by LEO SIMPSON

BUILD THIS: VHF amateur transceiver

Are you an amateur wanting to upgrade your two-metre gear? Then here's your chance to do it by putting together this up-to-the-minute transceiver which has all the most wanted features. The price? Just $199.

By any standard, the UHF transceiver described in the September, October and November 1983 issues of EA has been an outstanding success. Many hundreds have been successfully built and the kit supplier responsible, Dick Smith Electronics, has not been able to keep up with the demand.

As the reputation of the UHF transceiver has grown, more and more amateurs have decided to have a go at building a really worthwhile piece of gear for themselves. At the same time, they can save a substantial amount of money over the price of an equivalent commercial unit.

We're very glad to be able to report this development because it signals a resurgence in the construction of gear amongst amateurs who, for a long time, have been content to buy rather than build.

In fact, the UHF transceiver kit has been hailed both here and overseas as being perhaps the most significant amateur radio construction project to be published anywhere for a long time!

Just as night follows day, there was bound to be a call for a two-metre version of the transceiver. We ourselves remarked that the VHF version was just crying out to be produced.

Well now it has happened. The same team that produced the UHF kit, Garry Crapp VK2YBX/T, and Gill McPherson, VK2ZGE, have put their thinking caps on and produced a two-metre transceiver that will certainly set any keen amateur longing.

Features

As the accompanying spec panel shows, this new two-metre transceiver from Dick Smith Electronics has very good performance which is matched by the features that most amateur radio operators want. Note also that there are very few options available because they are all built in to the basic price.

Topping the list of features is, of course, the price. One hundred and ninety-nine dollars buys you a complete transceiver with all the features pictured, including the press-to-talk dynamic microphone. That has to be a really good deal.

And Dick Smith Electronics has gone one step further in providing a basic antenna kit so that there will be no temptation to switch on the transmitter with no load as soon as it is completed. The antenna kit comprises a quarter-wave vertical radiator, gutter-grip mounting base and feed, a PL-259 connector and three metres of good quality coax cable, all for $24.95.

For those amateurs not in a club and not sure of their ability to complete the transceiver successfully, DSE have their "Sorry Dick, it doesn't work" service coupon. This costs an additional $50 and may take up to three weeks service time if the constructor decides to take advantage of the offer but at least it is a sure way of getting an operational unit, if all else fails.

Operating facilities on the new transceiver are all that most amateurs would want without all the "bells and whistles" of some of the fancy imported models. There are none of those hard-to-remember-how-to-use memories and the frequency readout and selection is via no-nonsense push-button type "thumbwheel" switches.

As is usual practice with two-metre amateur transceivers, the two most significant digits of the frequency section are omitted which means that there is an assumed decimal point between the first and second digits of the three-digit readout (ie, 14- --MHz). In the photos, this means that the transceiver is set for a frequency of 147.02MHz.

Standard controls for volume and squelch require little comment as does the signal strength-cum-power meter. The microphone socket is a standard configuration allowing press-to-talk operation.

