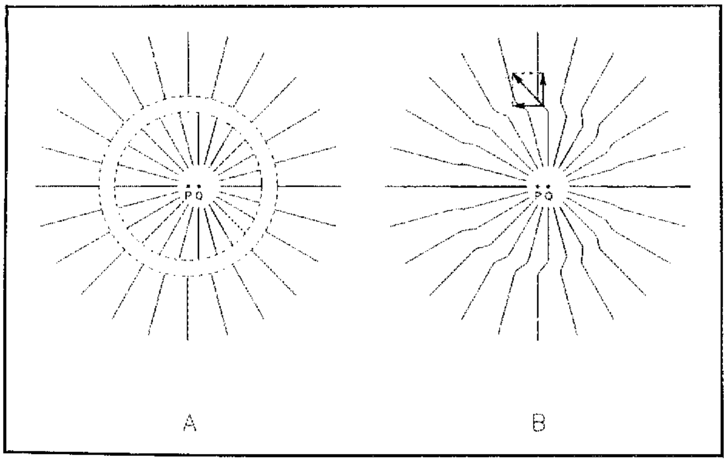


Fig 3—The electric field of an electron that was accelerated recently. The resulting disturbance in the field is traveling outward at the speed of light. The transverse component of the disturbed field is the radiation field.

essentially nothing but the radiation field.

Inside a vacuum-dielectric coaxial transmission line carrying power in one direction, the ratio of the electric to the magnetic field is equal to 377 ohms. In our pure radiation field, which carries power in the same manner even though there are no physical conductors present, this ratio is likewise equal to 377 ohms—a value that is sometimes called the characteristic impedance of space.

Why an Accelerating Electron Radiates

We've described the radiation field of a vibrating electron, but we haven't yet explained why it happens. The answer is hidden in Fig 3A.

Suppose that, until a short while ago, an electron was held at rest at point P in Fig 3A. It was then accelerated briefly to the right by our tweezers and afterward was kept moving to the right at constant speed. At the present time (which we'll call time zero), the electron is passing point Q.

Fig 3A contains two circles. The larger circle (the outermost broken line) is centered at P and has radius equal to the distance light would travel in the interval from the beginning of acceleration until time zero. The smaller circle is centered at the spot occupied by the electron at the end of acceleration; its radius is equal to the distance light would travel between the *end* of acceleration and time zero. As time marches on, the circles evidently grow at the speed of light. The space between the circles is equal to the distance light would travel during the period of acceleration. If the electron moves slowly in comparison with light, as it does in an antenna, the distance it covers during acceleration is small compared to the size of the circles, so the circles are nearly concentric. For clarity we have greatly exaggerated the distance PQ; it too would be very small if drawn to scale. Now we can determine what the electric field must look like at time zero.

Outside the larger circle, the field at time zero is a stationary coulomb field centered on P, as if the electron had never started to move.[5] Inside the smaller circle, the field is a moving coulomb field centered on the electron's present position, point Q. Between the circles the field is intermediate between the fields in the other two regions.

Now connect the field lines across the space between the circles and erase the circles, making Fig 3B. You can see that the electron, while accelerating, gave birth to an expanding electromagnetic disturbance. In the disturbed region, as shown by the arrows, there is a transverse field component—the radiation field—in addition to the outward-pointing coulomb field.

The radiation field resulting from a *vibrating* electron, Fig 2, is simply a continuous series of such disturbances caused by successive intervals of changing acceleration and deceleration.

The Bootstrap Forces

The radiation and induction fields of a vibrating electron exist right down to the electron's surface. Since the electron's surface carries an electric charge, and since an electric charge is pulled by an electric field, it's fair to ask whether these fields are able to exert forces on the very electron that is producing them. In other words, can an electron "feel" its own dynamic electric field? The answer is yes. The electron is pulled by its own bootstraps! The tweezers that are providing the motive power must overcome the bootstrap forces.[6]

The bootstrap forces are responsible for two very important properties of a conductor: radiation resistance and inductance.

Radiation Resistance Versus Ohmic Resistance

By our definition, an alternating radiation field is in phase with the accompanying magnetic field. At the surface of a vibrating electron the magnetic field is essentially in phase with the electron's speed, so here the radiation field, and the bootstrap force exerted by it, are likewise in phase with this speed. The direction of the force is such as to resist the electron's motion. It is evident that the force feels to our tweezers like a drag proportional to speed, as if the electron were moving through a viscous fluid. This drag force is the cause of radiation resistance.

An electron moving in a conductor also feels a drag force that is due to frequent progress-impeding collisions between the electron and the atoms in its path. This drag is the cause of ohmic resistance, the familiar R in Ohm's Law.

Both kinds of resistance dissipate energy at a rate equal to the resistance times the square of the current. Of course, energy dissipated this way doesn't actually disappear. An alternating current, flowing against *radiation* resistance, turns electrical energy into radiant energy, which wings its way off into space. Current flowing against *ohmic* resistance transforms electrical energy into heat, which is mechanical vibration of the atoms of the conductor—the atoms vibrate when they're hit by the moving free electrons.

Radiation resistance varies along the length of an antenna wire, but it is independent of the diameter and material of the conductor. The middle third of a half-wave, 14.1-MHz dipole has a radiation resistance of 3.7 ohms per foot. That's nearly 80 times the ohmic resistance of clean #12 copper wire at this frequency. Closer to the ends of the antenna, the radiation resistance is even higher.

Inductance

At the surface of a vibrating electron, the induction field, being 90 degrees out of phase with the magnetic field, is 90 degrees out of phase with the electron's speed (ie, the current). The bootstrap force of the induction field therefore opposes *the rate of change of current* rather than the current itself. Here we see the underlying cause of the property of inductance. In reacting to this bootstrap force our tweezers deliver energy *to* the electron during acceleration and receive back an equal amount of energy *from* the electron during deceleration. The delivered energy is stored in the magnetic field around the moving electron and is returned when the magnetic field collapses as the electron slows down.

Because the bootstrap force of the induction field is proportional to acceleration, it feels to the tweezers just like mechanical inertia. In consequence the electron has an *effective inertial mass* that greatly exceeds its gravitational mass.

Now let's step back and look at the fields in and around an entire antenna. You will recognize that the basic principles involved apply to any kind of antenna. Because of its simplicity, we will use an isolated, center-fed, half-wave dipole as an example.

The Big Picture

If our antenna doesn't contain any pith-balls, it doesn't contain any tweezers either. What is it, then, that causes the free electrons to vibrate? In real life it takes an electric field to move an electron. Inside an isolated straight dipole, the motive power comes from the combined coulomb fields of all the charged particles, positive and negative, in the antenna. We'll refer to this combined field as the *antenna's* coulomb field.

In addition to the coulomb field, the antenna as a whole exhibits a magnetic field that is the sum of the magnetic fields of all the moving free electrons. It also sports a dynamic electric field that is the vector sum of the dynamic electric fields of all the free electrons. As we did with an individual electron, we can separate the dynamic electric field of the antenna at any point in space into two components, one in phase with the total magnetic field and the other 90 degrees out of phase. We will call the in-phase component the radiation field of the antenna and the out-of-phase component the induction field. Right at the antenna, both fields are parallel to the metal surface.

It happens that the coulomb field and the induction field fall off much more rapidly than the radiation field with increasing distance from the antenna. At distances greater than a few wavelengths from the antenna, in what is called the antenna's *far field*, the electric field is essentially pure radiation.[7] Closer to the antenna, we have the *near field*, which is a mixture of the radiation, induction and coulomb fields.

Action of the Coulomb Field

We see in Fig 4 a snapshot of the coulomb field near the antenna. This picture shows an instant in time when the right-hand half of the antenna is positively charged and the left-hand half is negatively charged, as a result of a process that we'll examine in a moment. A half-cycle later, the polarity, and all the arrows, will be reversed. The spacing between the field lines indicates field strength. At the antenna wire or tubing, the field lines are nearly, but not exactly, perpendicular to the metal surface.

On alternating halves of the antenna, the perpendicular component of the coulomb field tries to pull electrons out of the surface. This effort is generally unsuccessful in amateur antennas because the "work function" for copper or aluminum—the energy it takes to dislodge an electron from the surface—is too great. If the transmitter power is very high, though, the field may be strong enough to pull electrons out into the air. The result is an exciting (but power-wasting) luminous display called *corona*. But because the coulomb field leans slightly away from the perpendicular at the antenna's surface, it can always pull free electrons *along* the surface.

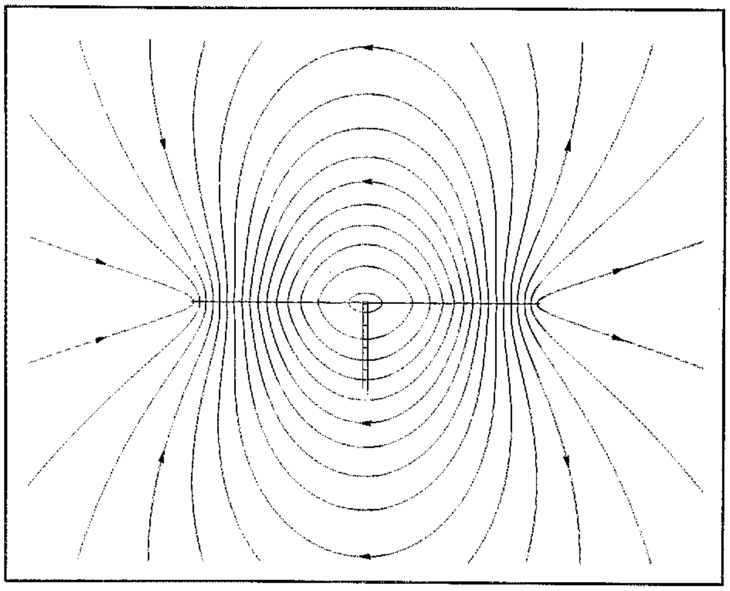


Fig 4—The coulomb field at an instant in time around a half-wave resonant dipole. A half-cycle later, the polarity, and all the arrows, will be reversed. The spacing between the field lines indicates field strength.

At one point in the RF cycle, free electrons throughout the antenna are moving to the right at or near their maximum speed. The right-hand half of the antenna thereupon begins to accumulate an excess of electrons, even if no single electron will shift to the right by more than a hundred-millionth of an inch. In the left-hand half of the antenna the departure of free electrons leaves an equal excess of oppositely charged metal ions, which are stationary atoms that have lost an electron. The coulomb field produced by this increasing imbalance of charges now opposes the electrons' rightward motion. By virtue of their effective mechanical inertia (also known as the bootstrap force of their induction field), the electrons coast for a while against the rising force of the coulomb field, which eventually brings them to a stop and then propels them back toward the left. After the electrons again reach maximum speed, now in the opposite direction, the foregoing scenario is repeated with left and right interchanged. The end result is the vibratory motion of free electrons that causes them to heat the metal and generate electromagnetic waves.

Newton's second law of motion tells us the relationship between the acceleration of an electron and the sum of the forces acting on it. In this case, one of the forces is the pull of the coulomb field parallel to the metal surface. The other two forces are the bootstrap force of the dynamic electric field and the drag of ohmic resistance. According to Sir Isaac, the sum of all three forces is equal to the gravitational mass of the electron times its acceleration. We will assume that an electron is so nearly weightless that its gravitational mass can be set to zero in this equation. Then the three forces must always add up to zero.

Turning this statement around another way, we can say that the dynamic electric field and the parallel component of the coulomb field partly cancel each other, the remaining field being just enough to overcome the drag of ohmic resistance. If the ohmic resistance is small enough to be ignored, the coulomb field is precisely equal and opposite to the dynamic electric field everywhere on the surface of an antenna.

This result leads to a procedure, which amounts to the construction and inversion of a matrix, for computing the current distribution on an antenna. Then, using the principles we've been discussing, we can compute the behavior of the system in detail.

