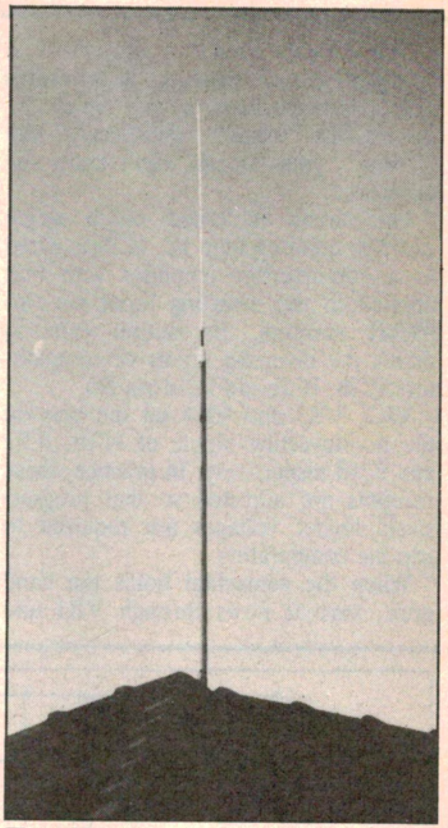
A tunable whip antenna for shortwave listening

What is the best type of antenna for shortwave listening? This article suggests the use of a tunable whip antenna instead of the classic "long wire". The tunable whip cuts down noise and interference, has good signal pickup and is compact.



The whip antenna should be mounted as high as possible above the house to avoid interference from mains wiring.

by RONALD SALTER

In contrast to the large number of refined antennas for the amateur bands, the shortwave listener is not well catered for. The usual text-book approach is to suggest a random length wire mounted as high as possible. Sometimes a noise-reducing feedline is mentioned, and occasionally an array of dipoles of different lengths is discussed.

There is little incentive to do better, because any reasonable length of wire will produce a wealth of signals. But this approach is sometimes impractical, firstly because it requires a fair amount of space, and secondly because a long antenna can often pick up broadcast band signals strong enough to cause splatter across most of the shortwave spectrum. The writer, who lives near the broadcast transmitters at Lower Plenty, is well aware of this problem. Furthermore, the radiation pattern of a long wire is random, and changes with frequency.

Many receivers are fitted with telescopic whips, which are non-directional, and generally do not pick up broadcast band signals of sufficient magnitude to cause splatter.

Whips, however, often do have a poor signal-to-noise ratio, because they are immersed in the household electromagnetic field. The writer wondered whether a whip could be installed clear of this field, which meant mounting it outside the house and preferably higher than about 10 metres. The problem is then how to couple the whip to the receiver via an efficient feedline. Experiments with high-impedance lines showed that only coaxial cable would give immunity to broadcast band pickup and other noise. So a device to match the high impedance of the whip to a 50 or 70Ω cable was needed.

A whip antenna, which can be defined as a vertical antenna shorter than a ¼-wavelength at the highest frequency to be used, exhibits a high impedance which can be broken into three parts — the radiation resistance, the earth resistance and the free-space capacitive reactance, which is the largest of the three. If a whip is connected to the usual low-impedance input of a receiver, much of the signal will be lost across the capacitive reactance. For example, a whip two metres long and 9 mm in diameter, the size used here, will have a capacitance of about 22pF, giving a reactance of 3500Ω at 3MHz. Connection direct to a 70Ω input will result in an attenuation of 17dB to an already small signal.

There are several existing methods of dealing with this problem; a coil in series with the whip will tune out the reactance — good at one frequency only — or a broadband transformer can be used when the impedance ratio is not too high. A better solution is to use a masthead amplifier with high input impedance and low output impedance. This method is used in at least one commercial "active antenna" and several types have been described in the literature. The writer tested two different designs but in each case cross-modulation was a problem. A high-pass filter ahead of the amplifier was only partly successful and made use of the broadcast band out of the question.

The writer uses an impedance matching device for an internal whip, consisting of no more than a tuned circuit with switched coil taps, and a low-impedance link winding. There is no observable cross-modulation, because of the short antenna length and extra selectivity of the coupler. So I wondered whether a similar system could be placed at the masthead.