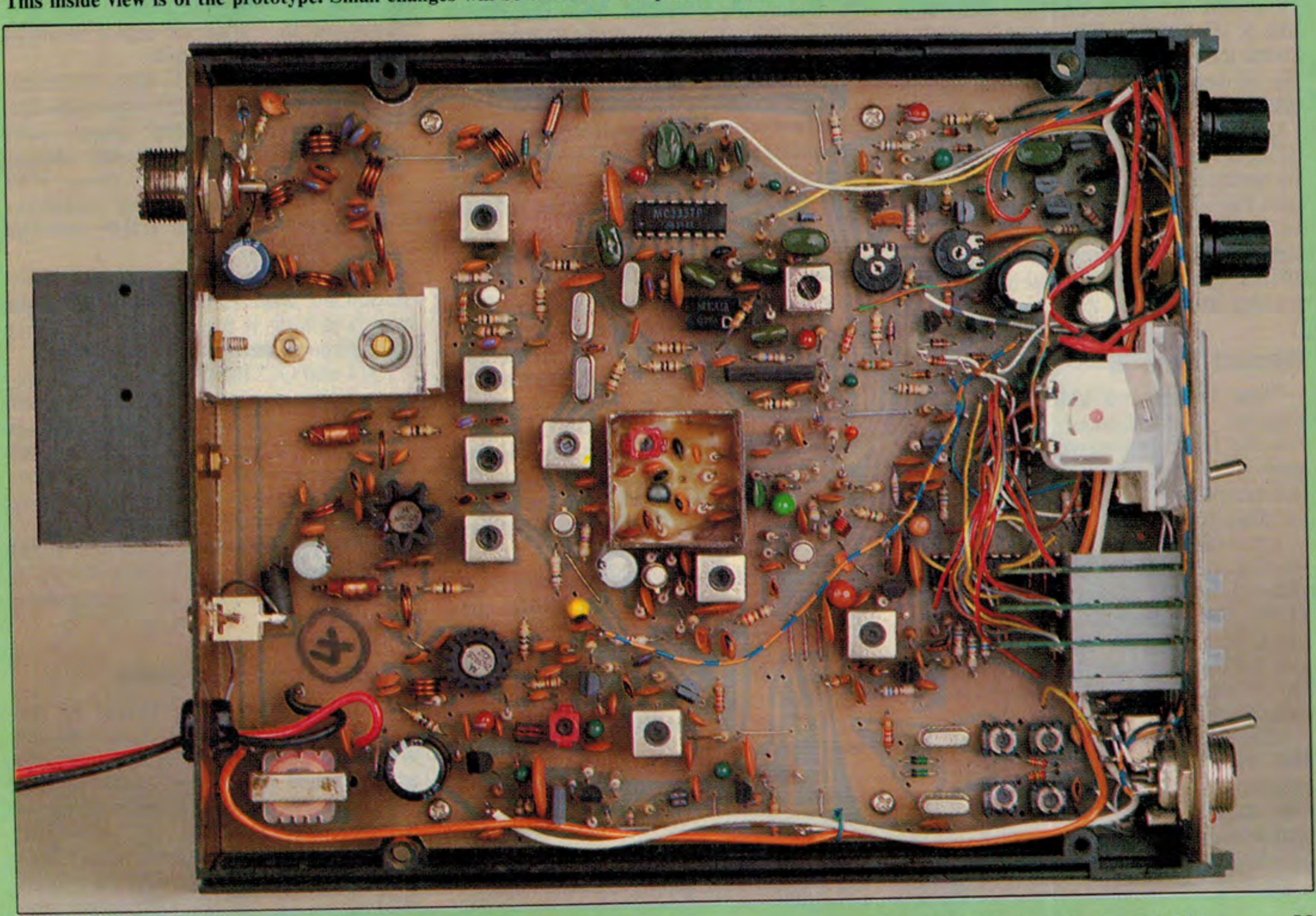
In addition, there is a three-position switch for simplex and plus or minus 600kHz transmitter offset for working into repeaters and there is also an anti-repeater button so that the transceiver can be used to listen in on the repeater receiving frequency.

Finally, there is the 5kHz offset switch which effectively doubles the number of channels from 400 to 800, albeit with 5kHz channel spacing.

How it works

Readers who have already taken a look at the circuit and block diagrams will have noted the similarities to the circuit of the abovementioned UHF transceiver described last year. Some sections of the circuit, notably the microphone preamplifier and audio power amplifier, are identical while other

This inside view is of the prototype. Small changes will be evident in the production models.



sections, such as the antenna filter, IF strip and power supply, are also very similar.

For those not familiar with the series of articles on the UHF transceiver, let's now go through the block diagram, before attacking the main circuit diagram. Refer now to Fig. 1.

The block diagram shows that the transceiver is split into two sections, receiver and transmitter, which come together in the antenna filter. Both these sections employ a common frequency synthesiser and voltage controlled oscillator.

The receiver is a conventional double conversion superheterodyne with intermediate frequencies at 10.7MHz and 455kHZ. The second conversion from 10.7MHz to 455kHz is achieved in an integrated circuit which also includes limiting amplifiers and an FM quadrature detector. From there the signal is passed to an audio amplifier.

The VCO (voltage controlled oscillator) has two modes and, as you might have guessed, these are transmit and receive. In the transmit mode, the VCO is set to an exact frequency within the range of 144 to 148MHz by the frequency synthesiser which, in turn, is controlled by the offset oscillator. The output of the VCO is fed via Q17 and Q18 to the RF power amplifier and thence via the antenna filter circuit to the output socket.