Power Flow Through Space

Electrical engineers use the term *real power* for power that flows in one direction past a given point. They also speak of *reactive power*, which is power that flows

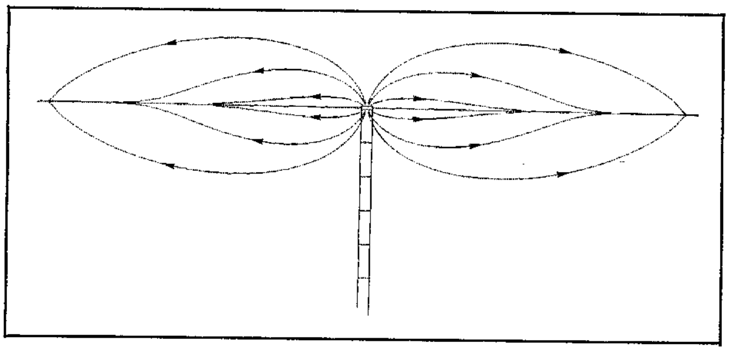


Fig 5—Flow of power from the feed point of a half-wave resonant dipole. The coulomb field around the antenna conductors carries power *through the space surrounding the conductors.*

back and forth in alternating directions with a net flow of zero in any one cycle. The radiation field of an antenna transmits only real power, which travels out toward distant localities without ever reversing direction. The induction field carries only reactive power, and the coulomb field carries both real and reactive power. Again we'll illustrate this with an isolated, center-fed, half-wave dipole.

Real Power Flow

How do you suppose your hard-earned RF power gets from the feed point to the rest of the antenna? You might think that it flows out through the wire or tubing of the dipole, but actually this real power is carried *through the surrounding space* by the coulomb field. Some lines of power flow are plotted in Fig 5.

As you see in the figure, when power coming up the feed line reaches the antenna it spews out into the air in all directions. It then arches to the right and left on curved paths that eventually intersect the antenna. At the points of intersection the coulomb field donates its real power to the free electrons, making up for the energy they are losing to ohmic resistance and radiation resistance.

Reactive Power Flow

During one interval in the RF cycle, the charge on the antenna reaches a maximum, and the current and the magnetic field go through zero. A quarter of a cycle later, the reverse is true. In the first interval, the antenna is surrounded by a cloud of electrostatic energy stored in the coulomb field. In the second interval, the coulomb field has disappeared, and we find the same energy stored in the magnetic field. The energy stored in the coulomb field is used in accelerating the effective inertial mass of the free electrons, which by their motion create the rising magnetic field. Energy thus moves from the coulomb field, via the induction field, to the magnetic field, only to move back again during the next quarter cycle as the magnetic field collapses. This is reactive power flow, with a net of zero.

You can think of the cloud of electrostatic energy as energy stored in the distributed capacitance between the two halves of the antenna. Similarly, the stored magnetic field energy can be thought of as energy residing in the distributed inductance of the antenna wire. If power is suddenly cut off by short-circuiting the feed point, the antenna doesn't stop radiating right away. Instead, it oscillates with diminishing vigor at its resonant frequency until the energy stored in the fields has been dissipated in ohmic resistance and radiation resistance. Our antenna can be accurately described as a resonant circuit made up of distributed capacitance, distributed inductance, and two kinds of distributed resistance.

Antennas and Non-Antennas

What do the following items have in common: a dipole antenna, a radar dish, the ground around a transmitting antenna, a coil and capacitor in parallel, and a wire carrying music to a loudspeaker? One answer: to a greater or lesser degree, they all radiate!

This is true because in operation they all carry time-varying currents and, consequently, accelerating electrons. The dipole antenna is an example of a distributed circuit that owes its existence to the fact that it radiates well. It is designed for efficient conversion of electrical energy into radio waves. But any system of conductors that carries varying currents behaves in accordance with the principles described earlier. The same processes, including radiation, take place whether we call the system an antenna or something else. For example, what we generally refer to as reflection from a conducting surface (the radar dish, the ground) is actually radiation from free electrons set in motion by incident electric fields.

In Sum

Perhaps the foregoing intuitive introduction to classical electromagnetic theory will inspire further development and refinement of the ideas presented. In any event, I hope you'll be able to contemplate an antenna, or a non-antenna, with a warm feeling for all the interesting things going on in and around it!

Notes

[1]1—False. 2—True. 3—False. 4—True.

[2]The classical electromagnetic theory we use in this article is valid at frequencies from dc through microwaves. At still higher frequencies one must venture into the realm of quantum electrodynamics.

[3]For some pertinent theoretical background see Feynman, Leighton and Sands, *The Feynman Lectures on Physics*, Vol II (Addison-Wesley Publishing Co, 1964).

[4]To get an outward-pointing field we must take the charge on the electron to be positive instead of negative as is actually the case. I find it easier to visualize the interaction of electric fields and electrons by thinking of the electron charge as positive. In the end it doesn't make the slightest difference. After all, Ben Franklin, on rubbing an ebony rod with cat's fur, could just as well have defined the charge induced on the cat to be positive. Life might be simpler today if he had.

[5]If you were observing from anywhere outside the larger circle at time zero, the electron would appear to be at point P instead of its actual position, point Q. That's because, according to Einstein's theory of relativity, the news that the electron has started to move can't propagate faster than the speed of light. If you were anywhere inside the smaller circle, the electron would appear at time zero to be in its actual position.

[6]The electron is pulled by its own coulomb field too, but equally in all directions, so the net effect is zero.

[7]In summing the radiation fields at a given point in the far-field region from all the free electrons, we must take into account the differing phases of the source electrons and the varying propagation times. The resulting phase variations cause partial reinforcement or cancellation of the fields, to a degree that depends on direction from the antenna. This effect is the basis of the very extensive subject of antenna radiation patterns, which we will not discuss further here.

Ken Macleish received his first Amateur Radio license 60 years ago at age 12. He now has an Extra Class ticket and still enjoys ham radio, especially CW ragchewing.

He holds a BS in physics (1939) from Caltech and a PhD in physics (1943) from the University of California at Berkeley. He was with Tennessee Eastman Company at Oak Ridge, Tennessee, during World War II, then transferred to Eastman Kodak in Rochester, New York, where his most recent position was assistant director of research and engineering in the Kodak Apparatus Division. In 1962 he joined the Perkin-Elmer Corporation in Norwalk, Connecticut, as a vice president of engineering. He retired in 1970 to enjoy the climate and scenery of Arizona.

Ken has authored QST *articles on frequency counters and frequency measurement. Also, over the years, he's had a nagging desire to understand why a radio antenna works. Combining this desire with a background in physics, a hobby of ham radio and an interest in computers, Ken has been working off and on for some time to help dispel some of the mystery surrounding this subject.*

THE UMBRENNA: THE ULTIMATE PORTABLE GROUNDPLANE ANTENNA FOR 2 METERS AND UP

◊ If you are tired of having a nearby signal cut in and out and sound weak while you are using an H-T, or if you like to walk in the rain, this project is for you. Here is a groundplane antenna (Fig 1) that can be collapsed and carried like an umbrella—because it *is* an umbrella, with a few modifications added.

First, select the proper umbrella for modification. One with the lowest number of moving parts is best. Get one with chrome plating on its stem, but not one made of aluminum. (Chrome is usually shiny; aluminum is usually dull.) Like aluminum, chrome will not take solder, but brass and steel will, and that's what underneath the chrome of a chrome-plated umbrella stem!

Umbrella-spoke hinges do not conduct RF very well, so you must connect each spoke—that is, radial!—to the stem with copper braid. To do this, carefully file the chrome plating off the stem as close as possible to its top end—*below* the umbrella fabric. If you solder the braid too far down, the umbrella will not fully open.

Try not to heat the braid too long or it will soak up solder and lose its flexibility. Tin the spokes and stem before soldering the braid on. Use pliers to heat-sink the braid when soldering each end. Remember to place a piece of heat-resistant material between the spoke and umbrella fabric while soldering; otherwise, your umbrella will no longer be an effective piece of rain gear. Cover your solder joints with noncorrosive silicone sealant (Fig 2).

Cut off the stem part that protrudes above the umbrella fabric. Remove the umbrella handle and drill a diagonal hole through the side of the handle to the bottom of the hole the stem plugs into (see Fig 3). Make the hole large enough to pass RG-174 coaxial cable.

Spray some silicone lubricant into the stem and pass the cable up the stem and out the top. Use only enough cable to give a comfortable handle-to-radio loop when you're holding the radio and the umbrella. (RG-174 is quite lossy at VHF, so keeping the cable short will minimize its impact.) I used one electrical wavelength (53 inches) of cable at 146 MHz so the antenna's impedance would be reproduced at the transceiver end.

File the stem top down to bare metal. Solder a female BNC connector to the cable, and then solder the connector to the top of the stem (Fig 4). Pull the cable slack out of the stem and glue the handle back onto the stem.

Now that you're done, you can enjoy the benefits of an antenna that doubles as rain gear. It sure was a pain getting the cable past the part of the antenna that locks the umbrella closed, wasn't it? But now you can plug your rubber ducky onto the top of your Umbrenna, plug in your H-T and go for a walk. You'll be pleased at the improvement in the operation of your H-T!

This groundplane also works very well on 70 cm and, with the help of adapters (Fig 5), will accept almost any type of antenna, including mobile whips. But watch out for low-hanging wires, and don't use it in a thunderstorm!—*Suzanne Gaeta, KB2RH, Brookville, New York*

Fig 1—Suzanne Gaeta's Umbrenna doubles as rain gear and a groundplane antenna with a plug-in vertical element. *(photo by Sherry Gaeta, KB2IRQ)*

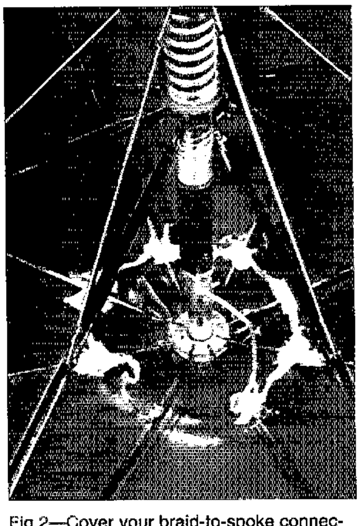


Fig 2—Cover your braid-to-spoke connections with silicone sealant after soldering them. (*This, and Figs 4 and 5 photos by Kirk Kleinschmidt, NT0Z)*

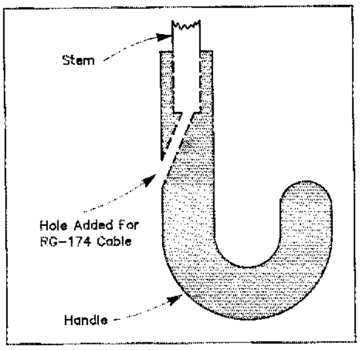


Fig 3—A hole drilled through the umbrella handle carries the Umbrenna's RG-174 cable.

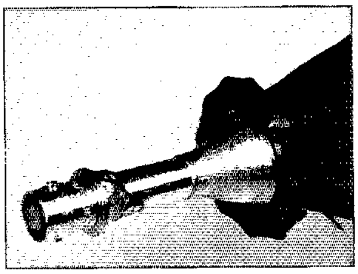


Fig 4–A BNC connector soldered to the umbrella stem takes your H-Ts "rubber duck" antenna.

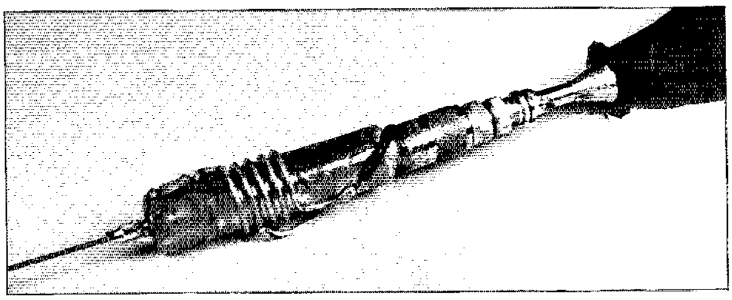


Fig 5—A BNC-to-UHF adapter allows experimentation with loaded whips.

BUILD A BUDGET 1:1 CHOKE BALUN

◊ Ferrite-bead choke baluns work well, but they can be quite expensive. The W2DU balun uses about fifty beads of #73 ferrite material (Amidon FB73-2401) on about 12 inches of coax cable to construct a balun for 1.8 to 30 MHz. At a retail price of $3.50 for each bead, many hams probably find the cost excessive. Even at a couple of dollars for each bead, total cost would be prohibitive. But as the *ARRL Handbook* indicates, baluns can work well when other ferrous materials are used.

