Construction Project:

ACTIVE ANTENNA FOR HF RECEPTION

Here's the design for a low cost, really easy to build unit which can provide surprisingly improved reception up to 30MHz, using either a telescopic rod, a few metres of wire draped from a picture rail or dangling from a window, or an indoor dipole. It can also be used to improve the performance of elderly shortwave receivers, in terms of both sensitivity and selectivity.

by JIM ROWE

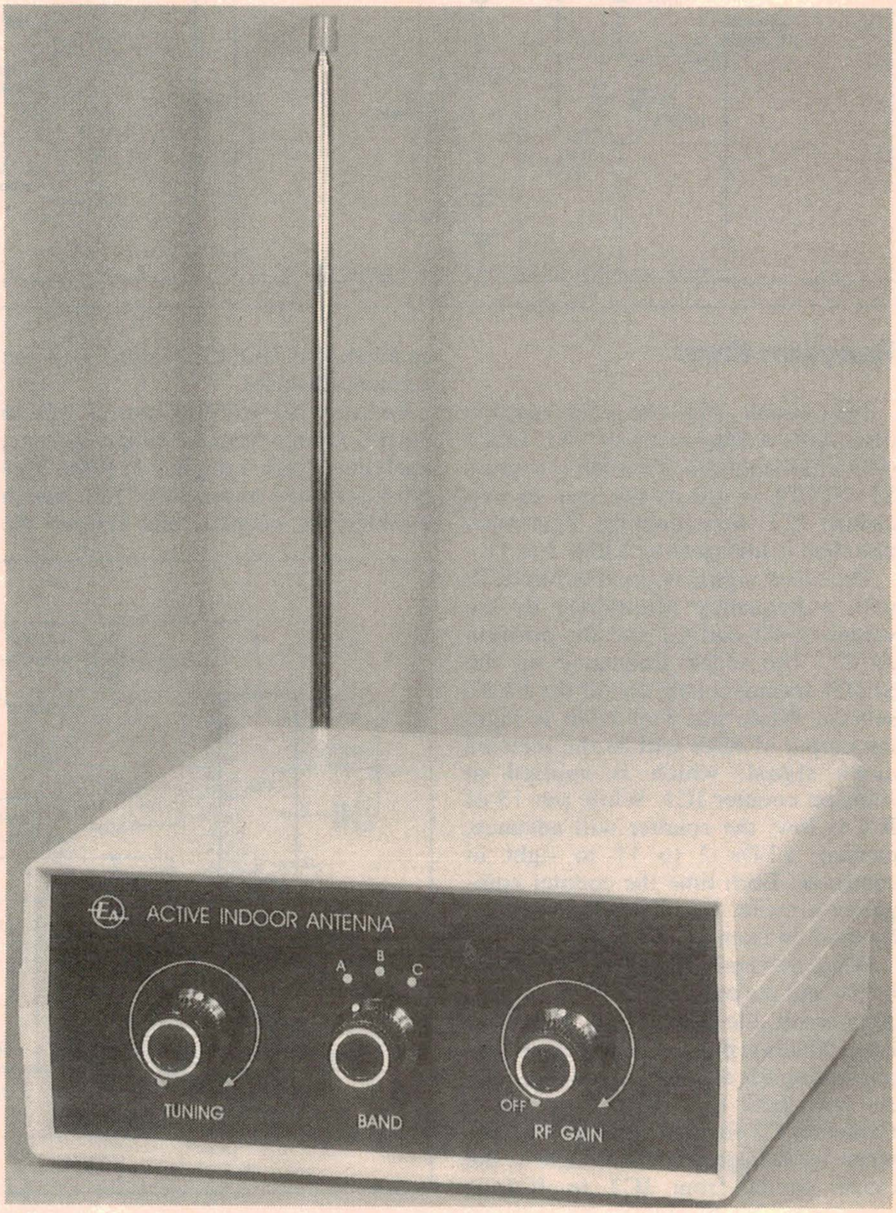
Nowadays many people live in fairly crowded urban and suburban situations, where setting up an efficient antenna for shortwave reception — or even broadcast band 'DX' — either isn't easy, may not be practical because of restricted space, or is possibly even 'not allowed' by the body corporate. As a result it's often a matter of having to settle for either a modest telescopic rod antenna or a few metres of insulated hookup wire, either poking or dangling from a window, or draped around the inside of a window frame, etc.