In the receive mode, the VCO is set at a frequency exactly 10.7MHz below the incoming frequency. This is necessary to give the 10.7MHz intermediate frequency at the output of the mixer, Q7. The lower VCO frequency is obtained by switching a different crystal into the offset oscillator.

Circuit details

Now let's have a look at the circuit diagram. Don't shudder. If you figured out the UHF transceiver described last year, this one is more straightforward in most respects. We'll consider the receiver circuitry first.

Input signals from the antenna are fed via the antenna filter and RF switching network on the extreme righthand side of the circuit diagram. The signals pass via L30, L29, L27, L26 and L28 and C123. From there they go to the input of Q6 via transformer L2 and C11 (on the extreme lefthand side of the circuit).

The RF switching is performed by D13 (near L28, on the RH side of circuitry). In the transmit mode, D13 is forward biased and thus shorts out any RF signal from the transmitter which would otherwise be fed into the receiver input.

Q6 is a conventional common emitter amplifier with L3 as its collector load. L3 is part of the three-stage bandpass filter which only accepts signals in the 144 to 148MHz range.

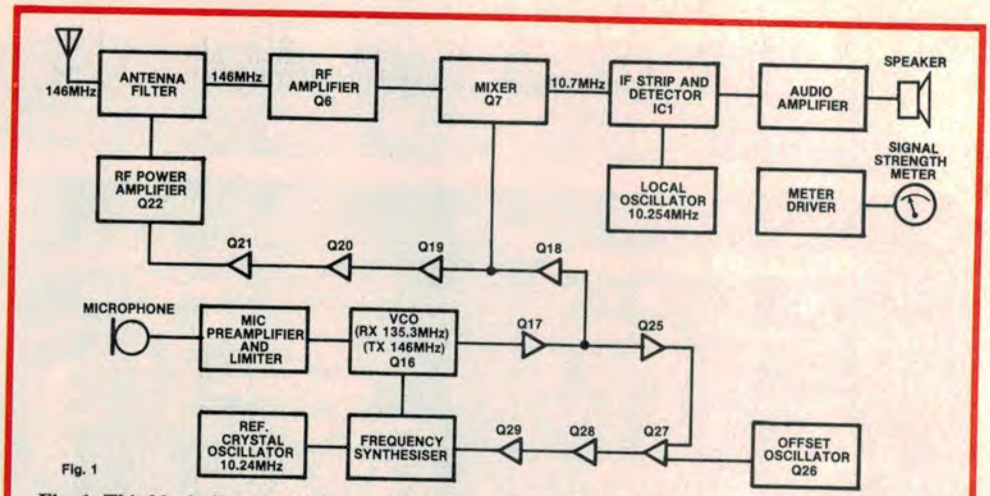


Fig. 1

Fig. 1: This block diagram of the new VHF transceiver highlights the conventional nature of the circuit.

Mosfet Q7 is the mixer. Gate 1 of Q7 is the incoming RF signal while gate 2 is the VCO (local oscillator) signal. L6 is the drain load of Q7 and the mixer output is the difference frequency, 10.7MHz. This is passed via FL1, a two-pole filter, to IC1.

IC1 is a Motorola MC3357 device specifically designed for use in a narrowband FM dual conversion communications receiver which is exactly what this circuit is. We have already talked about the first conversion which is from 144 (to 148MHz) down to 10.7MHz which takes place in mixer Q7. The MC3357 handles the second conversion using an internal 10.245MHz local oscillator.

This gives a second intermediate frequency signal of 455kHz which is amplified, limited and detected by IC1. IC1 also provides the squelch function.

In greater detail, crystal X1 at pin 1 of IC1 sets the local oscillator frequency to 10.245MHz. This is internally mixed with the 10.7MHz signal from Q7 to produce a 455kHz IF which is then fed to an external filter at pin 3. Transistor Q8 amplifies the filtered 455kHz signal and feeds it back into the limiting amplifier input at pin 5.

The limiting amplifier is a five-stage differential amplifier which boosts the 455kHz signal well into clipping, at its output. That is, we say the signal is limited. This effectively removes any amplitude variations (AM) so that the signal only contains frequency modulation.

The limited signal is then fed to the internal FM quadrature detector associated with coil L7 and capacitor C37 at pins 7 and 8.