For many years, I've used choke baluns made of cardboard (and, more recently, PVC) tube stuffed with steel wool as shown on page 39-7 of the 1992 *ARRL Handbook*. I placed them along coax feed line to attenuate RF energy outside the coaxial shield. Wanting to approximate the W2DU balun's performance on a budget, I began a search for a cheaper material that could do the job of #43 ferrite. I tried numerous materials before returning to fine steel wool (grade 000, or the finer 0000)!

This material proved to be most ideal in three important categories. First, its RF attenuation properties are excellent. Second, steel wool is mechanically pliable, and a distinct pleasure to use. Third, these fine steel wool pads may be purchased at very reasonable prices from almost any hardware store. Fig 6 shows the balun design.

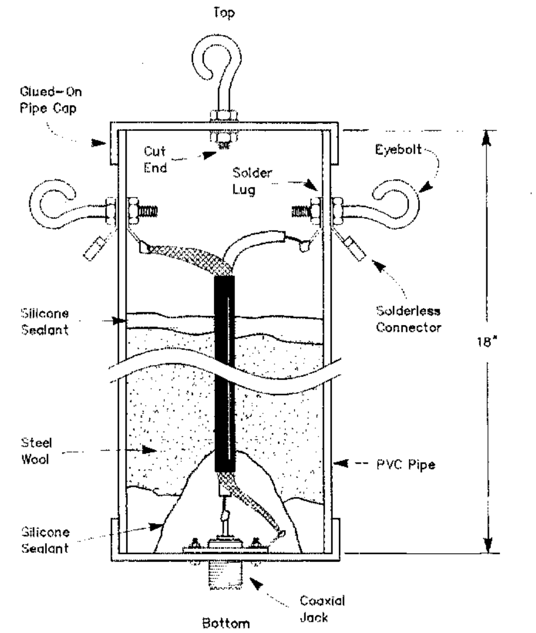


Fig 6—Curt Wilson's budget 1:1 choke balun adopts a tried-and-true balun design for outdoor use. Hints and Kinks adds two comments: (1) Since UHF-series coaxial connectors are not designed to be weatherproof, you can avoid having to seal your balun's jack and cable plug against the elements by using N connectors instead of SO-239s and PL-259s; and (2) especially in closed compartments, caulking compounds that liberate acetic acid vapor as they cure can severely corrode susceptible metals (such as steel wool), so avoid using such products when you build your balun.

White Schedule 40 PVC pipe, with an inside diameter of approximately 1.5 inches, forms the balun case. It is rather easily worked. I deliberately made the balun's main body quite long to isolate unprotected areas of the coaxial shield from high-current portions of the antenna. This reduces RF pickup from the antenna which could be conducted back into the shack. Also, the extra length provides space for more than an ample amount of steel-wool attenuation material.

Collect the following materials before beginning construction:

- 1 piece of 1.5-inch-ID Schedule 40 PVC pipe 24 inches long.
- 2 PVC caps to fit the ends of the Schedule 40 pipe. (Be sure the caps have flat ends. This will assure a weatherproof seal for the balun's SO-239 coaxial connector.)
- 1 29-inch length of RG-8, or similar 50-Ω coax cable.
- 1 SO-239 coaxial jack.
- 1 large tube of high-grade silicone-rubber caulk.
- 3 stainless-steel eyebolts, each 3/4 inch long with #10-24 threads.
- 2 #6 terminal lugs intended for outdoor use.
- 2 solder lugs (to mount internally over the ends of the eyebolts).
- PVC cement.

Appropriate nuts and washers to mount the eyebolts, SO-239 and associated hardware.

If you assemble your balun in this order, you should encounter little or no difficulty:

1) Drill the necessary holes in one pipe cap, and mount the SO-239 in the center of cap using lock washers and one solder lug on the inside, so that a securely soldered coaxial connection can be made.

2) Mark one end of the 24-inch PVC pipe *TOP* and the opposite end *BOTTOM*.

3) Using an 11/64-inch drill, careful drill two holes exactly opposite each other, 1.5 inches from the top end of the pipe. These will later receive two eyebolts, with solder lugs and external connectors.

4) Strip one end of the coax, and solder it to the SO-239 in the bottom pipe cap. Make sure the coax shield goes to the SO-239 shell, and the coax center conductor goes to the SO-239 center pin.

5) Be sure soldered connections within the pipe cap are correct and secure. Then apply silicone rubber over the SO-239 connections. Use caution to prevent sealant from getting on the inside lip fo the cap; it must be joined to the pipe later.

6) Let the silicone rubber cure for 12 to 18 hours. This is important to promote strength.

7) Apply PVC cement to the outer bottom end of the pipe and the inner surface of the bottom pipe cap. Immediately insert the coax cable through the bottom end of the pipe and mate the cemented surfaces of pipe and cap, pushing the cap on until it is properly seated. This must be done rapidly—all within three or four seconds—while the PVC cement is still soft and pliable.

8) If enough time has elapsed, the silicone rubber will be tough enough to withstand packing the steel wool into the top of the pipe. Take each smaller, individual steel-wool pad and stretch it to uniformly fit around the coax cable. (A length of smaller-diameter PVC pipe is ideal for tamping. This smaller pipe must be large enough to fit loosely over the coax, and small enough to slip in and out of the main pipe body.

9) Continue to fit and pack steel-wool pads into the pipe until it is filled to within 1/2 inch of two eyebolt holes at the top end of the pipe.

10) Apply a 1/2-inch layer of silicone rubber over the end of the steel wool, to within 1/2 inch of the eyebolt holes. Stand the assembly top end up and let the silicone-rubber caulk cure for at least 12 hours.

11) Attach the two eyebolts, each with a solder lug *inside* the pipe, solderless connectors outside, with nuts and washers.

12) Cut the protruding end of the coax cable to a length that will just allow a **U** bend in the braid and center conductor. Solder the shield to one eyebolt solder lug, and solder the center conductor to the other eyebolt solder lug.

13) Mount an eyebolt in the center of the top cap with appropriate nuts and washers inside and out. This eyebolt will be used to hang the balun in some applications. Cut off any excess eyebolt protruding inside which might interfere with the coaxial connections.

14) Make a final check with an ohmmeter to assure that there is no short between the center-conductor and shield connections of the coax, and that all other connections are

accurate and secure.

15) Apply PVC cement to the outer surface of the top end of the pipe, and to the inner lip of the top cap. Push the cap on quickly, making sure that it is properly seated. This completes construction of a simple, economical current balun.

To assure efficiency, I made this balun 24 inches long. Some subsequent models were made shorter, but showed a slight loss in efficiency and isolation. A side-by-side comparison with a variety of other baluns indicates that the 24-inch model performs very well indeed, so it has become my standard.

These simple, rugged baluns have been utilized on a variety of antenna systems with 50-Ω feed-point impedances, at power levels from 5 watts to 1 kilowatt. It appears to be a very cost-effective balun without any signs of weakness.—*Curt Wilson, WØKKQ, Pueblo, Colorado*

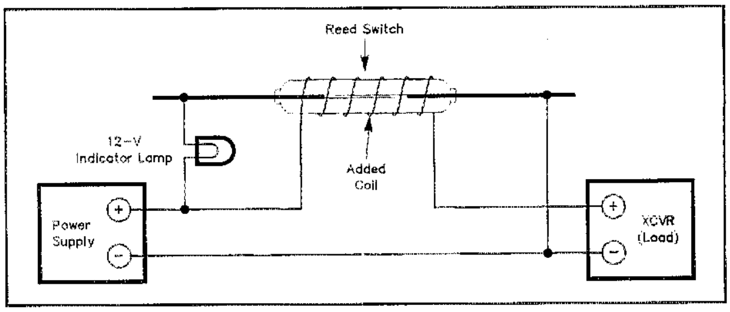


Fig 7—Emerson Hoyt used copper wire and a magnetic-reed switch to construct a high-current reed relay that controls a 12-V **TRANSMIT** indicator lamp. Consult the *ARRL Handbook*'s copper-wire table (Table 11 in Chapter 35 of the 1992 edition) for the wire size to use at your transceiver's current drain—the "conduit or bundles" current rating is the one to use in this application. Reed switches may be hard to find; if you can't locate them new through *QST* advertisers or the part-suppliers list in the *ARRL Handbook* (Table 42, Chapter 35), you may be able to use the switch from a reed relay. Radio Shack and other suppliers carry them.

A CURRENT-SENSING TRANSMIT INDICATOR

◊ When operating VHF packet and other digital modes, I like to know if and when my transceiver is keyed. From my operating position I am unable to see its liquid-crystal **ON AIR** display. To solve this problem, I use the circuit shown in Fig 7. It senses the transceiver's increased dc current drain in transmit and turns on a pilot light located near my keyboard.

Current sensing is easily accomplished with the use of glass-encapsulated reed switch and a few turns of wire wound around the capsule. This forms a reed relay. The reed switch turns on the light when the current through the coil produces a magnetic field strong enough to close the switch. You can determine the number of turns necessary to operate the switch as follows:

1. Measure your transceiver's current drain in receive and transmit (use the manufacturer's specifications if measurement isn't possible).

2. Determine the number of ampere-turns (AT) at which the reed switch operates and releases, using a variable current source, ammeter and ohmmeter. Wind 10 to 20 turns of wire around the capsule and vary the test current to determine the switch's operate and release currents. Calculate the switch's operate AT (AT_{OP}) and release AT (AT_{REL}) values by multiplying the current (A) flowing under these conditions by the number of turns around the capsule.

3. Assuming that AT_{OP} will be set at 50% of the transceiver's transmit current, I_{TR} (a conservative choice for reliable switch operation), calculate the number of turns (N) necessary for your application: $N = AT_{OP} \div (0.5 \times I_{TR})$. For my particular reed switch, N was 6 for an AT_{OP} of 33 at an I_{TR} of 10 A. (This works out to 6.6 turns, which I arbitrarily rounded down to 6. The switch works just fine with 6 turns.)

4. If steps 1-3 are not feasible, you can determine the number of turns by "cut and try," putting the coil wire in series with the power feed wire and determining the operate point with an ohmmeter or buzzer. Use about twice the required number of turns and, of course, a wire size appropriate for the current involved. (I used #18 enameled wire.) The resistance the coil adds to the transceiver power feed is negligible. Be sure the transceiver's receive current drain is less than the current at which the reed relay drops out.

5. Be sure the pilot lamp is wired to the supply side of the switch coil, or the lamp current might latch the switch on.—*Emerson M. Hoyt, WX7E, Beaverton, Oregon*

STOPPING UNWANTED AFSK OUTPUT IN THE PK-232

◊ My station includes MF/HF and VHF transceivers, both of which are connected to an Advanced Electronic Applications PK-232 multimode communications processor. I experienced audio problems while operating HF SSB with the PK-232 operating VHF packet via the other radio. Somehow, transmit audio intended for the VHF radio was getting into the MF/HF radio. Examining the PK-232 schematic, I discovered that the PK-232's design allows it to feed AFSK to both radios regardless of the position of its **RADIO 1/RADIO 2** button. Although some radios include means of disabling their mike inputs in the AFSK mode, mine does not. So I looked for a way to break the unwanted audio feed.

I solved this problem as follows. I unsoldered the ungrounded ends of resistors R151 and R152 from the PK-232 circuitry. Using a short piece of hookup wire, I connected the free end of R151 to terminal 11 of the PK-232's SW2. Fig 8 shows the PK-232's circuitry after this modification. I can now operate SSB voice with Radio 2 while the PK-232 sends and receives data via Radio 1 (or vice versa).

This modification would not have been necessary if I could key the affected radio with the PK-232's direct FSK output instead of using AFSK, but my MF/HF radio can't operate direct FSK.—*Robert Syler, KI6AT, Sun City, California*

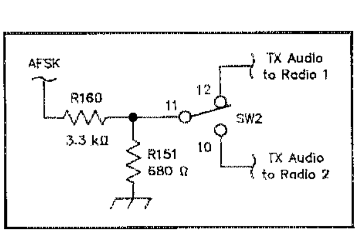


Fig 8–The transmit-audio switching circuitry associated with SW2 in Robert Syler's PK-232 now looks like this. He also disconnected the ungrounded end of R152 as described in the text.

