ACTIVE RECEIVING ANTENNA

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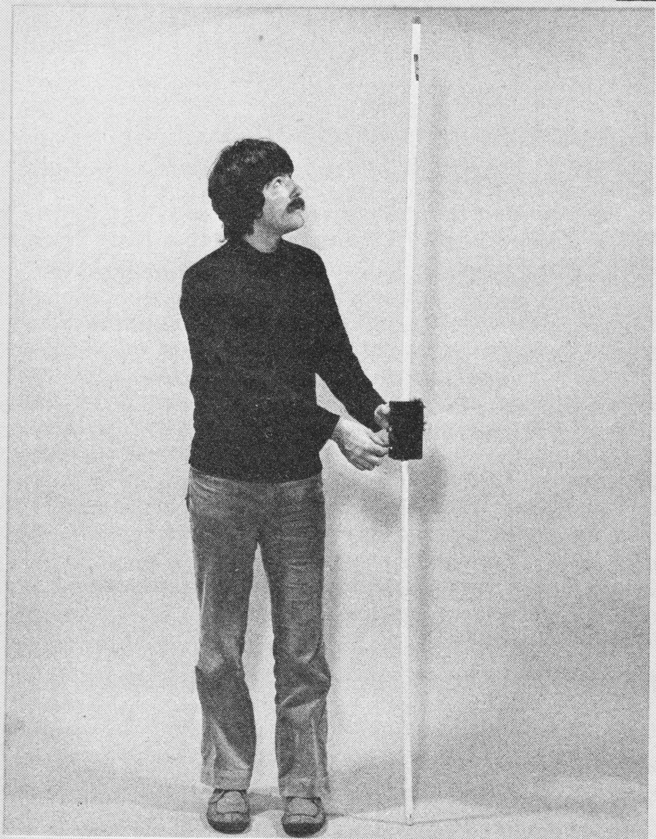


Due to limitations of space (and money), few of us are able to indulge in the antenna system that we would really like. Yet most of us recognise that the antenna system is crucial in determining the overall performance of any receiving or transmitting station. Those with large gardens who are fortunate enough to be able to install full-size antennas (e.g., a half-wave dipole for 80m) are relatively few and far between. Even then the available antenna space may have to be used in favour of some bands rather than others. For those dwelling in flats or town-houses the problems are even worse. If h.f. antennas can be installed at all they have to be very much smaller than the ideal and may well have to be made as inconspicuous as possible.

The active antenna described has a physical length which is only a small fraction of the operating wavelength, yet exhibits many of the properties of a full-size dipole. Its desirable features may be summarised as follows:

(a) Comparable directivity and polar response to that of a full-size dipole.
(b) Appreciable gain over a random length wire antenna.
(c) High degree of electrical balance between elements.
(c) In-built balun for coaxial output.

The antenna may be used over a wide range of frequencies, typically from 60kHz to 30MHz, and its directional properties are essentially the same as its full-size counterpart. The antenna may thus be rotated to provide optimum reception in a particular direction or, alternatively, may be used to "null" interference from an unwanted signal on an adjacent channel. Furthermore, the depth and symmetry of the null makes the antenna ideally suited to direction finding applications.

The antenna consists of a helically-wound short dipole which has a nominal half-wavelength at approximately 50MHz. The physical length is actually that of a half wavelength at 70MHz, however the helical winding increases the inductance of the antenna in a distributed fashion and provides a further reduction in overall length. To preserve the electrical balance of the dipole a symmetrical high input impedance matching stage is incorporated and this feeds a two-stage wideband amplifier, which provides a voltage gain in excess of 20dB. Construction is straightforward and uses readily available components. Because of its small size, the active receiving antenna is ideally suited for indoor use and thus will prove to be invaluable to the s.w.l. who, due to space limitations, is unable to construct a full-size antenna.

What is an Active Antenna?

Active antennas would, at first sight, appear to be a relatively new concept. However this is, in some measure, due to the comparative lack of information on the topic. Indeed even the distinction between active and passive antennas would appear to be somewhat hazy. For the purpose of this article we shall define an active antenna as one in which amplifying devices are incorporated as an integral part of the antenna. This has the further implication that there should be an uninterrupted length of feeder from an active antenna to the receiver rather than the more usual antenna/pre-amplifier/receiver arrangement where a length of feeder links each component in the system to the next.

