A 'universal' antenna matcher for shortwave reception

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This simple project can be connected in almost any desired configuration to match a random 'long wire' antenna to the input of a shortwave receiver and give much improved performance.

FOR GENERAL RECEPTION purposes over the 1.7 MHz to 30 MHz range, an end-connected wire antenna is popular. This may be anything from a few feet of insulated wire indoors, to a long, high outdoor aerial. Such antennas can, and do, provide good long-distance reception, but the matter of matching the aerial impedance to the receiver is often totally disregarded. There is a maximum transfer of energy from the aerial to the receiver only when the end impedance of the antenna approximately matches the input impedance of the receiver input circuit.

Many specialised shortwave receivers have an antenna input impedance of about 50 ohms. With other receivers, the input impedance may be unknown, and in any case it is likely to alter with changes in operating frequency.

The project is housed in a plastic utility box, the front panel being dressed up with a Scotchcal Panel.

The end impedance of the antenna, in its turn, depends on the length of the wire in terms of wavelength. If it is a half wavelength long, or a multiple of half wavelengths, its end impedance is high — it may easily exceed 1000 ohms. On the other hand, if the aerial is a quarter wavelength long, or an *odd* multiple of quarter waves, its end impedance is low. In fact it will probably be under 50 ohms at some frequencies.

The length of a half-wave antenna is found with sufficient accuracy from

$$\text{Length} = \frac{143}{f(\text{MHz})} \text{ metres}$$

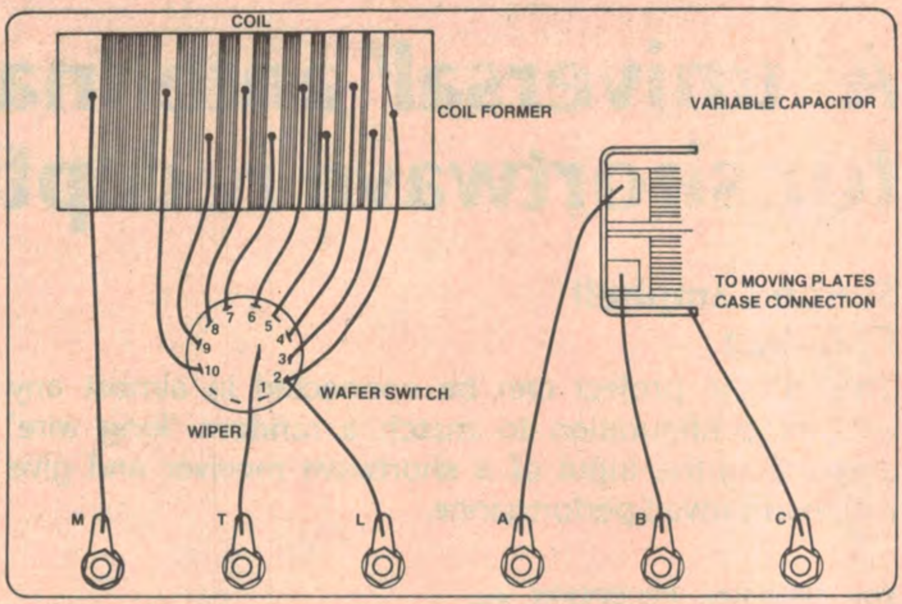
As much specialised shortwave listening takes place on the amateur bands, and as they are spaced at harmonic intervals throughout the HF spectrum (see accompanying table), it is convenient to use them as examples.

Say you have a long wire erected that has a total length of 10 metres. Now, this would work as a half-wave antenna on the '20 metre' amateur band since 143/14.3 gives an antenna length of 10 metres. The antenna would have a very high impedance at either end and this would have to be 'transformed down' to match the receiver's relatively low input impedance. At twice the frequency where the antenna is a half-wave long, i.e: 28.6 MHz, the antenna is clearly *two* half-waves and the end impedance is again high. But, at half the half-wave frequency, or 7.15 MHz, the antenna will be one-quarter of a wavelength long and its end impedance will be low. The exact impedance will depend on the height, ground conductivity and overall construction.