THE MEASURE OF A MAN

◊ Medieval sovereigns used their arms, legs, etc, to establish standards of measurement. You can do the same. Here's how it works: Say you're 6 feet tall. Take a piece of wire and put the end under your foot. Hold the wire up to the top of your head. Repeat this for longer lengths and think in multiples of six! For shorter lengths, such as 3 feet, put wire on the ground and raise the end to your waist. For 1-1/2 inches, use the end of your thumb to the middle joint. For 10 inches, use the length of your foot. All measurements depend on your sizes and are approximate, of course, but if you know your sizes, you'll come pretty close. It works for me! —*Richard Brash, KF2CE, Hudson, New York*

WJ1Z: If you stand with arms and hands outstretched, the distance between your fingertips very closely approximates your height. You can therefore make measurements based on your height by using this span. If you need to measure half your height, you can measure from the fingertips of one hand to your nose.

Technical Correspondence

Conducted By Paul Pagel, N1FB
Associate Technical Editor

DIPOLES ABOVE REAL EARTH

☐ Most textbooks and articles treating elementary antenna theory present the familiar curve of Fig 1—radiation resistance, R_r, at the feed point versus height of an infinitely thin, 180°-long dipole above perfectly conducting earth.[1] The trouble is that most so-called "half wave" dipole antennas:

- Are not infinitely thin.
- Are not installed above a perfectly conducting earth.
- Are most often shorter than 180° because, since the advent of coax, they are trimmed to resonance to present a pure resistive load at some selected frequency.

So why do we use that graph? I am reminded of the gambler who knew the game was crooked—but played because *it was the only game in town!*

I've developed a method of calculating the feed-point impedance of finite-thickness horizontal dipoles that produces values reflecting the effect of *imperfect* earth below them. *MININEC* cannot do this because it calculates impedances using *perfect* earth. (For those interested in the rather extended mathematics, the method is explained in the Appendix.) So let's look at some of the practical aspects of this matter.

Fig 2 shows R_r versus height for a resonant 7.15-MHz dipole of #14 wire above earth of poor quality (dielectric constant of 13 and conductivity of 0.002 S/m). Note the following characteristics. The extremes of R_r are not as great as those of the antenna of Fig 1 (included in Fig 2 for reference). The resistance value approached at great heights is in the high 60s rather than the 72.3 Ω generally accepted for the theoretical antenna of Fig 1. R_r does not go to zero at zero height. The peaks and troughs are only slightly displaced horizontally relative to the 180° theoretical antenna. These characteristics result because the antenna has a finite thickness and the radiated wave reflected from the earth lying more or less directly below the antenna (as opposed to the large area of earth responsible for pattern formation) absorbs part of the reflected wave determining R_r and introduces a small phase shift. This phase shift (while small) is, at the high wave angle involved and in the frequency range considered, just about right to cancel the phase delay caused by penetration of the earth and return to the surface as evidenced in the rather small horizontal shift in the peaks and troughs. Thus, above earth of the usual parameter ranges, the earth's electrical surface appears to be approximately where you see it—contrary to some popular concepts.

Fig 2 also includes a small segment showing the R_r value obtained using a current version of *MININEC*, which—although making allowance for wire diameter—still calculates impedances using perfect earth.

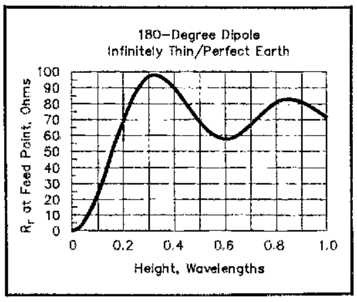


Fig 1—The customary R_r versus height curve for an infinitely thin 180°-long dipole above perfectly conducting earth.

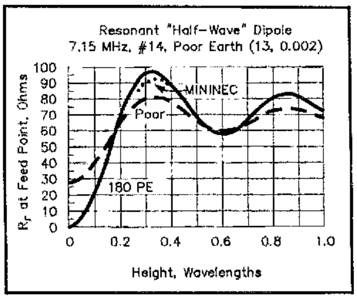


Fig 2—R_r versus height for a resonant "half-wave" dipole at 7.15 MHz above real earth of poor characteristics (e_r = 13, σ = 0.002 S/m) compared with the antenna of Fig 1. Note the R_r values produced by *MININEC* in the vicinity of the first peak resulting from the perfect earth it assumes.

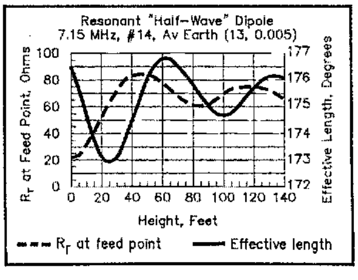


Fig 3—R_r and angular length of a resonant "half wave" dipole vary with height.

Most antenna books advise cutting a resonant "half-wave" antenna by the formula: L(ft) = 468 ÷ f(MHz). The 468 is approximately 0.95 × 983.57 ÷ 2, where 983.57 is the velocity of light in feet per microsecond and is divided by 2 for a half wavelength. The 0.95 approximates the shortening to eliminate the inductive component of a full 180°-long antenna, compensate for the finite diameter and the normal end loop, wire wrapback, insulator and supporting wire or line effects. It is just that: an approximation. The actual length required for a purely resistive feed-point impedance is usually obtained by some antenna trimming; it varies with antenna height and, to a very small extent, the earth characteristics. Fig 3 shows how the length of the resonant half-wave antenna varies with height above earth of *average* quality. The length is given in effective degrees, rather than feet, since the end loop, wrapback, insulator and support line effects are not included. Obviously, changing the height of an antenna changes the length required for resonance: It may be either shorter or longer, depending on the original height.

Figs 4, 5 and 6 provide curves to determine the feed-point impedance of resonant half-wave antennas as a function of height above earth in the *poor to very good* range at 20, 40 and 80-meter midband frequencies. Horizontal half waves above the usually cited 0.2-wavelength limit of such curves are rare on 160, where 0.2 wavelengths is 109 feet at 1.8 MHz, and Yagi or quad antennas are more common on the higher frequencies. The two curves show the limits for poor earth (e_r = 13, σ = 0.002 S/m) and very good earth (e_r = 20, σ = .0303 S/m) parameters. Of course adding an estimated "ground loss resistance," which increases as height decreases, to the values below 0.2 wavelengths can yield an approximation of input resistance to be expected at those heights. *The ARRL Antenna Book*, 15th Edition, p 3-3, Table 1, provides more information on earth parameters. Poorer earth qualities than the ones used are more related to urban industrial structures, etc, than any real earth characteristics and are not readily considered.

Although the accuracy of the R_r values shown below about 0.2 wavelength decreases, note that unlike the theoretical curve, R_r *does not* go to zero at zero height and that the difference in R_r increases with frequency. Thus, many hams have found that even with the antenna lying on the ground it still works and the SWR does not go to infinity. This may account for some of the physics-defying attributes ascribed to some faddish esoteric antenna types.

[1] J. Hall, ed., *The ARRL Antenna Book*, 15th ed, p 3-11, Fig 18, and E. Jordan and K. Balmain, *Electromagnetic Waves and Radiating Systems*, (Englewood Cliffs: Prentice Hall, 1968), 2nd Ed, p 397.

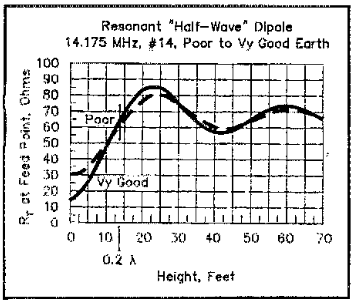


Fig 4—R_r versus height of a 14.175 MHz resonant "half wave" dipole above earth from poor (e_r = 13, σ = 0.002) to very good (e_r = 20, σ = 0.0303).

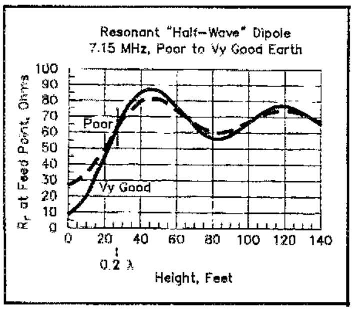


Fig 5—As in Fig 4, but for 7.15 MHz.

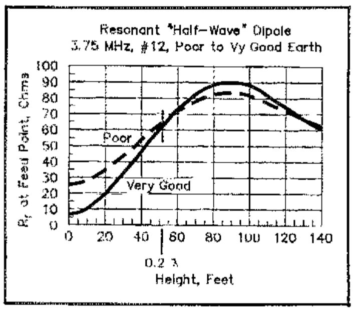


Fig 6—As in Fig 4, but for 3.75 MHz and using more appropriate #12 wire.

These curves should provide more realistic and accurate values for real antennas than the customarily cited curve of Fig 1.

Although the discussion is oriented to the popular resonant "half-wave" dipole, I have obtained excellent results with lengths such as short or random length dipoles, two half-waves in phase and extended double Zepps.—*Charles Michaels, W7XC, 13431 N 24th Ave, Phoenix, AZ 85029*

APPENDIX

Explanation of the calculation method: Schelkunoff's method of calculation yields quite accurate feed-point impedance (R and jX) of cylindrical dipoles.[1]

$$RI = (K\,G\,(K + (N \sin(2L)) - (M \cos(2L)))) \div Den \qquad \text{(Eq 1)}$$

$$XI = K\,(((G^2 + F^2 + M^2 - N^2 - K^2) \sin(2L) \div 2) + ((M\,N) - (K\,F)) \cos(2L) + ((M\,F) - (K\,N))) \div Den \qquad \text{(Eq 2)}$$

where:

- RI = Resistive component of dipole input impedance, ohms
- XI = Reactive component of dipole input impedance, ohms
- Den = $(G^2 (\cos^2(L)) + ((K + M) \sin(L) + F + N) \cos(L))^2)$
- G = $60(C + \ln(2L) - Ci(2L)) + 30(C + \ln(L) - 2\,Ci(2L) + Ci(4L)) \cos(2L) + 30(Si(4L) - 2\,Si(2L)) \sin(2L)$
- F = $60\,Si(2L) + 30\,(Ci(4L) - \ln(L) - C) \sin(2L) - 30\,Si(4L) \cos(2L)$
- M = $60\,(\ln(2L) - Ci(2L) + C - 1 + \cos(2L))$
- N = $60\,(Si(2L) - \sin(2L))$
- C = 0.5772157 (Euler's constant)
- Si = sine integral
- Ci = cosine integral
- ln = logarithm base e (natural log)
- L = angular half length of dipole, radians
- K = $120\,(\ln((48\,Lf \div d) - 1)$
- Lf = dipole half length, feet
- d = wire diameter, inches

The radiation resistance at the current loop(s) of an antenna is relatively independent of the wire diameter as is the mutual impedance at the current loop(s) between two antennas, such as an antenna and its mathematical "image." Carter provided an equation for the radiation resistance at the current loop(s) of a dipole that is quite accurate.[2] It's sometimes "transferred" to the feed point by a factor 1 − sin2L, but accuracy is then reduced. For example, when applied to a 360° dipole (two half waves in phase), it yields infinity. In this case, indicated resistance *is* very high, but not infinite.

$$RL = 60\,(((-\cos(2L)) \div 2)\,(\ln(4L) + C - Ci(4L) + (1 + \cos(2L))\,(\ln(2L) + C - Ci(2L)) + \sin(2L)\,((Si(4L) \div 2) - Si(2L))) \qquad \text{(Eq 3)}$$

where:

- RL = radiation resistance at the current loop, ohms.

Other definitions as in Equations 1 and 2.

The mutual impedance between two similar dipoles having similar current distributions (as in the case of half of a horizontal antenna and its mathematical "image") is given by Carter[3] as:

$$RM = 60\,(\sin(L) \cos(L)\,(Si(U2) - 2\,Si(V2) - 2\,Si(V1) + 2\,Si(V1) + 2\,Si(U1)) - ((\cos(2L)) \div 2)\,(2\,Ci(U1) - 2\,Ci(U0) + Ci(V1) - Ci(U2) - Ci(V2)) - (Ci(U1) - 2\,Ci(U0) + Ci(V1))) \qquad \text{(Eq 4)}$$

$$XM = 60\,((\sin(L)\cos(L))\,(2Ci(V1) - 2Ci(U1) + Ci(V2) - Ci(U2) - ((\cos(2L)) \div 2)\,(2\,Si(U1) - 2\,Si(U0) + Si(V1) - Si(U2) - Si(V2) - Si(U1) - 2Si(U0) + Si(V1))) \qquad \text{(Eq 5)}$$

where:

- RM = resistive component of mutual impedance, ohms.
- XM = reactive component of mutual impedance, ohms.
- U0 = spacing between antennas, radians.