The detected audio is extracted from pin 9 and fed via R33 and C35 to VR40, the volume control. At the same time, a sample of the signal is coupled via R32 and C33 to an internal amplifier between pins 10 and 11.

This amplifies any noise signal (hiss) above the expected audio passband which is then rectified by D7 and used to "squelch" the audio output via control pin 12. VR39 is the squelch control.

Transistor Q8 feeds a portion of the 455kHz signal (before limiting is applied) to IC7, the meter amplifier. This produces an indication of signal strength when in the receive mode.

Transistors Q9 to Q12 form a conventional audio amplifier. Q9 is a straightforward common emitter stage with negative feedback applied to the emitter via R44. Q10 is a class-A driver with bootstrapping via the output capacitor, C47. Its collector load is R49 and the speaker itself.

If the speaker is disconnected for any reason the whole amplifier will latch up which is how it manages to withstand open-circuits continuously (see specs).

Q11 and Q12 form a fully complementary output pair with quiescent current set by R46 and D8. R47 and R48 are rather high in value at 2.2Ω which gives good bias stability, limits the power output to some extent and gives momentary short circuit protection.

Resistors R44 and R43 set the audio amplifier gain to around 25 (ie, 5600/220 = 25) while C45 rolls off the response above 3kHz.

Transmitter operation

The transmitter is controlled by the press-to-talk switch on the microphone and this controls the various supply rails, as mentioned above. We'll come back to that. The signal from the microphone is fed to the preamplifier, Q13 and Q14, which provide substantial gain. The amplified signal is fed via C52 to a diode limiting circuit, D9 and D10, which prevent the following stages from being overloaded.

The signal from D10 is fed to Q15, a two pole active filter stage with a gain of unity. The output of this stage is the modulating signal which is applied from trimpot VR61 to varicap diode D11 via R62, C57 and R64. D11 is in the tank circuit of the VCO (Q16), and thus is able to frequency modulate the VCO according to the microphone signal voltage.

The VCO is a conventional grounded gate oscillator using an N-channel FET. It oscillates at a nominal 146MHz (centre of band) as set by L8 and C64. Varicap D12 sets the VCO to the exact frequency required, as controlled by the frequency synthesiser.

The main VCO output signal is taken from its source and fed to Q17 and Q18, which are transformer coupled, and thence to Q19 and Q20 which are more or less conventional common emitter amplifier stages. Q21 and Q22, on the other hand, are class-C power amplifier stages which operate without forward bias at their bases.

By way of explanation, in a class-C amplifier such as Q22, the collector current flows for substantially less than every alternate half cycle with the tuned circuit preventing the generation of harmonics. In effect, a class-C amplifier tank circuit can be considered as the analog of a flywheel which has a short burst of energy applied to it during every cycle. It is a highly efficient amplifier.

The output power from Q22 is coupled to the antenna filter circuit mentioned previously. The path is via L26, L27, L29 and L30 to the output socket. A measure of the transmitter output is provided as follows: Gimmick capacitor C169 (two wires twisted together) feeds a small portion of the transmitter output to D14 which rectifies the signal and applies the resultant DC to the signal meter via R109 and filter capacitor C134.

Frequency synthesis

The method of frequency synthesis is essentially a variation on the conventional phase lock loop (PLL) circuit. A PLL normally comprises a voltage controlled oscillator (VCO), a reference oscillator, a programmable frequency divider (fed by the VCO), and a phase comparator which compares the frequency divided output of the VCO with the reference oscillator.

For a VHF transceiver it is usual to have three oscillators: a VCO, a reference oscillator and an offset oscillator. In this case the VCO is Q16, the reference oscillator is associated with IC6 and the offset oscillator is Q26. IC5 is the phase comparator and IC4 is the programmable divider.

Let's start by looking at IC6. This IC is a combined oscillator and divider with a division ratio of 1024. It drives crystal X2 at a frequency of 10.24MHz which when divided by 1024 produces a reference frequency of 10kHz at pin 7.

IC5, the phase comparator, compares the 10kHz reference frequency from IC6 against the 10kHz output from the programmable frequency divider, IC4. The output at pin 3 of IC5 is the PLL error voltage which is a series of pulses. These are filtered to produce smooth DC by R91, C156, R87, R86 and C153. This DC error voltage is then applied to D12 in the VCO (Q16) to maintain control over the VCO output.