If you measured the impedance of the antenna throughout the HF range, from 30 MHz down to 1.7 MHz, it would be found to swing from one extreme to the other, reaching a low impedance at 'quarter-wave' frequencies and a high impedance at 'half-wave' frequencies. ▶

Amateur Bands up to 30 MHz

160 metres	1.8 - 1.86 MHz
80 metres	3.5 - 3.7 MHz
40 metres	7.0 - 7.15 MHz
20 metres	14.0 - 14.35 MHz
15 metres	21.0 - 21.45 MHz
10 metres	28.0 - 29.7 MHz



Wiring diagram. Compare this with the photograph on the right.

Any random length of wire will exhibit these general characteristics.

To enable one to tune a wide range of frequencies, and to gain the maximum power transfer from the minute signals on the antenna to the receiver input, some variable compensation or 'matching' system must be employed.

The best way to go about this is to use a resonant circuit that can be tuned across the entire range of frequencies of interest and can be connected in a variety of impedance transforming configurations. The matcher described here uses a coil tapped at convenient intervals and a dual-gang variable capacitor. The actual capacitance range of the latter can be different to the 10-415 pF (nominal) of the Roblan gang specified but you may experience some restrictions at the low frequency end of the spectrum if the range is smaller, apart from mechanical problems, unless you intend to use a different case or style of construction.

The coil tappings are selected by means of a single-pole rotary switch, while the coil and capacitor may be connected as desired by means of coloured terminals and jumper leads. Suggested circuit configurations are shown on page 51, but we'll get to that later.

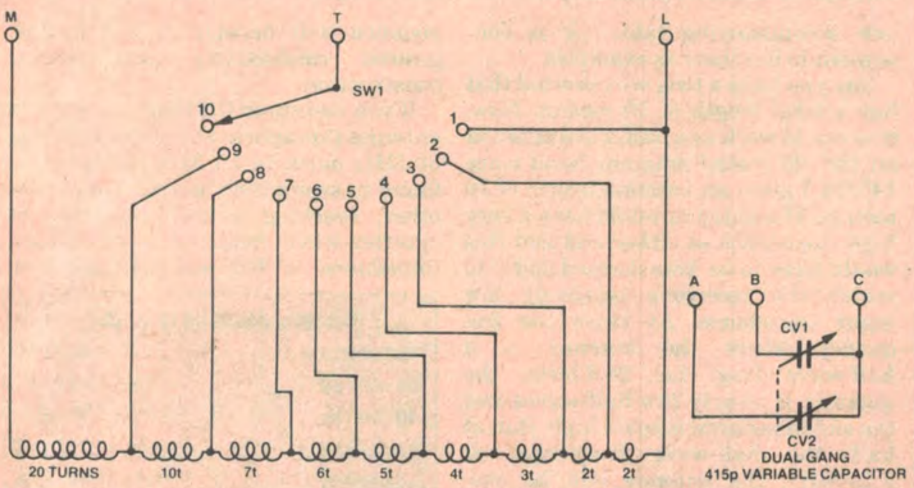
Construction

We housed our matcher in a plastic utility box measuring 190 x 110 x 60 mm. The plastic 'lid' of the box is used as the front panel and all the components were mounted on this. Six 'banana' socket-binding post terminals were mounted along the 'top' of the lid to provide the coil and capacitor connections. The rotary switch and capacitor are mounted in line beneath the terminals, the switch on the left and capacitor on the right. The capacitor we bought uses three screws which hold it to the front panel, mating with threaded holes in the front section of the capacitor frame. If you have or wish to use a different type, then mounting arrangements may have to be different. The Roblan, and similar type, gangs are quite small and fit neatly into the box we chose. If you plan to use a different type, make sure that it will fit in this box without fouling any of the other components, otherwise you will have to vary the mounting arrangements or use another box. Many of the older-style 'broadcast' tuning gangs have a capacitance swing of 5 -

HOW IT WORKS — ETI 727

The unit contains a coil with multiple taps which may be selected by a single-pole, multi-position switch, and a dual-gang variable capacitor. Terminals provide connections to the circuit elements such that they may be interconnected in a variety of configurations. Thus, various common matching configurations may be achieved. i.e: L-match, Pi-match, T-match, parallel tuned, series tuned, end-loading (L or C only) etc.