An active antenna designed for reception purposes will generally not be suitable for transmission, if for no other reason than it will not be capable of handling the level of r.f. power involved. Another consideration is the efficiency of the antenna system. This is vitally important in transmitting applications but very much less so in reception. Efficient free-space coupling is not essential for receiving antennas and hence very short antennas can be used despite their inherent inefficiency. What is important is the need to transfer as much power as possible from the antenna to the receiver without dissipating overmuch in the matching network. In other words, it is the matching that is important. Short antennas are capacitive and have a relatively high impedance. Effective matching can be achieved by the use of active devices connected in a voltage follower configuration, thus avoiding the losses normally associated with matching networks consisting of inductors, capacitors, transformers and the like.

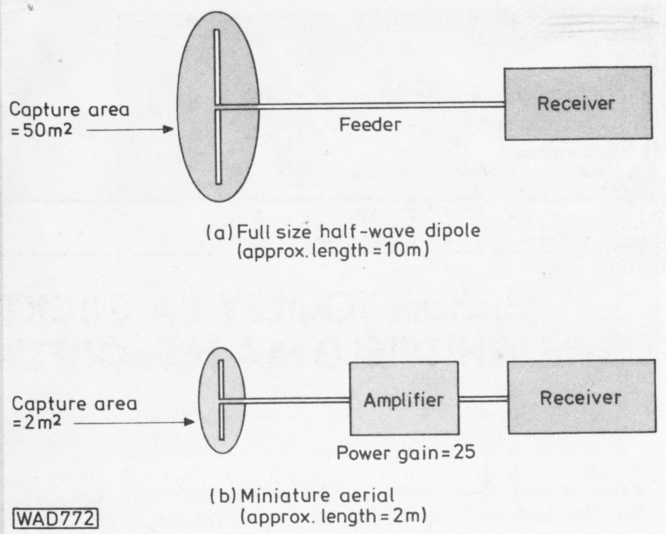


Fig. 1: Antenna systems with comparable performance at 15MHz

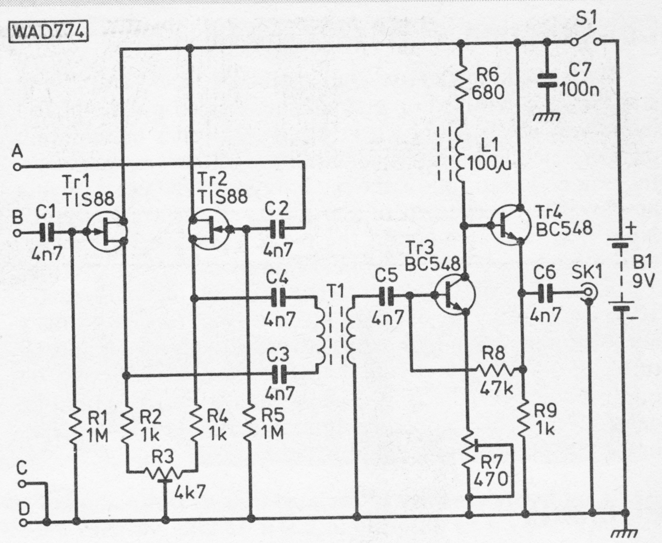


Fig. 3: Circuit diagram of the complete active antenna

Gain and Capture Area

A half-wave dipole captures energy from the area surrounding it. This capture area, which is somewhat greater than the physical area of the elements, is known as the equivalent aperture and effectively has an elliptical shape with the dipole aligned along its major axis. An antenna which is said to offer some "gain over a dipole" achieves this by having a correspondingly larger capture area. It therefore obtains more energy from an incident electromagnetic wave than would be acquired by a dipole. The capture area of a dipole is a function of frequency and is found by dividing the power delivered by the antenna into a matched load by the power per unit area available. It can be shown that:

$$\text{Capture area (half-wave dipole)} = 0{\cdot}131\lambda^2$$

$$\text{since } \lambda = \frac{v}{f} \text{ (where } v = 300 \times 10^6 \text{ m/s and f is in MHz)}$$

$$\text{Capture area (half-wave dipole)} = \frac{0{\cdot}131 \times (300 \times 10^6)^2}{f^2} \text{ m}^2$$

$$\text{or capture area (half-wave dipole)} = \frac{1{\cdot}179 \times 10^4}{f^2} \text{ m}^2$$

This relationship shows that the capture area is inversely proportional to the square of the frequency. To put this into context, at 10MHz a half-wave dipole exhibits a capture area of approximately 118 square metres, whereas at 30MHz its capture area would only be some 13 square metres. It should also be noted that this applies only to an ideal antenna supported clear of any obstructions and several wavelengths above earth.