As shown on the circuit, when the PLL is in the lock condition and the VCO output is 144MHz, then the error voltage at TP3 is 2.7 volts DC (after setting up).

Where the frequency synthesiser circuit diverges from normal PLL practice is that the programmable divider does not merely "divide down" the output of the VCO. Instead, IC4 divides the difference between the VCO output and the third harmonic of the offset oscillator.

The reason for this indirect procedure is that it is not possible to easily provide for programmable division directly from 144MHz.

What happens is this. The offset oscillator, Q26, operates at 44.234966MHz in receive mode and at 47.801666MHz in transmit mode. The relevant crystals, X4 and X3, are switched into circuit by diodes D23 or D22.

The collector output circuit of Q26 is tuned to the third harmonic of these frequencies ie, 132.704898MHz and 143.404998MHz.

Depending on whether the transceiver is in receive or transmit mode, one or other of these offset frequencies will be substracted from the VCO output frequency by the offset mixer, Q27. The difference frequency will range from 595kHz (eg, 144-143.405) to 4.595MHz (148-143.405).

It is this range of difference frequen-

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SPECIFICATIONS

GENERAL

Frequency Coverage	144 to 148MHz (see text)
Channel Spacing	10kHz; with 5kHz offset
Number of Channels	400 @ 10kHz; 800 @ 5kHz (see text)
Frequency Stability	within ±10ppm from 0 to 60°C
Modulation	Frequency Modulation
Temperature Range	from 5 to 50°C
Duty Cycle	two minutes transmit, two minutes receive
Supply Voltage	12 to 15V DC; test voltage 13.8V DC
Polarity	negative chassis
Current Drain	Receive: muted, 110mA; unmuted, 300mA Transmit: 1.9A at 10W; 2.5A at 15W
Protection	(a) 3A in-line fuse (b) diode reverse polarity protection (D1) (c) RF power amplifier can withstand up to 5:1 VSWR and open or short-circuit conditions for at least two minutes (d) audio power amplifier can withstand open circuit continuously and momentary short circuits