The matching circuit will transform the unknown impedance of the feedpoint of a random length antenna to the impedance of the antenna input of the receiver, effecting maximum power transfer of the signal.



General circuit diagram, showing the number of turns on each coil section.

PARTS LIST — ETI 727

- **1 x** dual-gang variable capacitor, 10 - 415 pF (nominal; Roblan type RMG2 or similar).
- **1 x** single-pole, ten-position switch; C&K type RA, or similar.
- **6 x** banana socket-binding post terminals, all different colours; plus banana plugs to suit (get the stackable variety).
- **2 x** knobs with numbered skirts.
- **1 x** plastic jiffy box, 190 x 110 x 60 mm.

Miscellaneous

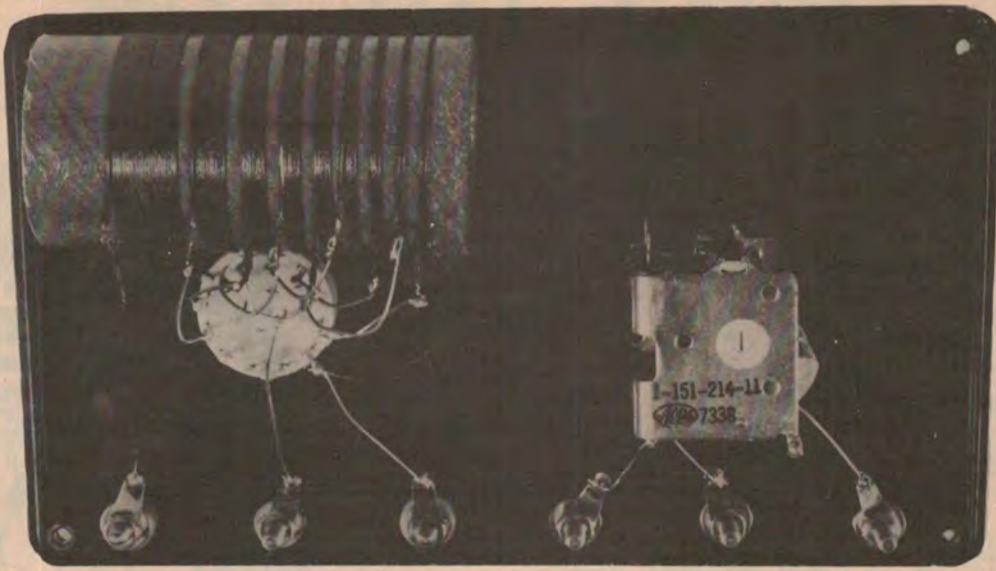
Coil former: 40 mm diameter, 80 mm long (see text); enamelled coil winding wire, any gauge between 22 swg and 28 swg; tinned copper wire; hookup wire; nuts, bolts etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$15 - $20

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the actual price of a project, whether bought as separate components or made-up as a kit.



365 pF, which is quite adequate, but are about twice the size of the modern types and may have a 9 mm diameter shaft, necessitating a 'shaft reducer' extension piece. We'll have to leave that up to you.

The coil is mounted directly behind the switch and, since it is very light, the wires from the windings to the switch lugs are used to support it. All interconnecting wiring in the project is made with 20 swg tinned copper wire.

First, drill the lid of the box. Mark out carefully the hole positions and centre-punch each one before drilling. You can use the front panel artwork as a template. If you are using a Scotchcal front panel, don't remove the backing at this stage. Drill the holes in the front panel *before* attaching the Scotchcal, otherwise you're likely to tear it.

Having drilled the holes, carefully deburr them with a larger size drill bit. Now you can attach the front panel artwork. Next step is to attach the terminals, switch and capacitor. Take care not to damage the front panel artwork when tightening screws or nuts.