(Note that the spacing between an antenna and its image is very close to twice the antenna's height above the earth's surface (see text).

- U1 = $(S^2 + L^2)^{1/2} - L$, radians.
- V1 = $(S^2 + L^2)^{1/2} + L$, radians.
- U2 = $(S^2 + (2L)^2)^{1/2} + 2L$, radians.
- V2 = $(S^2 + (2L)^2)^{1/2} - 2L$, radians.
- S = 4 pi H, radians.
- pi = 3.1415926.
- H = antenna height, wavelengths.

(Note: H in wavelengths = H(feet) × f ÷ 983.5710564.)

Because the earth involved is only that in the area immediately under the antenna, the reflected waves are principally vertically polarized and confined to relatively high angles where the horizontal and vertical polarization coefficients are very nearly equal. Reflection coefficients vary very little for a rather wide range of wave angle around 90°.[4] For this application, the wave angle is essentially 90°, so the conventional vertical polarization reflection coefficient[5] is reduced to:

$$VRC = (e_r - jX - (e_r - jX)^{1/2}) \div (e_r - jX) + (e_r - jX)^{1/2}) \qquad \text{(Eq 6)}$$

where:

- VRC = vertical polarization reflection coefficient.
- e_r = earth dielectric constant relative to air/vacuum.
- X = $18000 \times \sigma \div f$.
- σ = earth conductivity, S/m.
- f = frequency, MHz.

$$TF = RI \div RL. \qquad \text{(Eq 7)}$$

where:

RI and RL are as in Equations 1 and 3.

Rationale

Since the free space RL of the Eq 3 antenna manifests itself as the free space RI of Eq 1, so also must any mutual impedance appearing at the loop(s) be transferred to the feed point by the ratio of RI to RL. Recognition of this concept led me to development of this method.

Procedure

Calculate RI and XI using Equations 1 and 2.

Calculate RL using Eq 3.

Calculate RM and XM using Equations 4 and 5.

Calculate VRC using Equation 6.

Calculate TF using Equation 7.

Noting that the vertical reflection coefficient for horizontal antennas is reversed in sign,[6] multiply RM by − VRC, multiply by TF and add to RI. This result is the resistive component of the dipole feed-point impedance.

Multiply XM by − VRC, then multiply by TF and add to XI. This result is the reactive component of the dipole feed-point impedance.

To obtain the resistive feed-point impedance of a resonant dipole, repeat the process with variations of dipole half-length until the reactive component is so small that further refinement of the half-length results in negligible variation of the resistive component.

The curve of Fig 1 was produced with Eq 1 by setting the half length to 90°, e_r = 1, σ = 10^{15} and diameter = 10^{-35} inches. The resulting R_r is within about 0.4% of R_r by Eq 3.

Footnotes for Appendix

[1] S. Schelkunoff, *Electromagnetic Waves* (New York: D. Van Nostrand, 1948), Chapter 11, pp 461 and 453, and S. Schelkunoff, "Theory of Antennas of Arbitrary Size and Shape," *Proceedings of the IRE*, Sep 1941, p 493.

[2] E. Jordan and K. Balmain, *Electromagnetic Waves and Radiating Systems* (Englewood Cliffs: Prentice Hall, 1968), pp 540-544.

[3] See referent of Note 2, p 540.

[4] See referent of Note 2, p 632 eq (16-8) and Figs 14-3 and 14-4.

[5] See referent of Note 2, pp 397-398.

[6] See Note 5.

M² Enterprises 2M-CP22 and 436-CP30 Satellite Yagi Antennas

Reviewed by Dick Jansson, WD4FAB, ARRL Technical Advisor

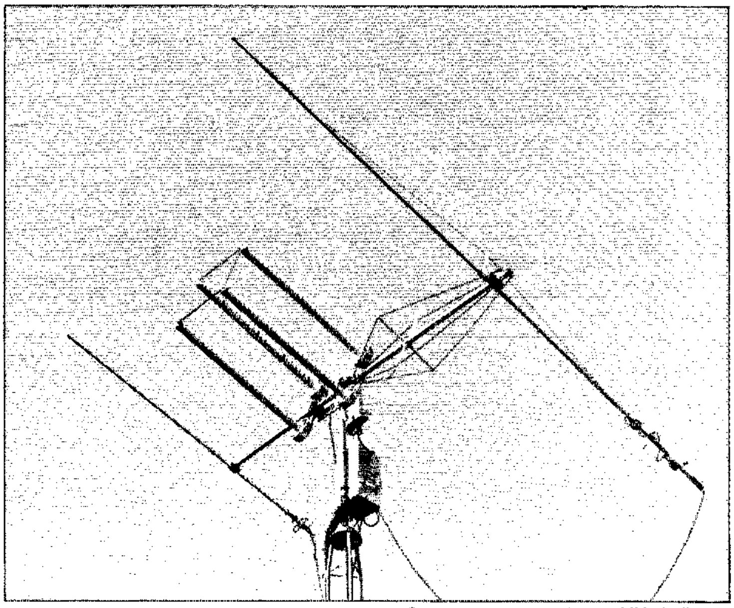


Fig 1—Satellite antennas at WD4FAB, from left: M² 436-CP30; array of 1269-MHz helixes (described in Chapter 23 of *The ARRL Handbook*); and the M² 2M-CP22. The M² antennas are mounted on insulated extensions of the horizontal cross boom. The 2-meter antenna's PVC cross-boom extension is braced with nonconductive guy wire and PVC struts. *(photos by the author)*

Amateur satellite communication continues to attract many hams. Satellites offer many modes—voice, CW, digital, video—to suit many different interests, from local and international rag-chewing on low-earth-orbit (LEO) satellites to DXing on the high-orbiting OSCARs 10 and 13. The selection is so varied that an adherent to one mode may never take the opportunity to sample the others!

Antennas for satellite work are major subjects of discussion. This month we review two of the newest commercial VHF and UHF circularly polarized (CP) Yagis for amateur satellite communications. These antennas were designed by Mike Staal, K6MYC, longtime KLM engineer. I'd heard good things about the M² VHF and UHF antennas, so I was anxious to check them out.

Design

The computer-optimized M² CP antennas, Fig 1, use refreshingly innovative principles and materials that should serve users well for many years. These antennas use proven assembly methods, such as insulated, through-the-boom, element mounting with stainless-steel element-retaining clips ("keepers"). All the other antenna hardware is also stainless steel, except for the U bolts that mount the boom and mast to the boom-to-mast plate. (The nuts and washers used with these U bolts are stainless steel, however.)

Like most CP Yagi antennas, the M²s use one set of elements oriented horizontally and another set oriented vertically. The vertical set is located ¼ wavelength forward of the horizontal set. When fed in phase, the two sets of elements generate a CP wave. Right-hand circular polarization (RHCP) or left-hand circular polarization (LHCP) depends on the feed sense. Mounting the antennas with the elements in an X configuration, with neither set horizontal or vertical, makes it quite difficult for birds to light on the elements and has no effect on antenna performance.

Probably the most notable design innovations in these antennas are the driven elements. The basic design is a 200-Ω folded dipole, with the main portion mounted through the boom, like the other elements. The driven half of this element consists of a pair of aluminum-rod half-elements protruding through Teflon insulators installed on opposite sides of an aluminum block. This block is contoured to the boom and mounted to it with a screw. The dipole halves are joined to the longer rod with two machined aluminum plates and set screws.

The magic of this design is in the driven-element center block. In addition to the protruding half elements, this block also supports three female F connectors. These are the same 75-Ω connectors used in television sets, but with a difference: M² uses sealed F connectors on the cables with a jam nut containing an O-ring gasket to fully close the open threaded end of the connector when it is attached to the female connectors on the block. Two of the connectors are joined with a half-wavelength 4:1 balun made of RG-6 coaxial cable. The third connector is for the input feed line. Moisture won't affect this block, as it's encapsulated with a sticky compound. Don't even consider fooling with the innards of this block, as you will have an awful mess on your hands.

> **The Bottom Line**
>
> For high-orbiting satellites like AO-13, these high-gain, well-built, wide-bandwidth antennas work wonderfully. But for low-earth-orbiting satellites (LEOs), such as the PACSATs, the lack of polarization-switching capability limits their usefulness.

Matching sections made of RG-6 cable join the two planes of elements. These cables are routed from the driven-element blocks to a T-shaped aluminum block. This block also contains a female N connector to which you attach the feed line to the station.

The use of 75-Ω cables and F connectors in the M² antennas is less of a compromise than you might think. The matching lines should ideally have an impedance of 70.7 Ω; 75 Ω line and connectors represent an insignificant difference. The balun connections don't have to be 50 Ω, either: The balun cables are ½ wavelength long, so the impedance is the same at each end.

The M² antennas are designed for RHCP. Polarization sense isn't switchable, unlike most commercial CP antennas.

Operations with OSCAR-10 were considerably more effective with the occasional use of LHCP when the satellite was off-pointed. With OSCAR-13, LHCP operation is needed only on rare occasions—at 436 MHz, when the satellite is off-pointed by 60° or more. I've never found switching from RHCP to LHCP with the 2-meter antenna to be of any help with AO-13. So, for OSCAR 13, the fixed polarization sense of these antennas poses no problem. For stations in North America, operation on the LEO PACSATs, such as AO-16, on the other hand, *requires* CP switchability. The polarization sense of an approaching satellite can differ from that when it's moving away from the observer.

So why did M^2 choose not to include CP sense switching? On one hand, the improved performance by the absence of losses of a CP-switching relay helps AO-13 operators. On the other, those interested in the PACSATs have limited operating flexibility with these antennas. Several polarization-switching schemes can be applied to these antennas, but they require some fussing and careful measurement with reasonable test equipment. Caveat emptor.

Assembly

These antennas arrived well protected in their UPS-shippable boxes. Small parts are bagged, and the elements for each antenna come in a single bundle. You must separate the elements into two bundles, one for each plane.

Assembly instructions are complete, albeit terse. Two complete assembly diagrams are included—one marked in inches and one in centimeters.

The 2-meter antenna's boom is made of two 1-inch sections, two 1¼-inch sections and one 1½-inch center section. The boom-section swaging results in an excellent fit. For the 436-MHz antenna, two 1-inch boom sections are used, also with a good-fitting swaged coupling.

The documentation recommends assembling the elements one plane at a time. I suggest following this instruction. Install one element at a time, after carefully measuring each element, by sliding insulators on from each end as you place the element into the correct boom hole. Select the correct element and *carefully* measure each element for proper centering. Some of the element lengths differ by 1/16 inch or less, so use great care in measuring. Further, the director lengths are not of a uniform taper (a progressive shortening from the driven element forward). It's very easy to make a mistake here if you're not careful.

Pressing on the keepers while keeping the elements centered is a challenge. The kit includes a piece of aluminum tubing intended for this job. Pressing on keepers with the bare tube is hard on the hands; use heavy gloves or add a handle to the tube to make the job easier.

When all of the passive elements have been assembled on the boom, it's time to complete the driven elements. Mount the driven element shorting blocks on the ends of each pair of rods, carefully measuring the block position. The instructions for installing the shorting blocks are slightly ambiguous. They call for placing the blocks "...at the ends of the driven-element rods" (2-meter antenna) and 1/8 inch from the ends of the rods (436-MHz antenna). As the main rod and the half-element rods are not exactly the same length, it's uncertain which rod the instructions refer to! In practice, which you choose makes very little difference in the antenna match. These shorting blocks give you some tuning latitude, if the proper measurement equipment is available. In any case, measuring the shorting-block position from the aluminum center block and placing them exactly equidistant from it is important to antenna performance.

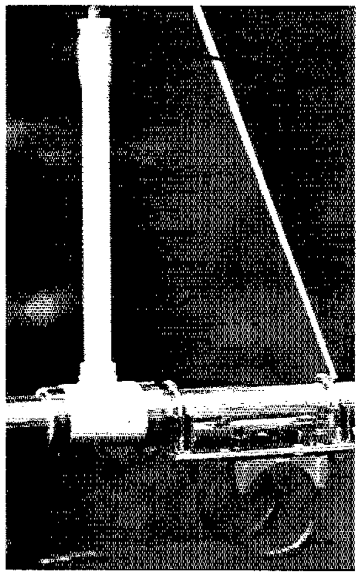


Fig 2—One method of bracing the 2M-CP22's boom when the antenna is mounted on a horizontal mast requires only some PVC pipe and two stainless-steel hose clamps.