Switched coils were out, so a system based on the multi-resonance circuit was considered.[1,2] But what to use for the tuning capacitor(s)? Varicap diodes, which change capacity in proportion to an applied DC bias, looked promising and it was apparent that they had other advantages. A drawback to the multi-

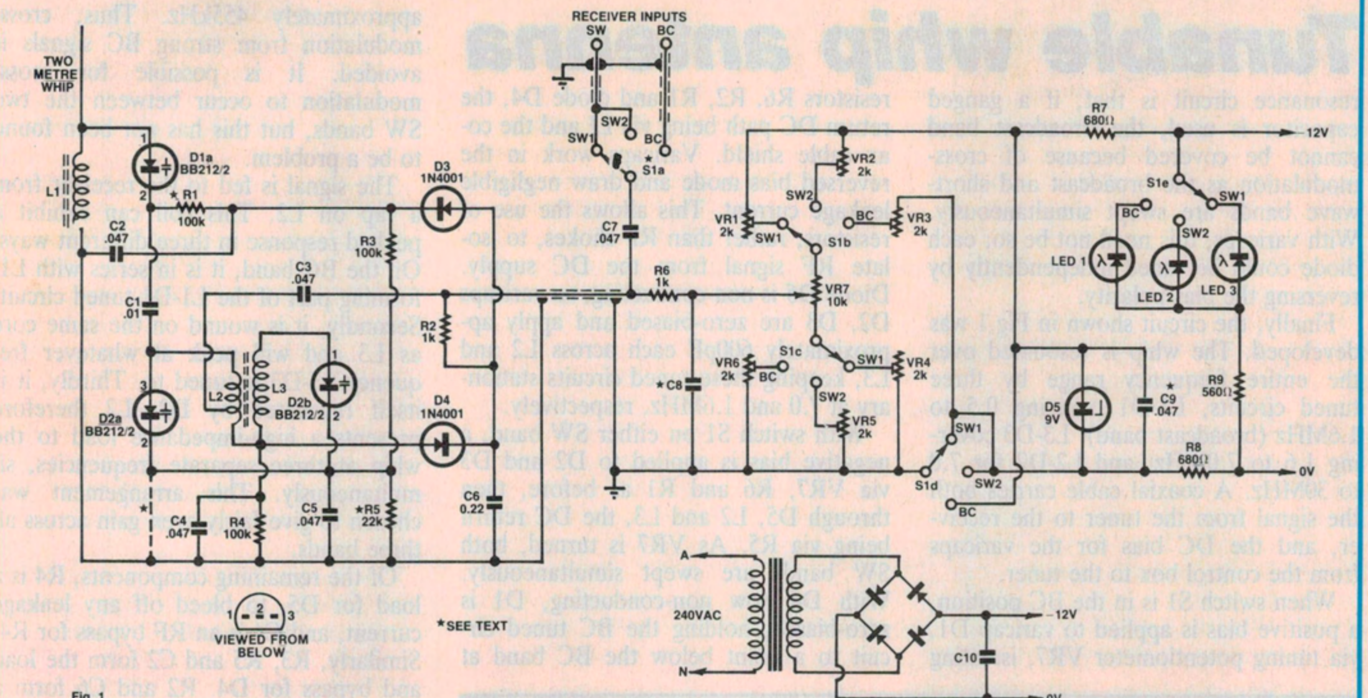


Fig. 1

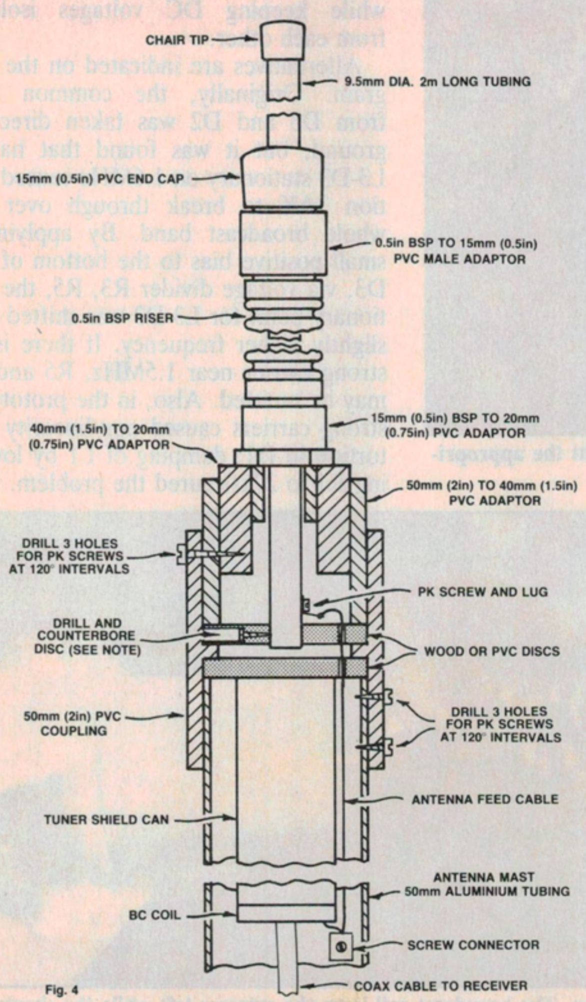
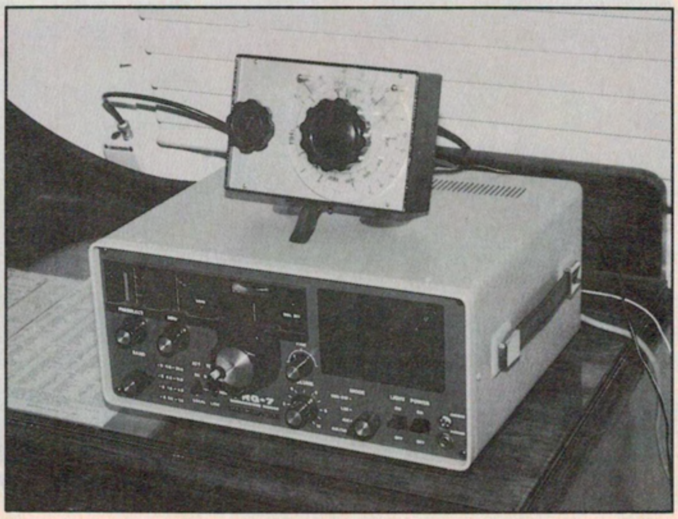


Fig. 4



This photo shows the antenna control box in position on top of the receiver and connected with coax cable to the wall socket.