The coil

Now wind the coil. We wound ours on an 80 mm long piece cut from a cardboard mailing tube about 40 mm in diameter. You can buy these from newsagents and stationery suppliers. Alternatively, the centre tube from a toilet roll could be used but is not quite as rigid. The drawing here shows how the coil is wound. Start by 'locking' the wire to one end of the former by looping the wire through two small holes poked in the end of the former about 5 mm apart. Pull the wire tight and commence winding from left to right, passing the wire over the former, away from you then up towards you etc, for 20 turns to the first tap. The coil is wound in sections, the tap in between each section being wired to the switch. To make the first tap, form a small loop in the wire and, while still maintaining tension on the already-wound section, put several twists in the loop. Commence winding the next section about 4 mm from the end of the first. Wind 10 turns and make another tapping. Start each successive section 4 mm from the end of the previous section, making tappings as you go, until you reach the finish. Refer to the diagram for the correct number of turns for each section. Anchor the end of the winding as you did the start. Don't forget to leave sufficient length of wire at the start and finish of the coil to reach the terminals to which they connect. About 80 - 100 mm is sufficient. You can give the coil a coating of acrylic cement to help hold it in place and prevent moisture affecting it.

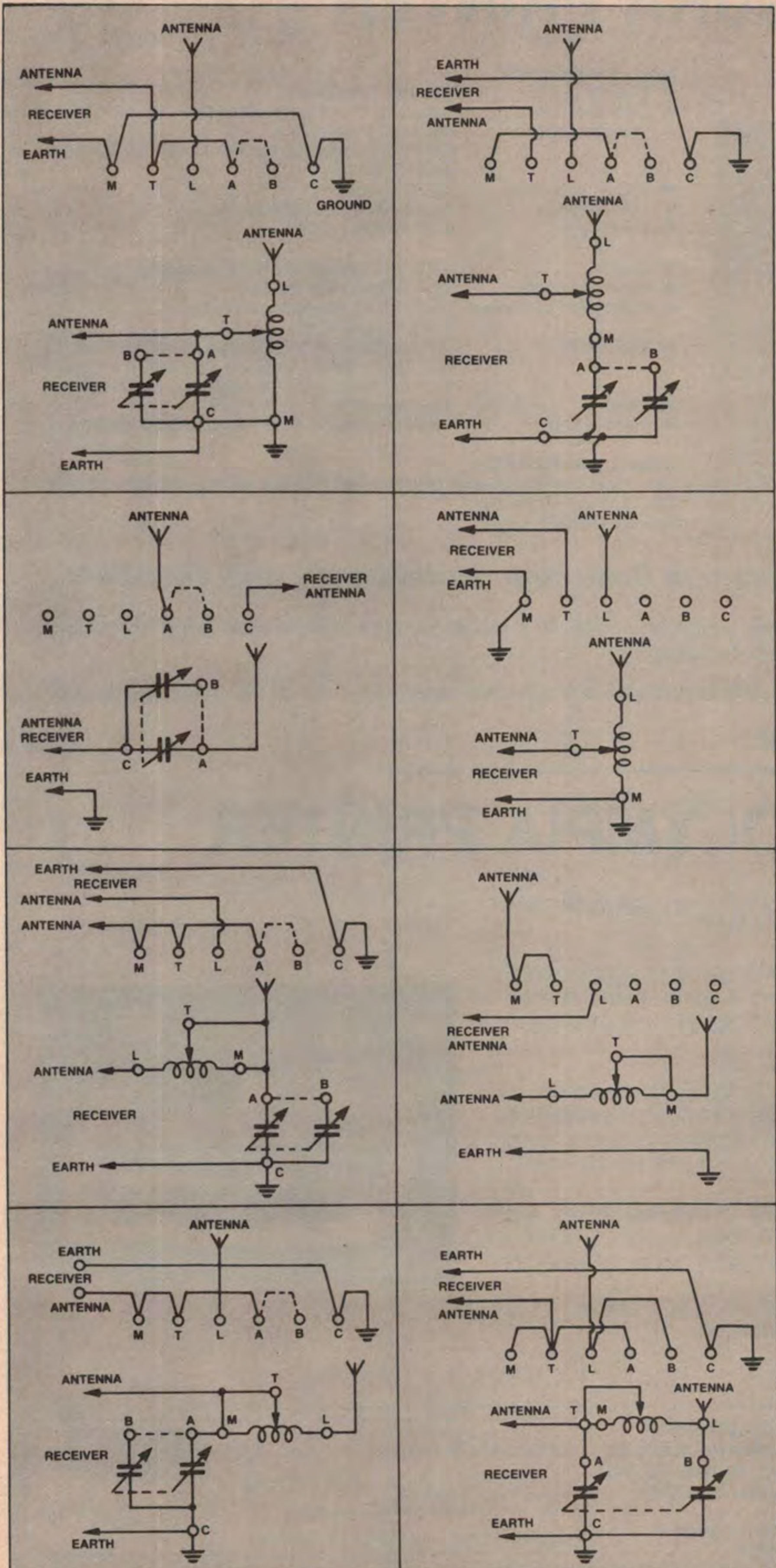
Using a knife or other sharp blade, carefully scrape the enamel off the ends of the tapping points and solder 50 mm length of tinned copper wire to each. Taking care to get everything in the correct sequence, solder each wire to the appropriate lug on the rotary switch. The coil will then be supported by these wires from the switch. The 'start' end of the coil (beginning of the 20-turn section) should be soldered to the 'M' terminal, while the other end of the coil connects to the 'L' terminal. Terminal 'T' is connected to the pole of the rotary switch with a length of tinned copper wire.