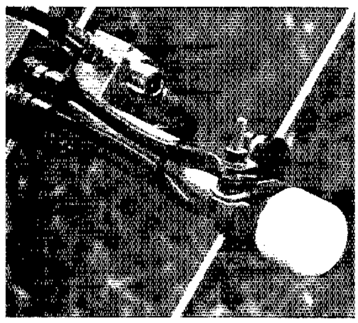


Fig 3—Cushioned cable clamps provide a strain-relieved boom-end attachment for coaxial feed lines. On this antenna, the feed line will run through the cushioned clamp to the N connector on the feed-point block (upper left). Also shown is a PVC boom-end cap.

Balun attachment comes next, then mounting the T block with the phasing lines to each antenna. Line positioning and dress are important, as the lines are in the fields of the antenna elements. Mispositioning can cause detuning.

I made a couple of small changes to the M^2 antennas. Antenna booms are some of the insect world's most favorite places to build homes, so I closed the boom ends with ¾-inch PVC pipe caps. The open end of the cap may need to be notched with a drill and file to fit around element insulators. I glued the PVC caps onto the boom ends using silicone adhesive.

Another area that needed attention in my installation was the 2-meter antenna's boom brace. (The 436-MHz antenna is short enough that it doesn't need a brace.) M^2 provides a black Dacron cord for this purpose. M^2 doesn't provide a support post for the stay, apparently on the presumption that you'll mount the antenna on a vertical mast and attach the brace to it. In installations like mine, where a horizontal cross boom supports both antennas, there's no attachment point for the stay.

Fig 2 shows how I adapted a 1½- × ½-inch PVC reducing T for this purpose by sawing out the side opposite the ½-inch branch. With a sharp knife, I carved out the ridges inside the T to make it fit well over the 1½-inch boom section. I secured the T with a pair of stainless-steel hose clamps, then glued in an 18-inch extension of ½-inch PVC pipe. Use a ½-inch PVC cap, or fill the end of this short pipe and drill a hole to pass the rope. Anchor the rope to the U bolts provided, and include at least one of the supplied turnbuckles. Be sure to safety-wire the turnbuckle. This arrangement braces the antenna's boom independently of the mounting arrangement.

Route the coaxial feed line from the reflector end of the boom, as shown in Fig 1. This keeps the cable from affecting the antenna's radiation pattern. Fig 3 shows how I attached the feed lines to the booms using a pair of cushioned cable clamps (such as the ADEL MS21919). The two clamps, 7/8 and 3/8 inch, respectively, are held at the boom end with #8-32 stainless-steel hardware.

Installation

Mounting CP Yagi antennas requires somewhat greater consideration than conventional horizontally polarized antennas. Stray metallic objects near the plane of the

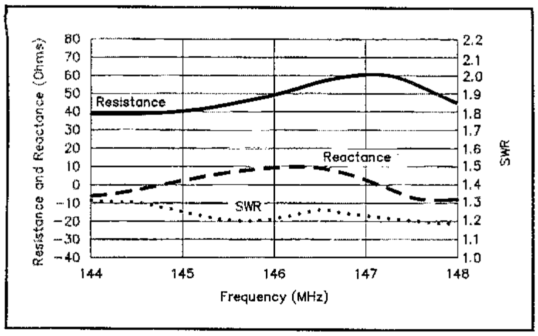


Fig 4—Resistance, reactance and SWR curves for the M[2] 2M-CP22 satellite antenna. The solid line is resistance, the dashed line is reactance, and the dotted line is SWR. The 2M-CP22 antenna has a good match across the band.

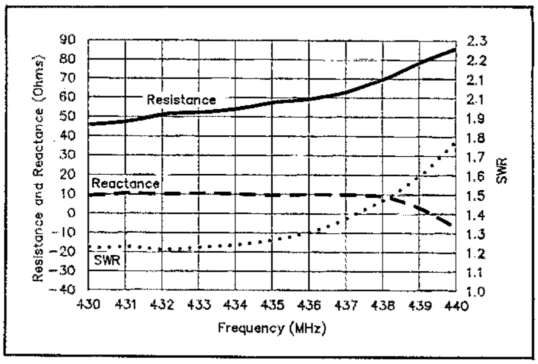


Fig 5—Resistance, reactance and SWR curves for the M[2] 436-CP30 satellite antenna. The solid line is resistance, the dashed line is reactance, and the dotted line is SWR. This antenna presents a good load from less than 430 MHz to more than 440 MHz, well beyond the satellite band.

elements affect antenna performance. As shown in Fig 1, I placed each antenna at least ¾ wavelength from the metallic portions of the elevation axis. This distance is more than adequate. The elevation-axis boom is a 1½-inch steel pipe. This pipe is extended with a piece of 2-inch PVC pipe for the VHF antenna mount. As PVC isn't very stiff, I made a nonmetallic truss from four Phillystran ropes.[1] It may *look* awful, but it works and is quite stiff.

I used a piece of 1½-inch fiberglass tubing to mount the 436-MHz antenna ¾ wavelength from the steel-pipe cross boom. This tube extends the pipe and is attached to it with a machined adapter. I filled the ends of the nonmetallic booms with wooden dowels to avoid crushing the tubing where it's clamped to the antennas.

Performance

Before putting these antennas on the air, I made some measurements on one of the AMSAT Phase-3D antenna test ranges. I used a Hewlett-Packard 803A VHF bridge, along with a Measurements, Inc, generator as an RF source and a dual-band hand-held transceiver as a tuned detector, to measure the antenna impedances.

Fig 4 shows the measured results for the 2M-CP22, indicating good performance across the band. SWR in the satellite range (145.8-146 MHz) is quite good—about 1.2:1. Fig 5 shows the same data for the 436-CP30. This antenna displays good RF characteristics across the 430- to 440-MHz band segment. This antenna should perform well below 430 MHz, covering the band's ATV segments. (I didn't take data below 430 MHz.) The antenna's electrical characteristics are more than adequate for its intended application.

[1]Phillystran is a nonconductive guying material made by United Ropeworks, Inc, 151 Commerce Dr, Montgomeryville, PA 18936, tel 215-368-6611, fax 215-362-7956.

The real performance evaluation of an antenna comes in live operational tests. A technician can measure the network until hell freezes over, but that would not answer the question of how it works. As qualitative as they are, these tests are meaningful when compared against experience with similar antennas. The VHF antenna, with its 18-foot, 6-inch boom and 22 elements, provides more than enough gain. Lengthy evaluations using this antenna, including the completion of the last 25% of my Satellite DXCC, proved that it's an unqualified success for the satellite service. Two-meter signals were always adequate on OSCAR 13's uplink and downlink.

I was somewhat concerned that the 30-element UHF antenna wouldn't perform as well as I was accustomed to. Its 9.7-foot boom is just two-thirds the length of the 40-element antenna I previously used. Operating experience has shown, however, that the M[2] antenna has gain comparable to the 40-element antenna. This may result partly from its lack of a lossy polarization-switching network, as previously discussed. Operating with this 30-element Yagi has not left me wanting for performance.

M[2]'s well-constructed satellite antennas warrant your consideration.

Price: 2M-CP22, $229; 436-CP30, $229. Manufacturer: M[2] Enterprises, 7560 N Del Mar Ave, Fresno, CA 93711, tel 209-432-8873.

AEA ISOLOOP 10- to 30-MHz LOOP ANTENNA

Reviewed By Brian Battles, WS1O

I've been a ham since 1976, but I've never considered myself a DXer. Not because I don't care for the sport of DXing, but mostly because I've never had the equipment—or the time—to make a serious attempt at working DX. I don't have a tower or beam antennas, and I've never owned a power amplifier. Because I've achieved unspectacular performance from my 133-foot wire dipole for 10 through 80 meters (which I feed with 50 feet of ladder line and a tuner), I figured I'd try the IsoLoop.

To the untrained eye, it looks as if a miniature alien spacecraft has landed on my house, but installing the IsoLoop turned out to be a good move. I mounted the antenna in the horizontal plane on the mast that supports my 2-meter vertical and my HF dipole. The IsoLoop can handle masts up to 2 inches in diameter. I used the 50-foot control cable that AEA supplies with the antenna to interconnect the control box and antenna. The mast is attached to the chimney about 35 feet above the ground. I didn't expect to see much of an improvement over the dipole with this 43-inch-diameter loop of flat aluminum, but I was pleasantly surprised.

Overview

This IsoLoop is the second-generation model.[2] It now comes fully assembled and covers 10-30 MHz (the first version covered 14-30 MHz), but its power handling—150 watts—and principle of operation haven't changed: It's an electrically small, inductively-coupled antenna with a very low radiation resistance and a remotely controlled, high-Q matching network located at the feed point.[3] The antenna's

[2]See Product Review, *QST*, Apr 1991, pp 45-46.
[3]For more on the theory and operation of small loop antennas, see the following: T. Hart, "Small, High-Efficiency Loop Antennas," *QST*, Jun 1986, pp 33-36; J. Hall, ed, *The ARRL Antenna Book*, 15th ed (Newington: ARRL, 1991), Chapter 5.

The Bottom Line

A small, efficient multiband antenna, the IsoLoop is just the ticket for antenna-restricted environments. But it costs enough that you should consider other options.

bandwidth is very narrow (10 kHz is typical at the low-frequency end, 100 kHz at the high end), and the matching network has a big job stepping the 50-Ω coax impedance down to the antenna's very low feed-point impedance with minimal loss. The sub-20-pound antenna uses a round, continuous, wide anodized-aluminum strap as its radiator (the earlier version used straight tubing sections). The benefit of the new design, presumably, is less loss in the loop itself. The new radiator has no junctions. Even low-loss connections can be problematic in such low-impedance systems, so AEA eliminated them in this antenna. Another of the newer antenna's features is a completely sealed feed system. It uses a redesigned, more rugged plastic housing for its gear-driven high-voltage tuning capacitor and exposes no connections to the weather when mounted horizontally with the supplied stainless-steel hardware.

The IsoLoop's LC-2 control box, also revised, goes in your shack. It's about 3 inches tall, 4 inches wide and 6 inches deep. The front panel has two large buttons for tuning (designated by large, raised arrows on the surface of each), thumbwheel controls for **SENSITIVITY** and **SPEED**, and four LEDs. On the back are jacks for 12 V dc input (from the supplied power cube), receiver audio in and out, and the control cable to the antenna. You remotely tune the IsoLoop by pressing the front-panel up- and down-arrow buttons until the antenna is matched at the desired frequency. The **SPEED** control makes it easy to find resonance: Transmitting with a few watts while monitoring the SWR, you move through the tuning range rapidly to get close, then slowly tweak the tuning to zero in on the peak, just like the earlier IsoLoop. It sounds confusing, but once you try it, it's simple.

The LC-2 control box lets you tune the antenna without transmitting, as follows: Tune to a spot close to where you want to operate, preferably where there's just band noise. Rock the tuning up and down with the buttons until the received noise peaks. What about the **SENSITIVITY** control and LEDs? They serve as an amplified relative signal-strength meter that lets you tune the antenna a bit more precisely, still without transmitting. Use the supplied cable to feed your transceiver's audio output to a jack on the control box (you can also run a cable from the LC-2's audio-output jack to an external speaker). Then, tune the IsoLoop until it lights the red, yellow and green LEDs, which means the antenna is properly tuned (or at least, that it's hearing the loudest noise from the transceiver). The **SENSITIVITY** control lets you adjust the display for best resolution while you're tuning. I found it equally quick and convenient to tune by ear, or by transmitting and watching the SWR meter. The LED approach is useful for shortwave listening, though.

Performance

Since I put up the IsoLoop, I've worked a couple of dozen new countries that had I barely, if ever, heard before—including some rather rare ones. Most stations I asked told me that there was no difference in signal strength when I switched between the IsoLoop and the dipole, although a few said that the IsoLoop adds one or two S units. No stations reported that the IsoLoop gave a weaker signal.

I couldn't convince my boss at HQ to send me on a DXpedition to Aruba or Trinidad to see how easy it would be to travel with the IsoLoop and find out what results I'd get from "the other end." From my results at home, I think it's safe to say that it would perform at least as well as a wire, but not as well as a Yagi.