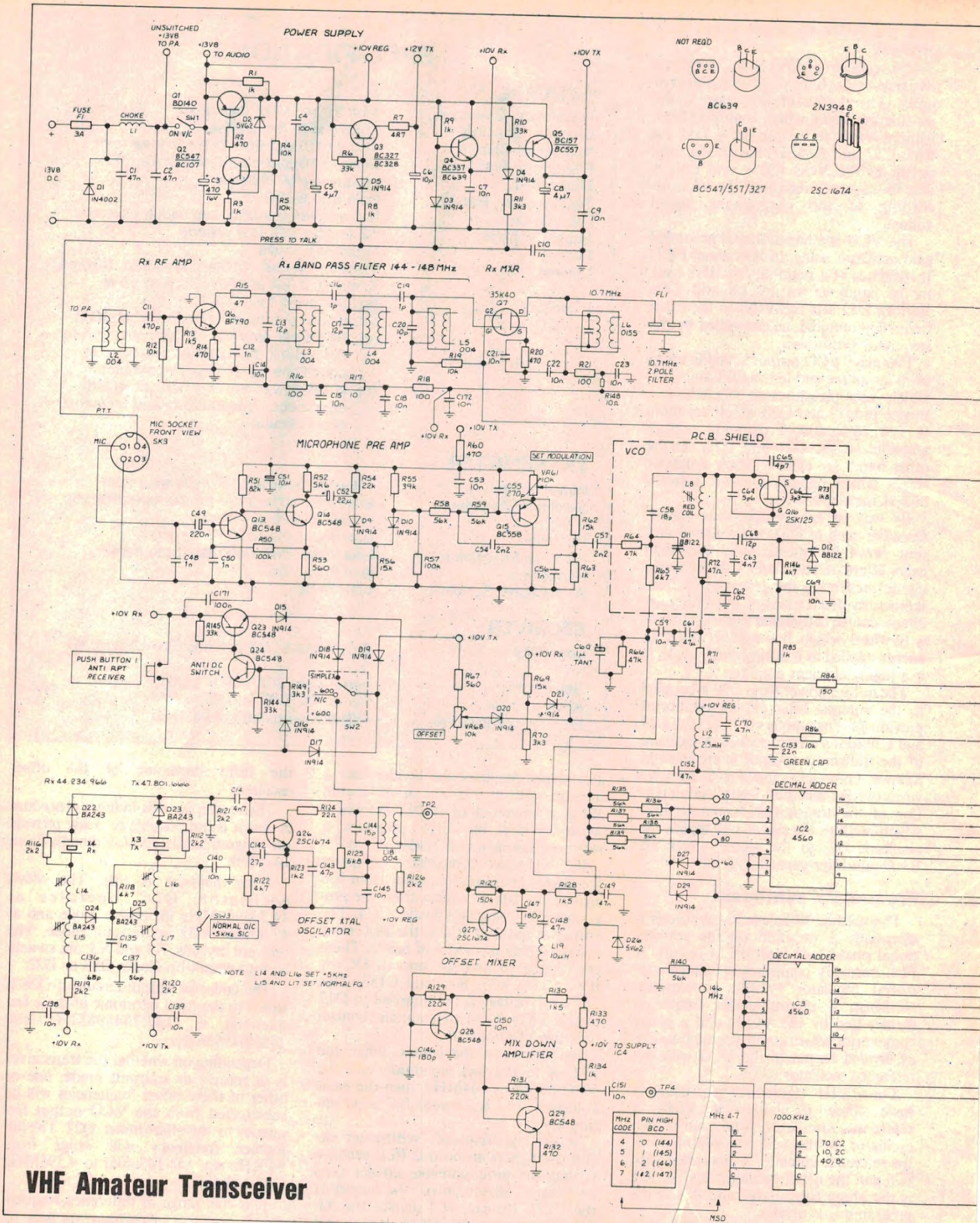
TRANSMITTER

Power Output	10 watts nominal; 15 watts maximum
Maximum Deviation	limited to 5kHz under normal operation; up to 10kHz with overdrive
Distortion	less than 10% at 3kHz deviation
Spurious Emissions	less than 60dB with respect to carrier
Harmonics	less than 60dB
Microphone Sensitivity	5mV RMS