Next wire the capacitor. The frame (common connection for the moving plates) connects to terminal 'C', while the two fixed plates' connections go to terminals 'A' and 'B'. If your capacitor doesn't have a solder lug connection for the frame you will need to attach a bolt to some convenient point on the frame and put a solder lug under the bolt head to provide a connection point.

That completes the internal wiring of the project; however, you will need to make up a number of 'jumper' wires to 'patch' the different terminals together to get the circuit configuration you want. 'Banana' plugs are convenient connectors and will mate with the terminals we have specified. Get the 'stackable' variety. The jumper leads should be no longer than 200 mm, and something between 100 mm and 200 mm will be fine. It's an advantage to use different coloured hookup wire to make the jumpers so that you can identify the leads more readily when changing or making up a circuit configuration. Make up a length of coaxial cable for the receiver antenna connection with the appropriate coax plug on one end and the banana plugs on the other.

Transmitting use

It is possible to use this project to match a low power transmitter to a long wire antenna, but we haven't actually tried it. We estimate transmitter output power should be no higher than 5 W - 6 W carrier or 12 - 15 W PEP on SSB. It would be fine for Novice amateur use or for the QRP enthusiast, providing the power limitation is kept in mind. The principal problem is the voltage rating ▶



of the capacitor and switch when using the matcher on an antenna having a high impedance at the feedpoint. Voltages can get *very* high, sufficient to cause flash-over, possibly destroying your matcher and/or your transmitter final amplifier.

Using the matcher

A variety of useful circuit configurations (by no means all the possibilities) are indicated in the accompanying diagrams.

Write down or make a mental note of the *total* length of your antenna, including the lead-in wire. When you tune to a particular band of interest, do a quick calculation to determine whether the antenna is close to an even number of half wavelengths long, close to an odd number of quarter wavelengths long, or shorter than a quarter-wave. This will indicate whether the antenna is likely to have a high, low or high impedance at the lead-in, respectively, and will point to the sort of circuit configuration to use.

Having determined that, make the appropriate jumper connections and tune in a signal. Adjust the matcher controls for a peak in the receiver's S-meter reading. For best results, use a weak signal when peaking the matcher's controls.

You'll find that tuning adjustments are relatively broad when you have a longish antenna connected, but peak more sharply for short antennas. A little experimentation will soon indicate the best configuration for each band of interest. It is wise to keep a note of the circuit, jumper connections and control settings for each situation. Those configurations using the coil *and* the capacitor will allow small increments of adjustment, permitting better 'fine tuning'.

For best receiver performance, a configuration that shows 'sharp' (i.e: high circuit Q) tuning will considerably reduce the strength of signals away from the band of interest. This will aid 'double-spotting' problems with those inexpensive single-conversion receivers prone to this problem as well as reduce the problem of crossmodulation and front-end overload — quite apart from the benefit of improving the signal strength by matching the antenna to the receiver input! However, there is a slight drawback in that if you wish to move frequency by several hundred kilohertz within a band then you will most likely have to retune the matcher's capacitor. If you want 'broader' tuning (i.e: lower circuit Q) then use less 'L' and more 'C'. Some 'hand capacity' effects may be noticed at the higher frequencies when tuning high impedance antennas. ●