Because the IsoLoop has such high Q, it minimizes interference from nearby frequencies—rather like an external preselector. Don't be tempted to use the internal automatic tuner in your radio to reduce the system SWR. AEA warns against this in the IsoLoop manual. The reason: Antenna matching done at the IsoLoop end maximizes radiated power; matching done at the transmitter end increases line loss and makes your radio happy, but doesn't increase the IsoLoop's radiated power. If you tune the antenna properly and adjust it when you change frequency, you should never need to use your rig's internal tuner. The IsoLoop works so well for such a small antenna because the tuning network is located at the feed point, rather than in the shack, and because its feed efficiency is very high. Unlike reviewer experiences with the first IsoLoop, I had no trouble tuning the redesigned antenna for a 1:1 SWR in the 10-meter band.

For me, one benefit of the IsoLoop is that it reduces the racket from my computer and TNC. On some bands, the ladder line and dipole pick up a barrel of hash from the digital toys. With the IsoLoop, a lot of this goes away.

The IsoLoop manual is well written and makes installation and operation easy. The antenna is omnidirectional when mounted horizontally. When I mounted it vertically (AEA supplies the hardware), it seemed to exhibit a figure-8 pattern, based on the signals I could hear and work. The vertical-mount configuration may yield a bit more gain; it sounded as though stations I regularly heard on DX nets and a few APLink stations were marginally louder.

The IsoLoop won't work as well as a Yagi, and it may look odd sitting on your roof, deck or a pole in your yard, but it gives you six HF bands in a single, small antenna without the need for a tuner, long wires or a large, cumbersome tower and beam setup. For those who need such an antenna, the IsoLoop's performance makes it a good value over a several-year period, because the antenna works well and looks like it should hold up over the long run.

Manufacturer's suggested retail price: $349.95. Manufacturer: Advanced Electronics Applications Inc, PO Box C2160, 2006 196th St SW, Lynnwood, WA 98036; tel 800-432-8873 or 206-774-5554.

MOSLEY TA-53-M MULTIBAND YAGI ANTENNA

Reviewed by Jeff Bauer, WA1MBK

Quintbander? That moniker just doesn't roll off the tongue as smoothly as *tribander* does. Like many others licensed before the 1979 World Administrative Radio Conference (WARC-79), in which US amateurs obtained allocations at 12, 17 and 30 meters, I find myself referring to multiband Yagis as tribanders, even if they're not. But in the wake of WARC-79, tribanders and "traditional-band" rigs are turning into the hula hoops of ham radio.

Description

The Mosley TA-53-M is a five-band, trap-resonated Yagi antenna similar in concept to the popular triband TA-33, but it uses two driven elements. Its driven elements, reflector and director work as a three-element antenna for 20, 17, 15, 12 and 10 meters. The antenna uses two aluminum-tubing phasing lines between the driven elements. The coaxial feed line attaches to the phasing lines partway between the driven elements by means of two formed-aluminum straps that are drilled for the feed-line mounting hardware.

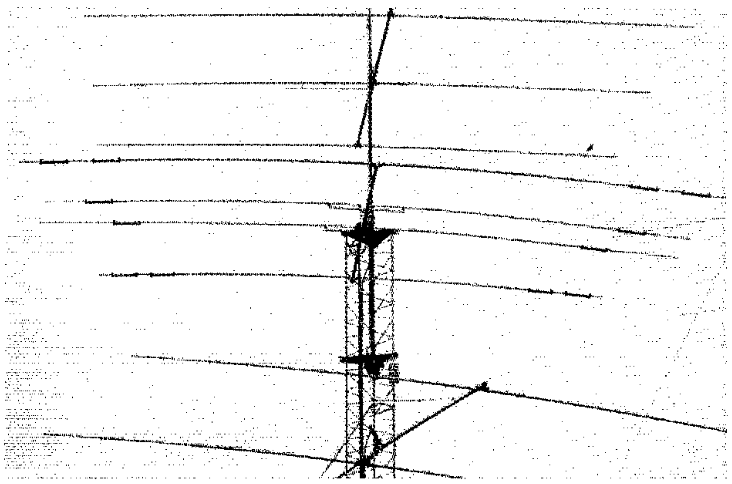
The shortest element is 20 feet, 5 inches long; the longest is 26 feet, 5 inches. The boom length is 14 feet, and the antenna's turning radius is 14 feet, 11 inches. At 55 pounds, this is no lightweight antenna—but it's no monster, either. Mosley specifies its front-to-back ratios as shown in Table 1.

Mosley recommends that you not use a ferrite balun, but suggests using a choke balun made of a few turns of the feed line coiled near the feed point to keep RF currents from flowing on the outside of the coax shield.

The antenna is shipped via UPS in two boxes. The trap box weighs 23 pounds, and

Table 1
Mosley's Claimed Front-to-Back Ratios for the TA-53-M

Band (MHz)	*F/B Ratio (dB)*
14	10
18	12
21	13
24	5
28	16



the boom/element box weighs 40 pounds. Somewhere in the shipping process, our trap box was bent slightly. This wasn't Mosley's fault, of course; both boxes are clearly marked with bright red stickers instructing package handlers to treat the boxes with care.

Assembly

Putting this antenna together is a snap. All elements and traps are color-coded, making parts identification easy. Like other Mosley antennas, the TA-53's traps and telescoping elements are locked in place with self-tapping screws. Virtually no measurement is required during assembly of the TA-53-M. The elements are premeasured and predrilled, making for fast and almost idiot-proof assembly. What few measurements that *are* required during assembly—the element placements on the boom and the feed-line tap point between the two driven elements—are *critical* with this antenna. If the feed-line attachment point off by half an inch, matching suffers.

The element spacings affect antenna performance, too. When the review antenna was initially installed, its SWR did not dip properly on a couple of bands. I had put the end caps on the boom early in the game and thought that having the director and reflector elements snug up to the end caps would be close enough. Was I wrong! A word to the wise: Do not assume that the colored ink markings on the boom are accurate element-spacing measurements. Grab a tape measure and work from one end of the boom to the other, and maintain the specified element spacings *exactly*. Then trim the boom-end caps to fit. Without the caps, the array is likely to collect insects and whistle or howl as the wind blows by the ends of the boom.

Test Setups

Some people have voiced concern that this antenna's performance suffers when installed near guy wires or other antennas. At W1AW, the TA-53-M was tested on a free-standing (unguyed) 60-foot tower in the following four configurations:

- At 60 feet, with no other antennas on the tower.
- At 60 feet, 10 feet above a 40-meter inverted V.
- At 60 feet, 10 feet above a 40-meter inverted V, and 14 inches below a four-element 2-meter Yagi.
- At 60 feet, sandwiched between a three-element 15-meter Yagi at 68 feet and a three-element 17-meter Yagi at 50 feet.

In the second and third test setups, the TA-53-M's SWR and directional properties remained what the antenna showed by itself. Although the test location is by no means a pure antenna-measuring environment, two transceivers used in the testing showed Mosley's front-to-back ratio claims to be accurate. (More on this later.)

Only in the last setup did the antenna show signs of performance deterioration. Specifically, the SWR curves became *much* sharper, and the front-to-back ratio fell off considerably. But this was admittedly a worst-case installation and any antenna that covers 15 or 17 meters would have behaved the same. Mosley clearly warns users about such interaction in the manual under **WATCH OUT FOR ARTIFICIAL GROUND**. To wit, "Artificial ground is presented to an antenna through various means. Guy wires up under the antenna, roof top, [and] other resonant antennas near by are the most common. The antenna should be at least [¼ wavelength] from any artificial ground at the lowest operating frequency of the antenna.... With this in mind the antenna should be at least 17 feet away from any artificial ground."

The manual goes on to say how you can identify an interaction problem: "A sign of artificial ground will be a shift lower in frequency of the SWR curves and possibly a dip that doesn't reach 1:1 at its lowest point. Also, the SWR will rise at a faster rate when tuning to the higher portions of the band."

This rings true with my experience. Sandwiching the TA-53-M (or any other similar antenna) between two monobanders is certain to cause a performance slide. But in the test setups in which the TA-53 shared tower space with the 40- and 2-meter antennas, it showed no ill effects from its proximity to them. Mosley specifies 8 to 12 feet of vertical separation between the TA-53-M and other antennas on the same support.

> **The Bottom Line**
>
> The TA-53-M's rugged, broadband coverage of five ham bands comes at the expense of low front-to-back ratio.

Documentation

The photocopied manual includes a 2-page part list, 8 pages of assembly instructions, and 7 pages of diagrams. The manual is of poor production quality compared to what other manufacturers offer with their products. A company like Mosley that produces high-quality antennas should ship their products with top-notch manuals, in substance and form. This isn't such a manual, but it is adequate.

Good Points

This is a no-tune antenna. All elements are measured, cut and drilled at the factory, so no trial and error is involved in assembly. This makes for fast and relatively trouble-free assembly.

The cast-aluminum boom, mast and element clamping blocks are well-designed and -machined. They fit perfectly and have no rough edges or barbs. Mosley did their homework with these blocks, as they have to provide clearance for a screw head on the driven element brace-to-mast junction. The blocks provide this clearance regardless of their positioning. This is more than just a nice touch; it's good engineering.

During the course of testing the TA-53-M, we called Mosley (anonymously) to obtain specifications (front-to-back ratios aren't specified in the documentation). This was a pleasant experience. Mosley's telephone representative was friendly and happy to read a rather long list of numbers over the phone. She went the extra mile by offering to either mail or FAX, at our choice, the requested information. Now *that's* customer service!

Rough Edges

Generally speaking, the antenna performs quite well. It covers all five bands with SWRs under 2:1 from band edge to band edge and has a directivity pattern that I'd expect from a three-element Yagi. But in designing this antenna, Mosley traded off front-to-back ratio for broadband coverage, as Table 1 shows. With the arguable exception of its 10-meter performance, this antenna's front-to-back ratios are rather dismal. Better performance isn't unusual in tribanders and monobanders. Depending on your reasons for buying a directional antenna, this performance characteristic could sway you away from the TA-53-M.

The TA-53-M's traps, element sections and boom are color-coded with marker ink. Stamped part numbers would be better because they don't fade and are less likely to be scratched into obscurity than ink markings.

Only one of the two factory feed-line attachment clips fit snugly, so I had to fabricate the other. For me this was a minor inconvenience, but not all antenna purchasers are prepared to do such metal-shop work to assemble an antenna. A nice touch would be for Mosley to flatten and drill the phasing lines at the feed-line attachment point, like they prepare the ends of these lines. This would render measuring and installing the feed clips unnecessary, and it would practically guarantee efficient power transfer at this current node. An insulating support between the phasing lines and the boom would further ruggedize the assembly.

If the boom- and mast-clamping blocks were welded or otherwise attached to the boom-to-mast plate, securing the array to a mast would be a much easier job. Juggling these blocks, the antenna, U bolts, lock washers and nuts is quite a trick—even for an experienced tower climber!

The traps and telescoping element sections are held in place with sheet-metal screws. Adding lock washers at these points seems like a good idea.

Summary

The TA-53-M is not for everyone. Most big-gun contesters and DXers probably aren't interested in a trapped, multiband antenna on a 14-foot boom—except as a multiplier-hunting antenna and for between-contests DXing on the two upper WARC-79 HF bands. For the rest of us, this rugged antenna is worthy of *serious* consideration. Through a single feed line, it provides gain and directivity on all the amateur bands between 10 and 20 meters. Miles of coax and antenna switch banks are rendered unnecessary with the TA-53-M. Its price is reasonable, considering the antenna's ruggedness.

For those upgrading from wires or a vertical, using the TA-53-M will be an exciting experience. It's a thrill to sweep the horizon, beaming in on a signal. It's also a real kick to null out QRM with a directional antenna. And you enter a new world when your radiator is up atop the ground clutter.

Price: $526.95. Manufacturer: Mosley Electronics, Inc, 1344 Baur Blvd, St Louis, MO 63132, tel 314-994-7872 or 800-966-7539 (orders only).

New Books

THE 1992 TRANSCRIPTS AND PROCEEDINGS: THE UNOFFICIAL PROCEEDINGS OF CERTAIN DAYTON EVENTS

By Richard Boyd, KE3Q

Published by LTA, PO Box 77, New Bedford, PA 16140, tel 216-533-0087. 1992. Paperback, 8½ × 11 inches, various page lengths, some with black-and-white diagrams. Four volumes: DXing, Antennas, Contesting transcripts and a Sweepstakes bonus, all for $29.