Short Antennas

For short antennas the capture area will, of course, be proportionally reduced. However the performance of a short dipole may be considerably improved by the incorporation of active devices to provide additional power gain. In this case, adequate arrangements must be made for matching the antenna over a wide range of frequencies. If this is not taken into account, losses due to mismatch will be appreciable and the overall performance will be somewhat dependent upon frequency. Two comparable systems are shown in Fig. 1, and assuming that the matching was perfect, they would both deliver the same signal power at the receiver input.

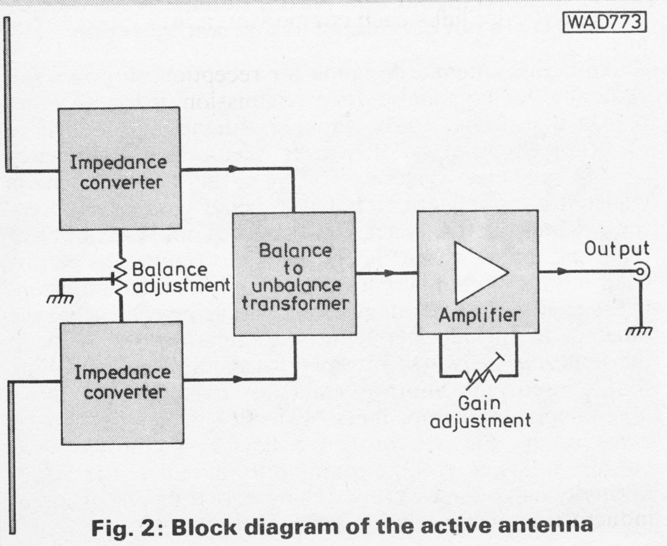


Fig. 2: Block diagram of the active antenna

Circuit Description

The simplified block schematic of the active antenna is shown in Fig. 2. Anti-phase signals from the antenna elements are connected to high-impedance, unity-gain matching stages. The outputs are combined in a balanced-to-unbalanced transformer (balun) and then fed to a wide-band amplifier. The complete circuit diagram is shown in Fig. 3. Transistors Tr1 and Tr2, connected as source followers, provide the input matching with R3, which sets the drain currents, acting as a balance control to compensate for variations in f.e.t. parameters and component values. Transistor Tr3 operates as a common emitter amplifier with peaking provided by L1 acting as part of the collector load. This inductor compensates for the stray capacitance at the collector and helps extend the h.f. performance of the amplifier. Emitter follower Tr4 provides matching to the relatively low impedance of the feeder which connects the active antenna to the receiver. Stabilisation of the bias is provided by R8, and the gain is preset by means of R7 which applies a measure of series current negative feedback.

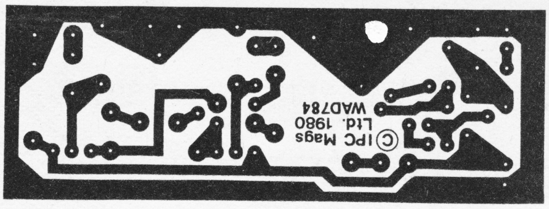
Construction

The components for the matching and amplifying stages are assembled on a small single-sided p.c.b., the foil layout of which is shown in Fig. 4. In order to maintain performance at high frequencies constructors are strongly recommended to follow the p.c.b. layout. The components are located on the top of the p.c.b. as shown in Fig. 5. Note that, since space on the p.c.b. is rather limited, the use of miniature components is essential. The transformer T1 is wound on a small ferrite ring of mean diameter 10mm according to the data given in Fig. 6. The primary and secondary windings consist respectively of 16 and 10 turns of 32 s.w.g. enamelled copper wire, closewound on opposite sides of the ring. The completed p.c.b. should be carefully checked and then mounted on stand-off pillars inside the plastics box, as shown in Fig. 7.