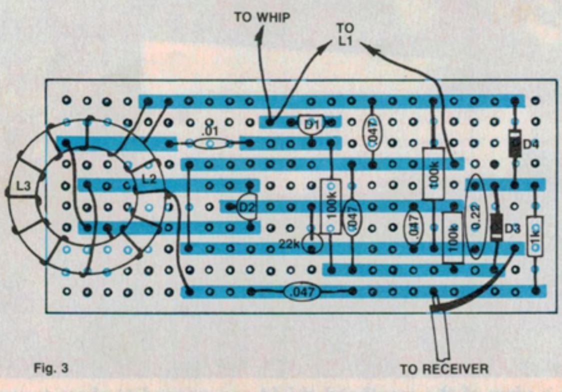


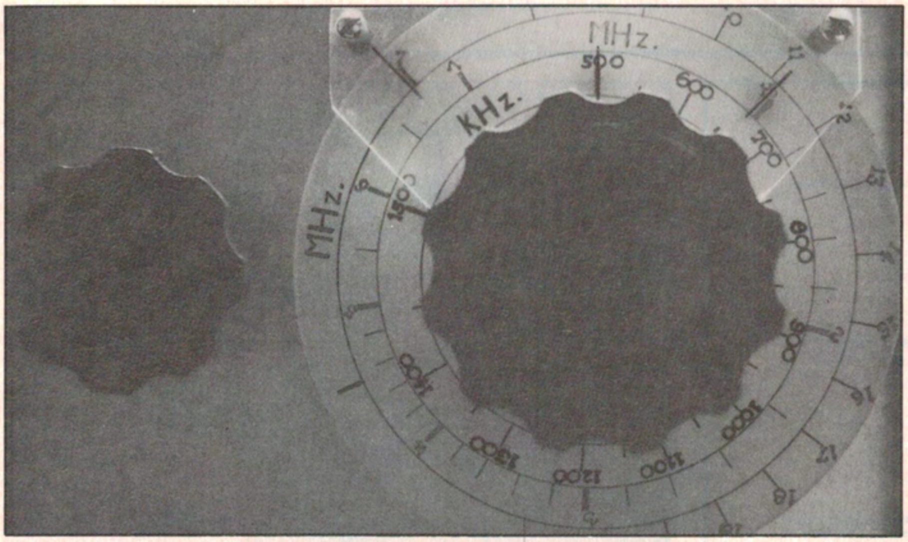
Fig. 3

resonance circuit is that, if a ganged capacitor is used, the broadcast band cannot be covered because of cross-modulation as the broadcast and shortwave bands are swept simultaneously. With varicaps, this need not be so; each diode could be tuned independently by reversing the bias polarity.

Finally, the circuit shown in Fig.1 was developed. The whip is resonated over the entire frequency range by three tuned circuits, L1-D1 covering 0.5 to 1.6MHz (broadcast band), L3-D3 covering 1.6 to 7.0MHz, and L2-D2 for 7.0 to 30MHz. A coaxial cable carries both the signal from the tuner to the receiver, and the DC bias for the varicaps from the control box to the tuner.

When switch S1 is in the BC position, a positive bias is applied to varicap D1, via tuning potentiometer VR7, isolating resistors R6, R2, R1 and diode D4, the return DC path being via LI and the coax cable shield. Varicaps work in the reversed bias mode and draw negligible leakage current. This allows the use of resistors, rather than RF chokes, to isolate RF signal from the DC supply. Diode D5 is non-conducting, so varicaps D2, D3 are zero-biased and apply approximately 600pF each across L2 and L3, keeping these tuned circuits stationary at 7.0 and 1.6MHz, respectively.

With switch S1 on either SW band, a negative bias is applied to D2 and D3 via VR7, R6 and R1 as before, then through D5, L2 and L3, the DC return being via R5. As VR7 is turned, both SW bands are swept simultaneously. With D4 now non-conducting, D1 is zero-biased, holding the BC tuned circuit to a point below the BC band at approximately 455kHz. Thus, cross-modulation from strong BC signals is avoided. It is possible for cross-modulation to occur between the two SW bands, but this has not been found to be a problem.

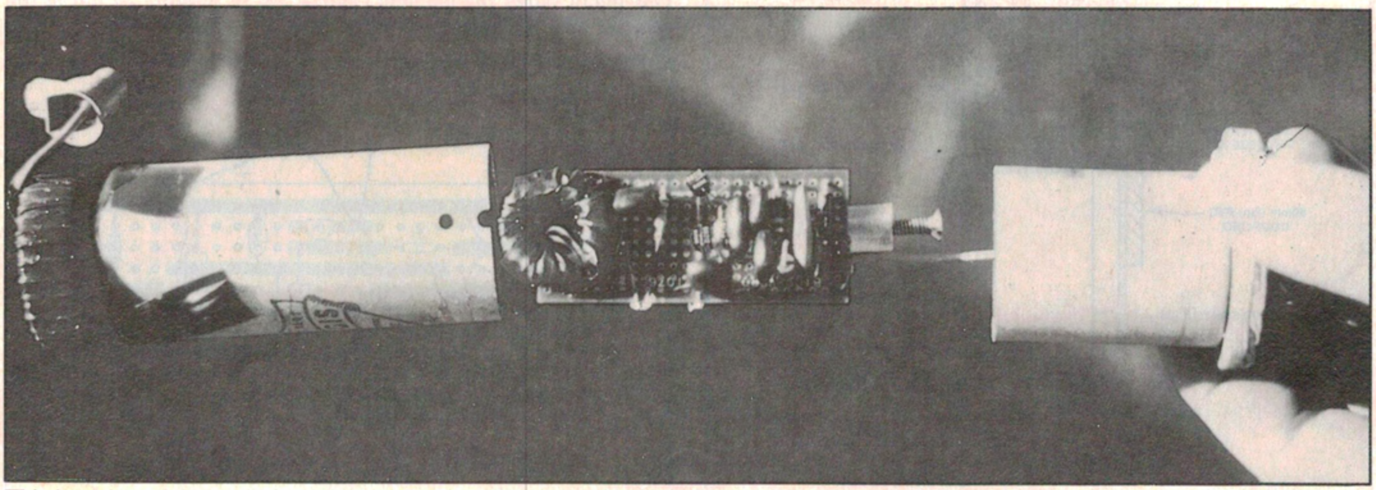


This is a close-up view of the control box. The LEDs are used to backlight the appropriate cursor mark.