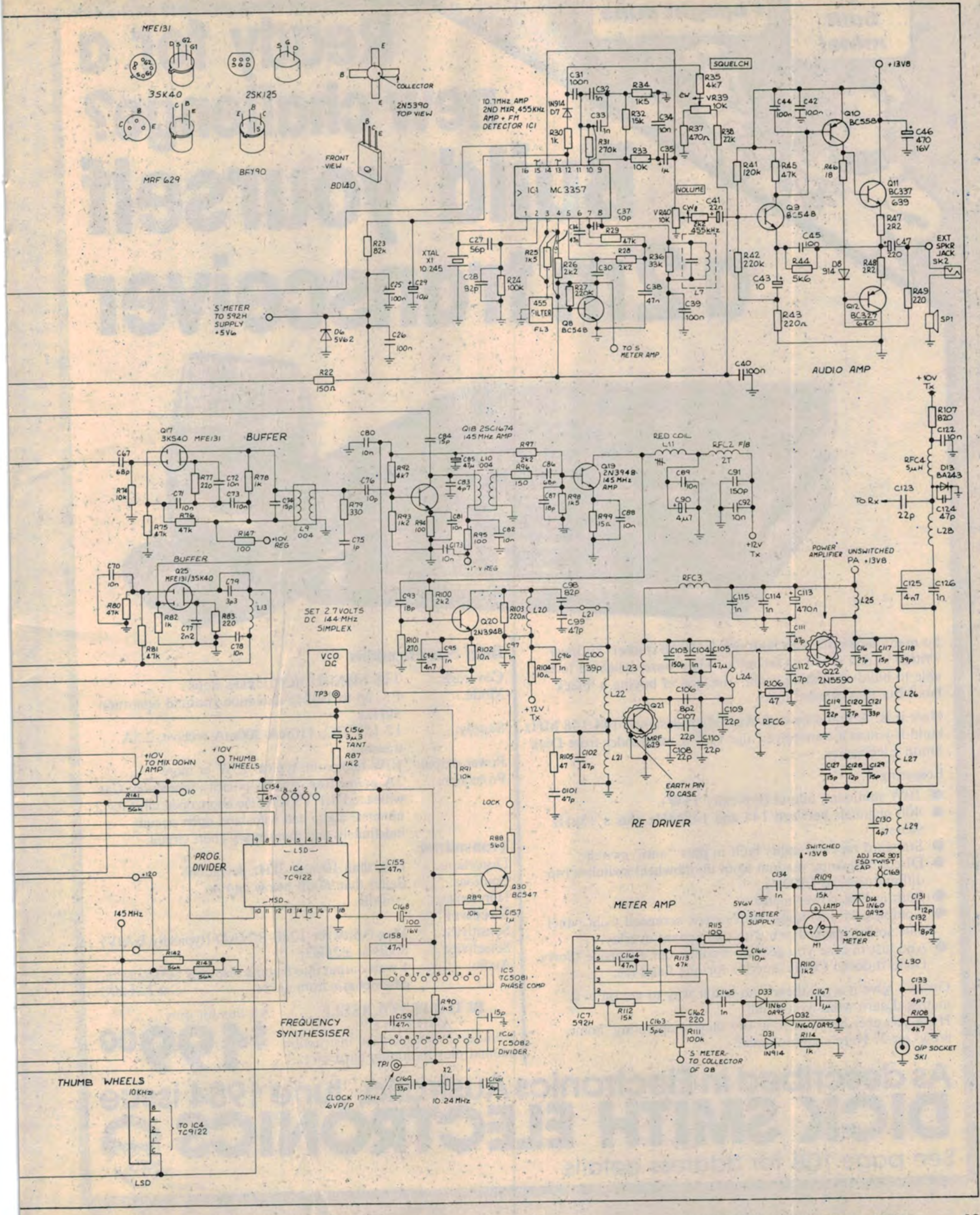
RECEIVER

Sensitivity	0.5μV into 50Ω for 12dB SINAD; typically 0.4μV
Selectivity	better than 60dB at ± 25kHz
Audio power	1W at 1% THD into 8Ω
Frequency response	6dB/octave rolloff above 1kHz

VHF Amateur Transceiver



MHz CODE	PIN HIGH BCD
4	0 (144)
5	1 (145)
6	2 (146)
7	1&2 (147)


MFE131
3SK40
2SK125
2N5390 TOP VIEW
COLLECTOR
MRF 629
BFY90
FRONT VIEW
BD140
10.7MHz AMP 2ND MXR, 455KHz AMP + FM DETECTOR IC1
IC1 MC3357
SQUELCH
VOLUME
XTAL X1 10.245
455 FILTER FL3
Q8 BC548
TO S METER AMP
S METER TO 592H SUPPLY +5V6
D6 5V62
R22 150Ω
+13V8
Q10 BC558
Q11 BC337/639
Q9 BC548
Q12 BC327/640
EXT SPKR JACK SK2
SP1
AUDIO AMP
Q17 3K540 MFE131
BUFFER
Q18 2SC1674 145MHz AMP
Q19 2N3948 145MHz AMP
RED COIL L11
RFC2 F/8 2T
+12V Tx
+10V REG
Q25 MFE131/3SK40
SET 2.7VOLTS DC 144MHz SIMPLEX
Q20 2N3948
+12V Tx
RFC3
POWER AMPLIFIER
UNSWITCHED PA +13V8
Q22 2N5590
Q21 MRF 629
EARTH PIN TO CASE
RF DRIVER
+10V Tx
RFC4 5μH
D13 BA243
TO Rx
VCO DC
TP3
+10V TO MIX DOWN AMP
+10V THUMB WHEELS
LOCK
PROG. DIVIDER
IC4 TC9122
LSD
MSD
Q30 BC547
145MHz
IC5 TC5081 PHASE COMP
IC6 TC5082 DIVIDER
FREQUENCY SYNTHESISER
TP1
CLOCK 10KHz 4VP/P
X2 10.24 MHz
THUMB WHEELS 10KHz
TO IC4 TC9122
LSD
METER AMP
IC7 592H
S METER SUPPLY
S METER TO COLLECTOR OF Q8
SWITCHED +13V8
ADJ FOR 90% FSD TWIST CAP
LAMP
S POWER METER M1
O/P SOCKET SK1

cies which is applied to the programmable frequency divider, IC4, via Q28 and Q29.

So IC4 is programmed by the thumbwheel switches to divide the relevant difference frequency from Q27 to provide a 10kHz output which is applied to the phase comparator, IC5.