Elements

The antenna elements are constructed as follows: Obtain a 2·143m (7ft) length of 20mm diameter plastics conduit from an electrical contractor. With the aid of a hacksaw cut this to exactly 2·083m and then mark the centre point. Using the hacksaw cut a V-shaped slot in the centre. (*n.b.*, take great care not to place any undue strain on either end of the conduit since this may cause weakening at the centre of the "V".) Obtain a 250mm length of 16mm diameter dowel. Wind 80 turns of 18 s.w.g. enamelled copper wire closewound (i.e., adjacent turns touching) on this former. The overall length of the completed winding should be approximately 114mm. Carefully draw the winding off the former into the conduit and gradually increase the pitch to about one turn per 25mm. The arrangement shown in Fig. 8 shows probably the best method of doing this, though constructors may prefer to develop their own technique. It is important that the pitch of the coil is kept as uniform as possible throughout the entire length of the conduit.

Cut holes in opposite ends of the plastics box. These should accommodate the conduit, which should be a fairly tight push-fit. Then slide the box onto the conduit and position it at the exact centre with the V-shaped slot uppermost. The conduit should be secured to the case with the aid of a suitable adhesive. Bend the ends of the helix over



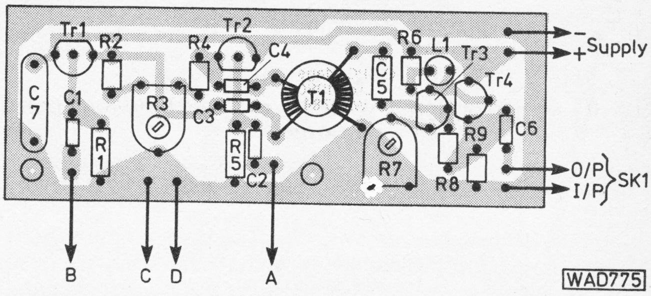


Fig. 4 (top): Full-size copper track pattern of the p.c.b. for the active antenna. Fig. 5 (above): The component placement diagram for the p.c.b. shown full size

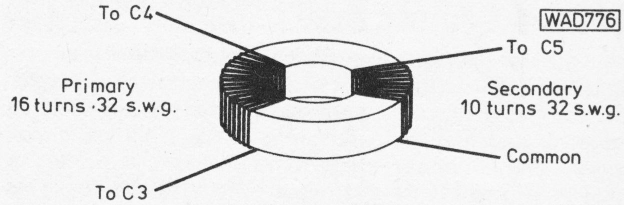


Fig. 6: Details of the toroidal coil. The windings should be secured with Denfix

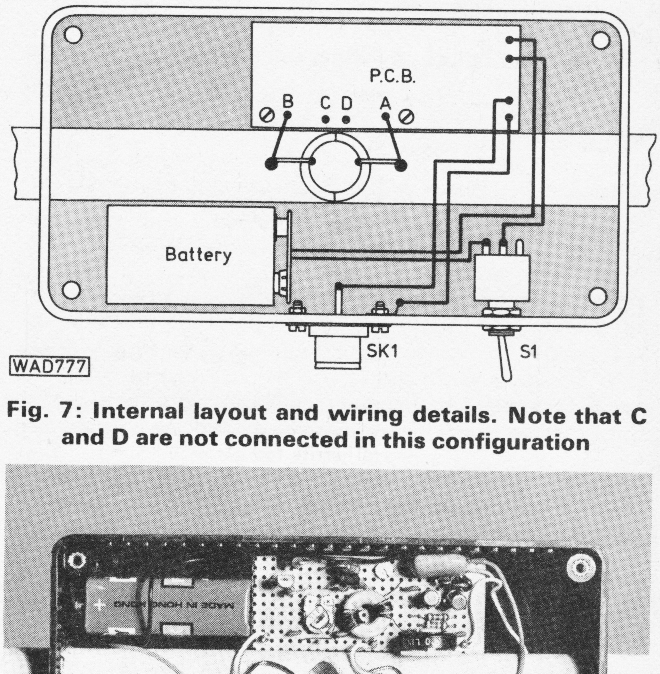
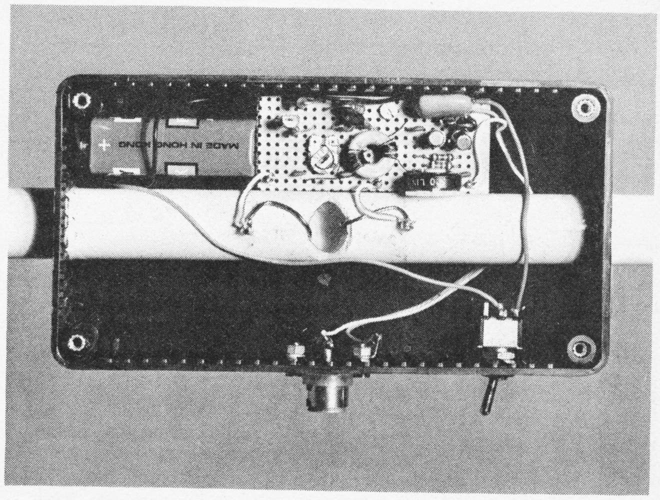