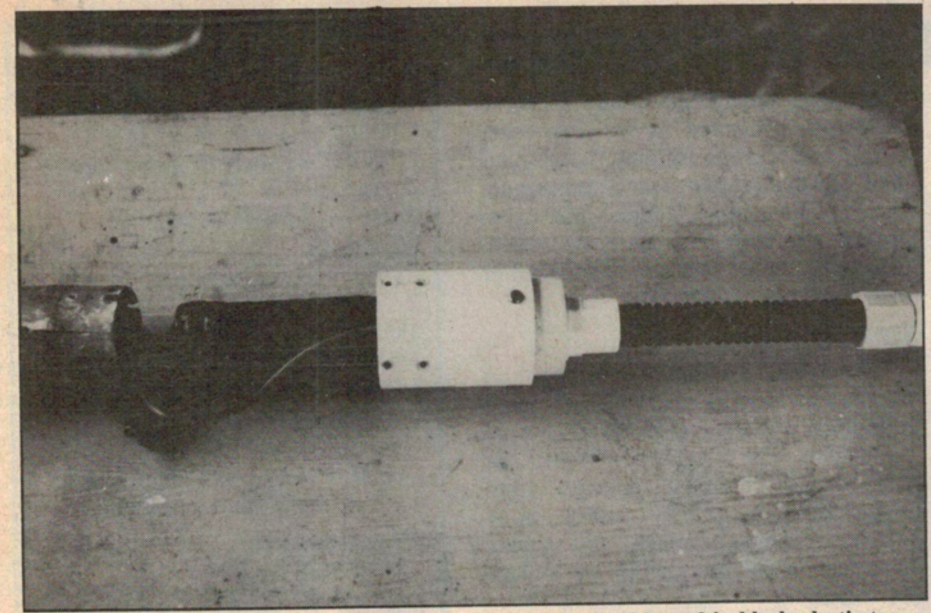
The signal is fed to the receiver from a tap on L2. This coil can exhibit a peaked response in three different ways. On the BC band, it is in series with L1, forming part of the L1-D1 tuned circuit. Secondly, it is wound on the same core as L3 and will peak at whatever frequency L3-D3 is tuned to. Thirdly, it is itself resonated by D2. L2 therefore presents a high-impedance load to the whip at three separate frequencies, simultaneously. This arrangement was chosen to give fairly even gain across all three bands.

Of the remaining components, R4 is a load for D5, to bleed off any leakage current, and C4 is an RF bypass for R4. Similarly, R3, R5 and C2 form the load and bypass for D4. R2 and C6 form a low-pass filter, allowing DC to pass to D4 and D5, while blocking the RF component. CI and C3 allow RF to pass, while keeping DC voltages isolated from each other.

Alternatives are indicated on the diagram. Originally, the common lead from D3 and D2 was taken direct to ground, but it was found that having L3-D3 stationary on 1.6MHz caused station 3AK to break through over the whole broadcast band. By applying a small positive bias to the bottom of L3-D3, via voltage divider R3, R5, the stationary point for L3-D3 was shifted to a slightly higher frequency. If there is no strong carrier near 1.5MHz, R5 and C5 may be omitted. Also, in the prototype, strong carriers caused non-linearity distortion in D1; damping of L1 by lowering R1 to 27kΩ cured the problem. In a



This is a view of the masthead shield can opened to show tuner construction. The broadcast coil is on the extreme left while the shortwave coils are on the Veroboard. The antenna feedline from the tuner has a screw connector (left) to make assembly easy.



This is the masthead assembly with shield can in position and bound in black plastic tape. The screw connector joins the feedlines from the tuner and whip.

location remote from BC stations, R1 should remain at 100kΩ.

At the receiver end, all that is needed to control the tuner is a DC supply, a means of varying this between 1V and 8V, and a switch to reverse the polarity. In addition, the writer's control box includes preset alignment pots to allow use of a calibrated dial, a switch bank to route the signal to the appropriate antenna terminal and three LEDs to give band indication and on/off indication. The writer used a 12V packaged supply, but since 20mA of the total drain of 22mA is LED current, a battery supply may be used if the LEDs are omitted. (See Fig.5.)