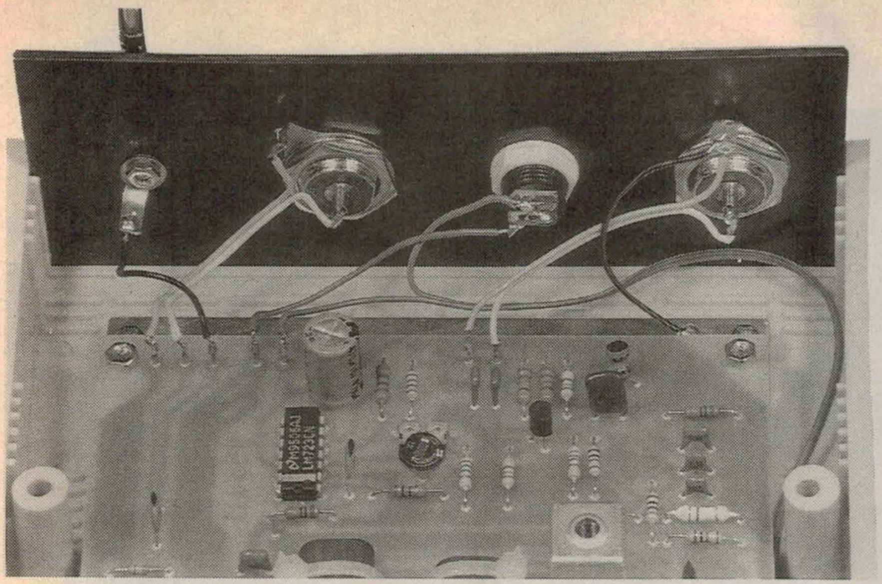
Of course there's no real substitute for a good outdoor antenna, suspended at the appropriate height and ideally balanced with respect to ground, so it picks up the least possible noise and interference.

But if such an antenna really is out of the question, as it often is, an alternative approach which can often deliver quite reasonable reception is to couple the small antenna you *can* use up to a small RF preamplifier and preselector unit like the one described here. The gain of the preamplifier boosts the relatively low signal levels delivered by the small antenna, while the additional selectivity provided by the preselection tuned circuit helps minimise interference and cross modulation from strong signals nearby.

Ideally the gain of such an 'active antenna' unit should be adjustable, to prevent receiver overload when the signal you're trying to receive turns out to be quite strong already. In fact smoothly variable gain is very desirable, allowing you to achieve the best compromise between gain, overload margin and interference rejection, whatever the level of your desired signal.

The unit described here has been designed to provide all of these facilities, in a compact and low cost form. It's also quite easy to build, with all of the parts readily available from normal stockists.





Use this view of the inside of the case, looking towards the rear panel, as a guide when wiring up the various connectors and also the rear section of the PCB. Note the use of PCB pins for the off-board connections.

Housed in one of the standard small plastic instrument cases, and with most of the components on a small PC board to simplify construction, it provides tuneable selectivity and a healthy but smoothly adjustable gain, from 500kHz (below the bottom of the AM broadcast band) right up to 30MHz, at the top of the HF shortwave band.

And it's designed to work with either a small telescopic rod antenna, as shown in the photo, or a short length of wire. In fact it also has an optional low impedance input, so that if you have the room to put up a small balanced antenna, this can also be coupled to the unit via a wideband balun. More about this later.