Fig. 7: Internal layout and wiring details. Note that C and D are not connected in this configuration



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...IMATE £7

Active Receiving Antenna, March 1981
The left-hand end track leadout of potentiometer R7 should **not** be connected to the earth plane. Remove sufficient copper from around this pin to ensure **no** connection is made.

+ T1 = Neosid 28-511-25 (12od, 6id, 3mm) enamel coated

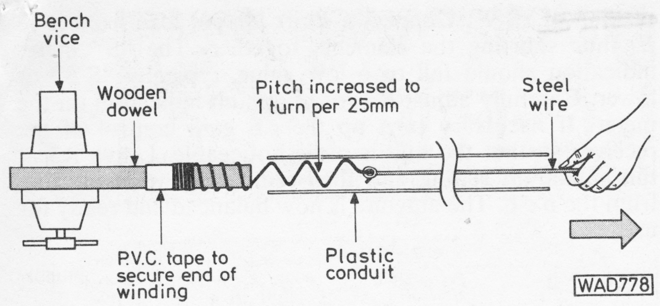

Fig. 8: Constructional method for the helical dipole elements

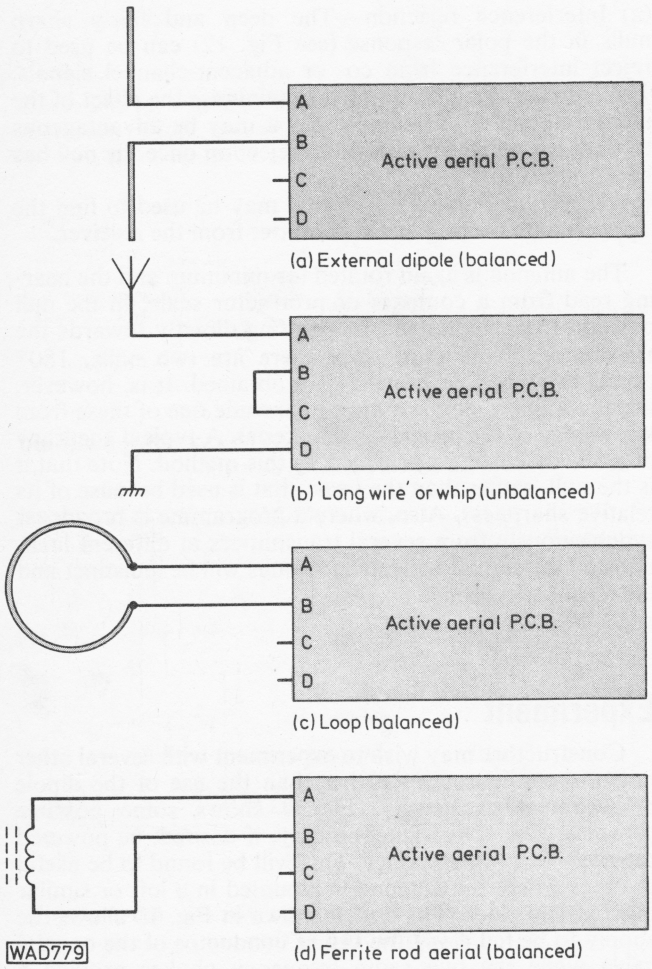

Fig. 9: Possible configurations of the active antenna

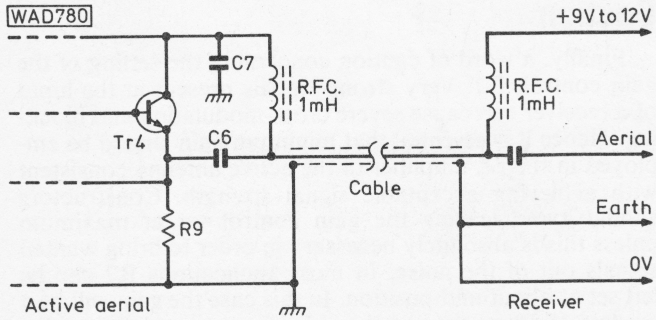

Fig. 10: Remote power feed to the active antenna

and secure them to the ends of the conduit using short lengths of pvc tape. Then, using the V-shaped hole for access, carefully cut the enamelled copper wire at the centre, bend and terminate it as shown in Fig. 7. The plastics conduit may be drilled to accommodate push-fit terminal pins, but do take care not to overheat the conduit when soldering the ends of the enamelled copper wire. Link the helical elements to the p.c.b. using short lengths of pvc-covered wire, and then connect the switch, battery connector and output socket, as shown in Fig. 7. The assembly is now complete and the active antenna is ready for initial checks and balancing.

Initial Checks and Adjustments

Connect a 9V PP3-size battery and insert a milliammeter to measure the supply current. Set R3 and R7 to mid-position and switch the supply on. The supply current should be in the range 12mA to 20mA. If this is not the case, carefully check the p.c.b. and associated wiring for errors. The output of the antenna should be connected to the receiver using a short length of coaxial cable. The impedance of this cable will normally be 50Ω but, if necessary, 75Ω cable may be used. Position the antenna horizontally and at some distance from the walls, ceiling and floor. Tune the receiver to a fairly weak signal in the range 1MHz to 2MHz. Observe the "S" meter indication and check that the signal is free from fading (QSB). Then vary the setting of the gain control, R7, and note the effect on the "S" meter. This should indicate an overall change of somewhat greater than 20dB. Adjust R7 to obtain a

★ components

Resistors		
¼W 5% Carbon		
680Ω	1	R6
1kΩ	3	R2,4,9
47kΩ	1	R8
1MΩ	2	R1,5
Potentiometers		
Linear preset		
470Ω	1	R7
4·7kΩ	1	R3
Semiconductors		
Transistors		
BC548	2	Tr3,4
TIS88	2	Tr1,2
Capacitors		
Polyester		
100nF	1	C7
Miniature Ceramic		
4·7nF	6	C1–6

Miscellaneous
100μH inductor; Miniature switch s.p.d.t.; Ferrite ring 9·53mm diameter T37-12 (Ambit); 9V battery; Plastics box, 150 × 80 × 50mm; Plastics conduit (Gilflex) 20mm o.d. (see text).