Control features

From right to left, the LEDs indicate each band, as selected by the switch bank. R7 and R8 serve the dual role of current limiting for the zener diode D6 and, in conjunction with C9, filtering any RF from the power supply leads.

S1, a 3-position 5-pole rotary switch, performs several functions. Pole S1a switches the RF to the BC or SW receiver inputs as required; for a receiver with one antenna terminal, the pole for S1a is not required.

With the switch set to shortwave band SW1 as shown in Fig.1, −9V is applied across alignment pot VR1, switch bank SWB, tuning pot VR7 and trimpot VR4. Fig.2 shows that about −1 to −9 volts is required across VR7, so 0.5V is dropped across each trimpot. A similar path is followed for band SW2, the trimpots now being VR2 and VR5. In the BC band position, the polarity across VR7 is reversed, +9V now being applied across VR3, VR7 and VR6 in that order. Some potentiometers used for VR7 were found to superimpose a rustling sound on the signal when being turned, which was annoying when trying to peak the tuning. The addition of C8 cured the problem; values between 0.1μF and 1μF can be tried. R6 and C7 allow separation of the signal coming from, and the DC bias going to, the coax cable.

The performance of a short antenna can be marred by accidental pickup, either via the power leads, building earth wire, or metal near the antenna, such as guttering or guy wires. Such signals are often noisy and it is worthwhile to reduce them as much as possible. One measure, the usefulness of which appears to depend on the band in use, is to use an earth system separate from the building's electrical earth. The writer's system consists of three 1.2 metre lengths of 25mm galvanised pipe, driven until only 100mm is above ground. These are spaced two metres apart and sited to allow the shortest cable run to the receiver. Seven-strand cable (the old "7/.029 earth wire") is used to bond the electrodes, the antenna pole, the coax, cable sheath, and a wall-mounted terminal near the receiver. The system has a DC resistance to earth of 10Ω with moist soil.

The writer also uses a line filter fitted with low current fuses (1A) to ensure good electrical fault protection when using the separate earth.

To evaluate the performance of the whip, two other antennas were erected — a 9.6MHz dipole and a long wire approximately 30 metres long. Comparative tests for gain, signal/noise ratio and fading depth, were run on signals selected at random from 2.5 to 21MHz, using a pen recorder coupled to the receiver's AGC line. Because of the difficulty of making such measurements in a domestic situation, only general conclusions can be drawn. Even so, the whip compared well with the other antennae.

At 9.6MHz the whip averaged +3.5dB gain over the dipole; however in the direction of the dipole's maximum response — due north and south — the whip was 3dB down. Compared to the long wire, the whip was about −5dB at the lower frequencies, rising to +4dB at the top end.

TABLE 1. COIL DATA

Coil	Band	Frequency Range	Inductance	Iron Powder Cores	Ferrite Cores
L1	BC	0.5-1.5MHz	210μH	92 turns on TI30 core, type 2 matl, 24g (max)	51 turns on FT114 core, type 61 matl, 20g (max)
L3	SW1	1.5-7.0MHz	18μH	36 turns on T106 core*, type 2 matl, 20g (max)	16 turns on FT50 core*, type 61 matl, 20g (max)
L2	SW2	7.0-30MHz	0.9μH	8 turns on T106 core*, type 2 matl, tapped 22 turns from "cold" end.** 20g (max)	4 turns on FT50 core*, type 61 matl, tapped 1 turn from "cold" end.** 20g (max)

*Coils L2 & L3 wound on same core.
**Try tap from 2 to 5 turns on T106 core, or from 1 to 2 turns on FT50 core.

Tunable whip antenna

Signal/noise ratio was measured by comparing carrier strength with the S-meter noise reading on the nearest clear frequency. The whip gave better figures than either the dipole or long wire — not the expected result for a vertical antenna. Listening tests showed that the whip was more susceptible to impulse noise, such as car ignition pulses, whereas the other antennae were victims of the BC cross-modulation hash mentioned above. Fading depth was measured as the difference, in dB, between the maximum and minimum signal strengths over a two-minute period. The whip averaged 2dB down against the long wire over the whole frequency range and was +6dB better than the dipole at 9.6MHz.