Note, by the way, that the difference between the transmit and receive offset frequencies is 10.7MHz which is the required intermediate frequency.

So far so good. But now we have to backtrack a little. There is a problem in that IC4 cannot precisely divide frequencies that are not an exact multiple of 10kHz. Therefore that example of 595kHz (the lowest difference frequency) is not valid. And in fact, those offset oscillator frequencies given above are not quite correct.

Because of the provision for 5kHz channel spacing, the offset oscillator crystals are in fact 1666Hz too high. When the third harmonic of each crystal is considered it will be 5kHz high. So in normal operation, the crystals are pulled low by L14 and L15 for X4 and L16 and L17 and X3. So the normal offset transmit frequency is 47.8MHz (143.4MHz 3rd harmonic) and the offset receive frequency is 44.2333MHz (3rd harmonic is 132.7MHz).

When these offset frequencies are subtracted from the VCO the range of difference frequencies will be 600kHz to 4.6MHz. And note that 600kHz is an exact multiple of 10kHz.

When the +5kHz facility is switched on, L15 and L17 are switched out of circuit by diodes D24 and D25, so that now the crystals do run 1666Hz high and so the VCO frequency is shifted up by 5kHz.

Band protection

Note that when the 10kHz outputs of IC6 and IC4 (the programmable divider) are locked together IC5 turns on Q30. This turns on Q18 and Q19 and thus allows the transmitter to operate. Thus the transmitter is prevented from producing signals which are outside the 144 to 148MHz band.

But what about that +5kHz offset we have just discussed. When that is applied it would be possible for the VCO to operate at 148.005MHz and still produce a lock condition. The circuit design takes care of this possibility too since the thumbwheels are wired to only permit a maximum VCO frequency of 147.99MHz. When the 5kHz is added this gives a maximum VCO frequency of 147.995MHz which is still inside the band limits.

Strictly speaking then, this means that only 399 channels are available with 10kHz spacing and 798 channels with 5kHz spacing (144.005 to 147.995MHZ).

±600kHz offset

Yet another factor has to be taken care of by the frequency synthesiser circuitry. For repeater operation, the transmitter frequency usually has to be offset by minus 600kHz from the receive frequency. Less often, it may have to be changed by plus 600kHz. This condition could be met by adding more crystals to to the offset oscillator circuitry but in this circuit it has been achieved digitally.

As well as avoiding the expense of extra crystals, the digital method of offset does not require any alignment. IC2 and IC3 are digital adders. They add a code of 60 or 120 to the code applied by IC4. In the normal simplex mode, the addition of the 60 code is the standard. For −600kHz repeater operation, this code is removed (controlled by D18 and IC2).

For +600kHz operation, IC2 and IC3 are brought into play by D29 and D27 to add a code of 120 to IC4.

A neat advantage of this scheme is that it allows the "anti-repeater" operation whereby the receiver only can be shifted by ±600kHz. This is achieved by the pushbutton in conjunction with Q23, Q24 and associated diodes. The advantage of the anti-repeater function is that it allows the operator to listen directly to his contact instead of via the repeater.

Note that when the 600kHz offset facility is in use, the out-of-band protection circuitry does not prevent transmission outside the band limits. In this case it is up to the operator to make sure he or she does not transgress.

Power supply

A +10V regulated supply derived from Q1, Q2 and D2 supplies power directly to the VCO, offset oscillator, frequency synthesiser circuitry and mix down amplifier (Q28 and Q29). The +10V regulated rail is also switched to various other sections of the circuit by Q4 and Q5, depending on whether the transceiver is in the receive or transmit mode.

When in the receive mode, the press-to-talk switch is open and D3, D4 and D5 cannot conduct. Therefore Q4 supplies the +10V Rx rail. When the PTT switch is closed for transmit mode, D3 and D4 conduct, turning off Q4 and turning on Q5 to supply the +10V Tx rail. D5 also conducts, turning on Q3 to supply the +12V Tx rail.

The final two stages of the RF power amplifier, Q21 and Q22, are powered directly from the 13.8V (battery) supply, as is the audio amplifier. This is OK since Q21 and Q22 are normally biased off and can only operate when Q19 and Q20 are turned on by the +12V Tx rail.

Continued next month

Rear panel view (left to right): supply leads, remote speaker socket, RF power transistor heatsink and antenna socket.