Reviewed By Brian Battles, WS1O
QST *Features Editor*

Missed the Dayton HamVention this year? Attended it but missed some forums? Went to the forums but didn't take notes? Rich Boyd, KE3Q, comes to the rescue with this series of verbatim transcripts of notable sessions held at Dayton.

One 84-page volume covers the DX Dinner, DX Forum and a brief interview with an official from the Philippines regarding the status of Spratly Island. This word-for-word transcript covers DXing in Asia; the developments in Albania; DXCC Computerization; VP8SSI; a presentation by Romeo Stepanenko, 1S1RR/YA0RR/XY0RR/3W3RR; Effective QSLing; the 1992 YASME Expedition; YX0AI; and more. The DXCC Countdown at the dinner is particularly entertaining. The interesting and witty speakers transcribed include Bob Eslaire, W9UI; Wayne Mills, N7NG; Yaesu's Chip Margelli, K7JA; Tom Warren, K3TW; the DXAC's Ted Pauck, K8NA; ARRL Roanoke Division Director John Kanode, N4MM; ARRL HQ's Tom Hogerty, KC1J; Don Daso, WA8MAZ (now WZ3Q); Terry Dubson, W6MKB; Tony de Prato, WA4JQS; Martti Laine, OH2BH; Ed Kritsky, NT2X; Lloyd (W6KG) and Iris (W6QL) Colvin; and Albania's Agim Muco.

A heftier tome is entitled *The Antenna Forum*, and has 87 numbered pages of transcripts, with a half-inch-thick section that consists of diagrams, plots and graphics. Topics include "Large 10-Meter Antennas, Design, Construction and Applications" by John Brosnahan, W0UN; "Yagi Stacking Update and Beverage Antenna Applications" by Frank Donovan, W3LPL; "Some Additional Yagi Design Ideas Based on Computer Modeling" by Jim Breakall, WA3FET; "Strengths and Weaknesses of Antennas" by Dave Leeson, W6QHS; and "Yagis vs Quads, Additional Data" by Carl Luetzelschwab, K9LA.

Contesters will enjoy the transcripts of the Contesting forums, which is nicely complemented by *Top Ops Talk Sweepstakes*, the most fun to read of the set. It's 41 pages of a fast-paced conversation between Trey Garlough, WN4KKN; Jeff Steinman, KR0Y; Tim Duffy, K3LR; and Randy Thompson, K5ZD. These veteran contesters discuss operating strategy, travel, QTH advantages, operating techniques, equipment, the "Qs that got away," their analysis and recap of past Sweepstakes, and the inevitable sprinkling of gibes, wisecracks and clowning around.

Boyd doesn't waste much space on editorial comments, other than a few notes to set the scenes or introduce the speakers. His parenthetical comments and "stage directions" make it easier to visualize what's happening at times when the speakers' words alone could be confusing. If you couldn't get to Dayton this April or missed some useful forums, pick up a couple of these transcripts and picture yourself sitting in the front row as you read. If you enjoy DXing, contesting or experimenting with antennas, add all four volumes to your library.

Strays

TOYS FOR TOTS RALLY

□ The second annual rally to collect toys for underprivileged children in the Southland is being held Saturday, November 28, from 10 AM-4 PM, at Jun's Electronics, 5563 Sepulveda Blvd, Culver City, California. Toys are being collected for the US Marine Corps Toys for Tots program. This event is endorsed by the Los Angeles Council of Radio Clubs.

In conjunction with the rally, special-event station KA6RJF will operate on 10 meters. Amateurs are invited to stop by after attending the nearby TRW swapmeet. For information, contact Bruce Nolte, N6TFS, PO Box 41446, Los Angeles, CA 90041; tel 213-257-5502.

QST congratulates...

The following amateur on 60 years of ARRL membership:

- Harold Chase Jr, W1EES, W Suffield, Connecticut

I would like to get in touch with...

□ anyone who can help an old-timer upgrading his old Yaesu FT-101E. I need FT newsletters from that period. Stefan Thorhallsson, TF3S, PO Box 354, 121 Reykjavik, Iceland.

Strays

LATEST PROCEEDINGS AVAILABLE

☐ Hot off the presses are journals on special Amateur Radio topics, consisting of papers by experts in a variety of advanced fields of ham radio research and operating.

Just published are the ***Proceedings of the AMSAT-NA Ninth Space Symposium***, ***Proceedings of the AMSAT/ARRL Educational Workshop*** and ***Proceedings of the AMSAT Annual Meeting***. The AMSAT-NA meeting was held October 9-11, 1992, at IntelSat Headquarters in Washington, DC. The ***Proceedings*** are available from AMSAT and the ARRL. 300 pages, $12. Highlights include the following:

"Drawing of the Phase 3D Spacecraft" by Dick Jansson, WD4FAB

"AMSAT-NA Operations Report" by Keith Pugh, W5IU

"The European Perspective" by Ron Broadbent, G3AAJ

"Marburg Meeting Minutes" by Peter Guelzow, DB2OS

"The Global Positioning System (GPS): Applications for Amateur Radio and Amateur Satellites" by Dr Tom Clark, W3IWI

"Satellite S Band: How to Become QRV on Our Highest Band" by Ed Krome, KA9LNV

"Phase 3D, A Student Manufacturing Engineering Challenge" by Robert J. Twiggs and K. W. Reister, N7MXF

"Phase 3D Antenna System Design" by Jack Colson, W3TMZ

"AMSAT Phase 3D Antenna Design Review: Phase 3D HF/UHF/Microwave Antennas" by Stan Wood, WA4FNY, and Dick Jansson, WD4FAB

"DSP and the Average Satellite Operator" by Gould Smith, WA4SXM

"The TAPR/AMSAT DSP 1 Project" by Lyle Johnson, WA7GXD

"*S*huttle *A*mateur *R*adio *EX*periment (SAREX) Hardware Configurations and Flight Operations Support" by Frank Bauer, KA3HDO, and Louis McFaddin, W5DID

"Digital Satellite Automation: Gateways and Gateway Nodes" by John Hansen, WA0PTV

"RUDAK-II on AMSAT OSCAR-21" by Peter Guelzow, DB2OS

"Microsat Engineering Test Results, August 1992" by Jim White, WD0E, Bruce Rahn, WB9ANQ, and Paul Williamson, KB5MU

"An Examination of PACSAT-1 Downlink Error Rates and File Server Operation" by Robert Diersing, N5AHD

"Communications Systems of SEDSAT1" by Kent Darzi, KD4MKD, and Dr John Champa, K8OCL

"*The SUSIE Project:* *S*atellites for the *U*nderstanding of *S*pace *I*nstrumentation and *E*xperimentation, or Bringing Space into the Classroom" by Joe Kasser, W3/G3ZCZ

"*ELMER*: An Expert System Based on a Finite State Machine" by Joe Kasser, W3/G3ZCZ

"An Amateur Space Exploration Ground Station Project Update" by Brent Helleckson

"The AMSAT Awards Program" by Andrew MacAllister, WA5ZIB

"AMSAT's Communication Backbone: What is AMSAT.ORG?" by Dr Tom Clark, W3IWI; Paul Williamson, KB5MU; and Brian Kantor, WB6CYT

"Amateur Television via the Phase 3D Satellite?" by Dr John Champa, K8OCL

"A Moveable Antenna System for AO-13 Modes B and J" by Stephan Greene, KA1LM

"Naval Academy Satcom Packet Radio Experiments" by Bob Bruninga, WB4APR

"Amateur Radio in Space: OSCAR at 30+ Years" by Joe Kasser, W3/G3ZCZ

"An Update on the ARSENE Project" by Bernard Pidoux, F6BVP

"OSCAR Satellites and an Amateur Radio Partnership with a High-Tech High School" by Ben Acton, KC3QP, Paul Skellchock and Dan Jayjock

"SUNSAT Microsatellite Programme Status" by Garth W. Milne

"Basic Satellite Terminology Explained" by Willem Nel, ZS6ALL

"SAREX Goes to College" by Dr H. Paul Shuch, N6TX

"An Educational Broadcast Transponder for Phase 3D" by J. Hans van de Groenendaal, ZS6AKV

"Use of Satellites and Satellite Signals to Inspire Interest in Natural Sciences in Developing Countries" by J. Hans van de Groenendaal, ZS6AKV

Another fresh, new publication is the ***Proceedings of the 26th Conference of the Central States VHF Society***, held July 16-19, 1992, in Kerrville, Texas. The ***Proceedings*** are available from the ARRL. 160 pages, $12. The following papers are included:

"Correlating Sun Noise Measurements to Solar Activity Data" by Dr H. Paul Shuch, N6TX, and Paul Wilson, W4HHK

"Laser Communications" by David Chase, KY7B, and Terry Wilkinson, WA7LYI

"Using TV Video Carriers to Monitor Propagation" by Al Ward, WB5LUA

"Aircraft Scatter" by Kent Britain, WA5VJB

"VHF/UHF Propagation Indicators" by Dave Meier, N4MW

"Historical Meteor Storms" by Joseph Lynch, N6CL

"Low-Down UHF/Microwave Antennas for High-Flying Satellites" by Stan Wood, WA4NFY, and Dick Jansson, WD4FAB

"Moondata Update—1992-93" by Derwin King, W5LUU

"Learning to Use an Audio Filter—The SCAF" by Henry Kasper, K2GAL

"This Baud's for You" by Henry Kasper, K2GAL

"Antenna Power Combiner Loss" by Henry Kasper, K2GAL

"QRP EME on 144 MHz: How and Why" by Ray Soifer, W2RS

"Physical Principles of 50 MHz F_2 Propagation" by J. R. Kennedy, K6MIO

"Bibliography of 33-cm (902- to 928-MHz) Articles" by Ron Neyens, N0CIH

"25th Central States VHF Society Conference Antenna-Gain Measurement Results"

"25th Central States VHF Society Conference Preamp Noise-Figure/Gain-Measurement Results"

"1992 International 6-Meter Beacon List" by Harry Schools, KA3B

"Transatlantic Sporadic-E Notes" by Emil Pocock, W3EP

"New Generation—50-MHz Smart Beacons" by Bob Cooper, et al

"An Overview of 50-MHz F-Layer Propagation" by Stephen Wagner, W7CI

Another new publication is the ***Microwave Update '92 Conference Proceedings***. The conference was held October 15-18, 1992, at the Holiday Inn Holidome, Rochester, New York. The ***Proceedings*** are available from the ARRL. 154 pages, $12. The following papers are featured:

"PHEMT Amplifiers for 2.3, 3.4 and 5.7 GHz" by Barry Malowanchuk, VE4MA

"Using TV Video Carriers to Monitor Propagation" by Al Ward, WB5LUA

"Beacon Thoughts" by Dave Meier, N4MW

"Software to Reduce the Drudgery of Repetitive Calculations" by Mel Graves, WR0I

"New Twist in Microwave Transverters" by Kent Britain, WA5VJB

"Tweaking DROs" by Kent Britain, WA5VJB

"Improving EME Antenna Temperature" by Kent Britain, WA5VJB

"No-Tune Microwave Transceivers" by Rick Campbell, KK7B

"Weak-Signal Source for 2, 3, 5 and 10 GHz" by Al Ward, WB5LUA

"Wavelength-Division Multiplexing Without Fuss or Filters" by Dr H. Paul Shuch, N6TX

"New and Not-Too-New Tips for No-Tunes" by Bill Olson, W3HQT

"Mixers, Etc, for 5760 MHz" by Paul Wade, N1BWT

"1296-MHz EME Notes" by Tommy Henderson, WD5AGO

"Meteor Scatter and Aurora at 902 MHz and Above" by Dave Halliday, KD5RO/2

"Mast-Mounted Amplifiers for UHF and Microwave Bands" by Tom Hodge, WA2YTM

"An IC-202 Interface Circuit" by Dave Robinson, G4FRE

"Low-Cost VHF-UHF RF Relay" by John Schroeder, K5ZMJ

"5.7-GHz, 10-GHz and 24-GHz All-Mode Linear Transverter" by Toshihiko Takamizawa, JE1AAH

"PIN Diode IF Switch" by Al Ward, WB5LUA

"PHEMT Low-Noise Amplifiers for 2304 MHz and 3456 MHz" by Al Ward, WB5LUA