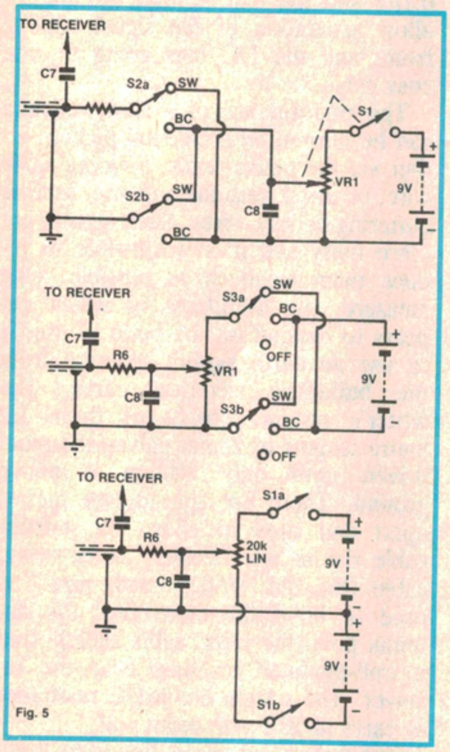


Fig. 5

Construction

The masthead circuitry is mounted on Veroboard (Fig.3) and housed in a cylindrical container made from two old shield cans. The layout isn't critical, but you should minimise leakage from tracks carrying RF by cutting away unused sections of track. Use epoxy fibreglass board, or similar, to reduce RF losses.

Coils for the prototype were wound on toroid cores too old to classify. Coil data in Table 1 is for Amidon cores, calculated from measurements made on the prototype. Minor adjustments to numbers of turns may be needed, to get correct band coverage with the trimpots near the centre of travel. This isn't as hard as it sounds — being a short antenna, the whole masthead assembly can be set up horizontally on the bench.

The writer's antenna pole is made from two aluminium tubes having a total height of 11 metres; it is held upright by a bracket screwed to the house eaves and guy wires are not needed. The masthead mounting was made up from PVC pipe fittings from the local

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PARTS LIST

3 BB212 varicap diodes
2 1N4001 silicon diodes
1 1N757 9V 400mW zener diode
3 red LEDs
1 3-pole 5-position switch

Resistors

(0.5W, 10% tolerance)
3 x 100kΩ, 1 x 22kΩ, 2 x 1kΩ/0.25W, 2 x 680Ω/0.25W, 1 x 560Ω/1W, 1 x 10kΩ (lin) potentiometer, 6 x 2kΩ trimpots

Capacitors

1 0.22µF/50VW ceramic
6 .047µF metallised polyester
1 .01µF metallised polyester

Miscellaneous

1 plastic zippy box
1 dial and cursor
2 knobs
Veroboard for circuit components (see diagram)
1 12V DC mains plugpack
Coax cable, enamelled copper wire for coils

Hardware

2 metres of 9.5mm diameter aluminium tubing
2 aluminium shield cans (see text)
1 15mm PVC end cap
1 ½in BSP to 15mm PVC adaptor
1 ½in BSP to 20mm PVC adaptor
1 20mm to 40mm PVC adaptor
1 40mm to 50mm PVC adaptor
1 ½in BSP riser
1 50mm PVC coupling