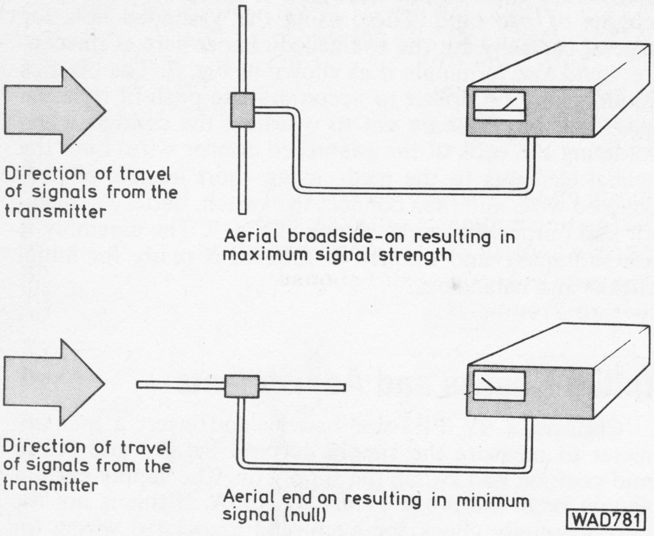

Fig. 11: Directional properties of the antenna

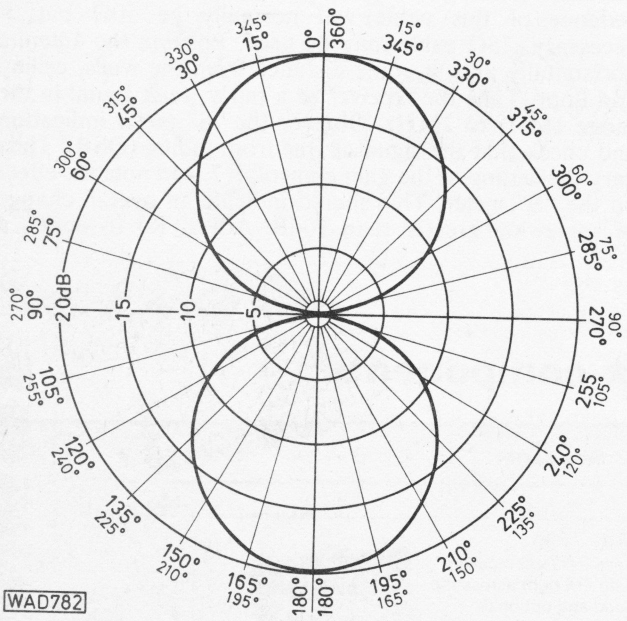

Fig. 12: Polar diagram of the active antenna at 1MHz

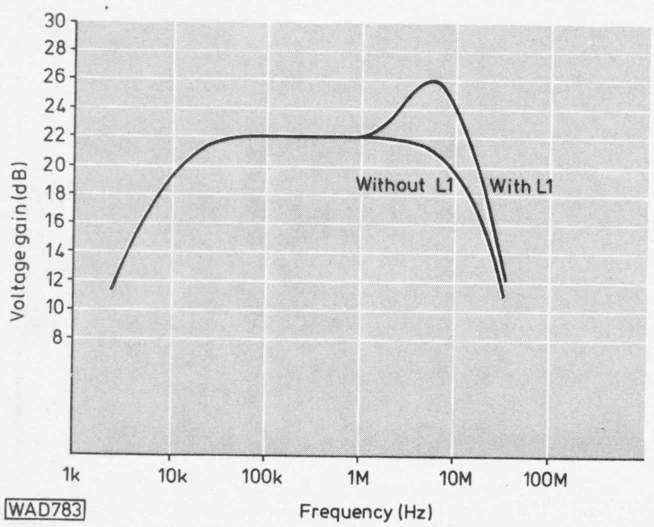

Fig. 13: Frequency response of the amplifier stage formed by Tr3 and Tr4

reading of "S-9". Connect a short jumper lead from *A* to *B*, thus shorting the elements together. The "S" meter indication should fall to a low value, typically "S-5" or lower. Carefully adjust R3 for minimum indication on the meter. If necessary turn up the r.f. gain control of the receiver so that the null is more noticeable. Leave R3 at this minimum setting and then remove the shorting link from the p.c.b. The antenna is now balanced and ready for use.

Using the Active Antenna

The directional properties of the antenna can be used in several ways:

(a) Interference rejection—The deep and fairly sharp nulls in the polar response (see Fig. 12) can be used to reject interference from co- or adjacent-channel signals. The antenna is simply rotated to minimise the effect of the interfering signal. In some cases it may be advantageous to slant the aerial for maximum rejection once the null has been found.

(b) Direction Finding—The null may be used to find the approximate bearing of a transmitter from the receiver.

The antenna is again rotated for minimum and the bearing read from a compass or protractor scale. In the null position the antenna will be pointing directly towards the transmitter. Note that, since there are two nulls, 180° apart, two possible bearings are obtained. It is, however, usually a fairly simple matter to exclude one of these