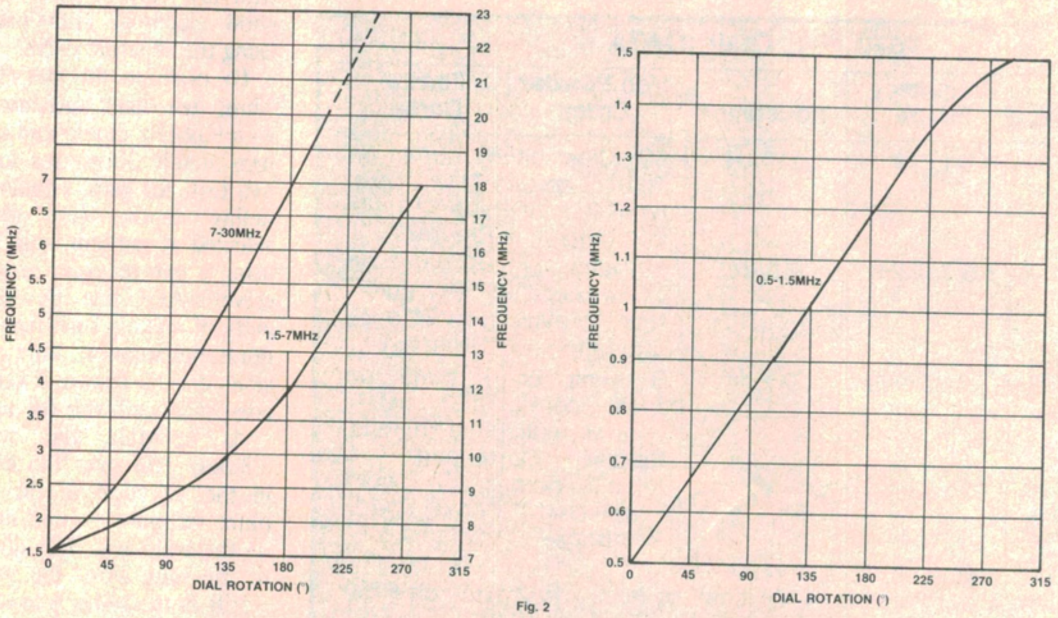

Fig. 2

Tunable antenna...from p.51

plumbing store, the largest of which was chosen to give an approximate fit with the outside diameter of the top of the pole (Fig.4). The "insulator" in the photos is a pipe fitting called a "½ inch BSP Riser". Two discs, cut to fit inside the 50mm coupling, must be made from 6mm thick PVC sheet or plywood. The coupling must have an internal ring, originally needed to ensure that each pipe can only be inserted in the coupling. This stop will keep the two discs apart.

The upper disc has a centre hole to take the bottom of the whip, which is held in place by a PK (self-tapping) screw passing through the disc edgewise, like a grub-screw. The screw hole should be counter-bored to keep the screw head from protruding above the edge of the disc. About 20mm from the bottom end of the whip, drill a hole to take a PK screw for the feedwire lug. Drill holes through the face of each disc to allow passage for the feedwire. The lower disc also requires two holes for shieldcan mounting screws. The heads of these screws **must not** touch the bottom of the whip when assembled.

Drill a hole in the PVC end cap to make a tight sliding fit for the whip. Use PVC glue when assembling the fittings, but fasten the coupling and 40/50 mm adaptor together with three PK screws as in Fig.4, so that these fittings may be taken apart for inspection. The writer used 6 PK screws to fasten the coupling to the top of the pole. In the prototype, the outside diameter of the pole was a little large for the coupling, so the pole diameter was reduced by cutting several slots in the top of the pole, then squeezing the diameter in a little. If the reverse applies, a shim made of aluminium (not gal. iron) can be inserted in the coupling.

The control box is held in place on top of the receiver by a mounting bracket fitted with rubber suction cups; if the receiver cabinet is steel, small ferrite magnets may be used instead. Inside the box, the trimpots were mounted on a scrap of circuit board, while the resistors and capacitors are mounted on a tagstrip. If an external DC supply is used, it will require an insulated socket in the back of the box, since each side of the supply is connected to earth alternatively. The writer used a 3.5 mm phone socket mounted in a rubber grommet. (It should be obvious that neither DC lead should be earthed at the power supply!) Keep the leads from this socket to R7, R8 and R9 as short as possible, to minimise stray RF from the power supply.

Three coax cables were taken out at the back of the box — one for the antenna feedline, and two for the receiver antenna terminals. The tuning dial was made from opal perspex, using fine tip brush pens for the scales. The calibration curves (Fig.2) do not utilise the full rotation of a normal potentiometer, but allow for some overlap on each range. Three LEDs, mounted behind the dial, shine through it to act as band indicators and pilot lights.

A calibrated dial is convenient but not essential. A simple numerical scale or just a large knob may be used, the antenna tuning being peaked on background noise or S-meter reading. Nor need the control circuit be as complex as the prototype. Fig.5 shows three simple arrangements, each of which was tried during testing.

References:

1. Two Solid-state Preamplifiers, by I. Pogson. Electronics Australia, July 1970.

2. Multiband Vertical Aerials, by I. Pogson. Electronics Australia, August 1972.