from knowledge of the programme material. A typical accuracy of ±5° can easily be achieved by this method. Note that it is the null, rather than the peak, that is used because of its relative sharpness. Also, where a programme is broadcast synchronously from several transmitters at different locations on the same frequency, the nulls will be indistinct and the results will be meaningless.

Experiment

Constructors may wish to experiment with several other antenna configurations rather than the use of the dipole arrangement exclusively. Fig. 9 shows some possible schemes. The active antenna may, if desired, be powered remotely from the receiver. This will be found to be useful in cases where the antenna is mounted in a loft or similar inaccessible place. The circuit shown in Fig. 10 allows the supply to be fed along the centre conductor of the coaxial cable while the two radio frequency chokes provide a relatively high impedance at signal frequencies.

Caution

Finally, a word of caution concerning the setting of the gain control, R7. Very strong signals present at the input of a receiver can cause severe cross-modulation and blocking. Hence it is essential that minimum gain should be employed in the r.f. amplifier of the active antenna consistent with achieving acceptable signal strength. Constructors should avoid leaving the gain control set at maximum unless this is absolutely necessary in order to bring wanted signals out of the noise. In most applications R7 can be left set at about mid-position. In this case the gain will be a modest 10dB or so, and the risk of cross-modulation due to overloading the receiver will be considerably reduced. ●