The preselector circuitry tunes smoothly over the frequency range in three bands, and the preamp has a maximum gain which varies from about 32dB at the low end down to about 20dB at the top end.

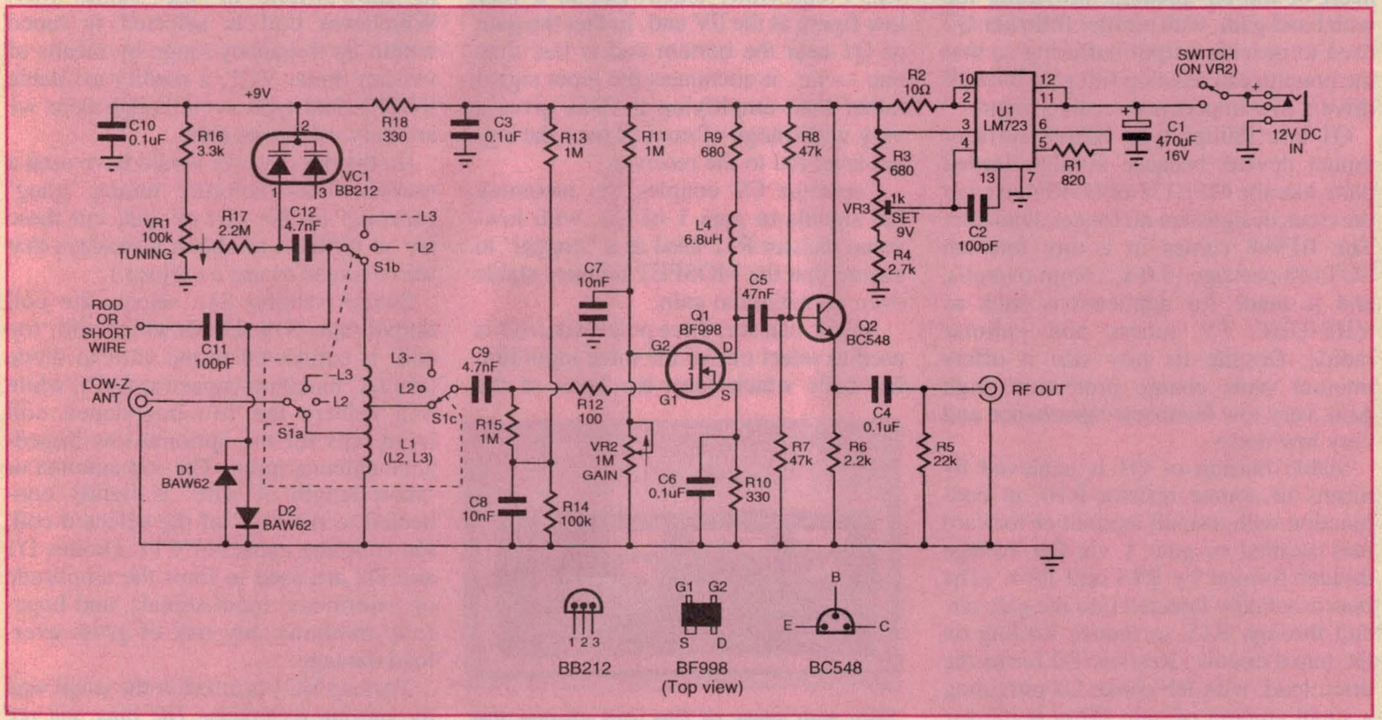
This is more than enough gain for the job, and provides a very noticeable boost in reception — especially with older or simpler receivers.

A dual-gate MOSFET is used as the main gain element in the preamp, and this has some important advantages. One is that these devices have far better overload and cross-modulation characteristics than bipolar transistors or ICs. Another is that they provide very stable gain, because of the very low signal feedback provided by their internal 'cascode' structure. Yet another advantage is that the gain of a dual-gate MOSFET can be adjusted very smoothly from maximum down to virtually zero, by simply varying the DC bias voltage on gate two.

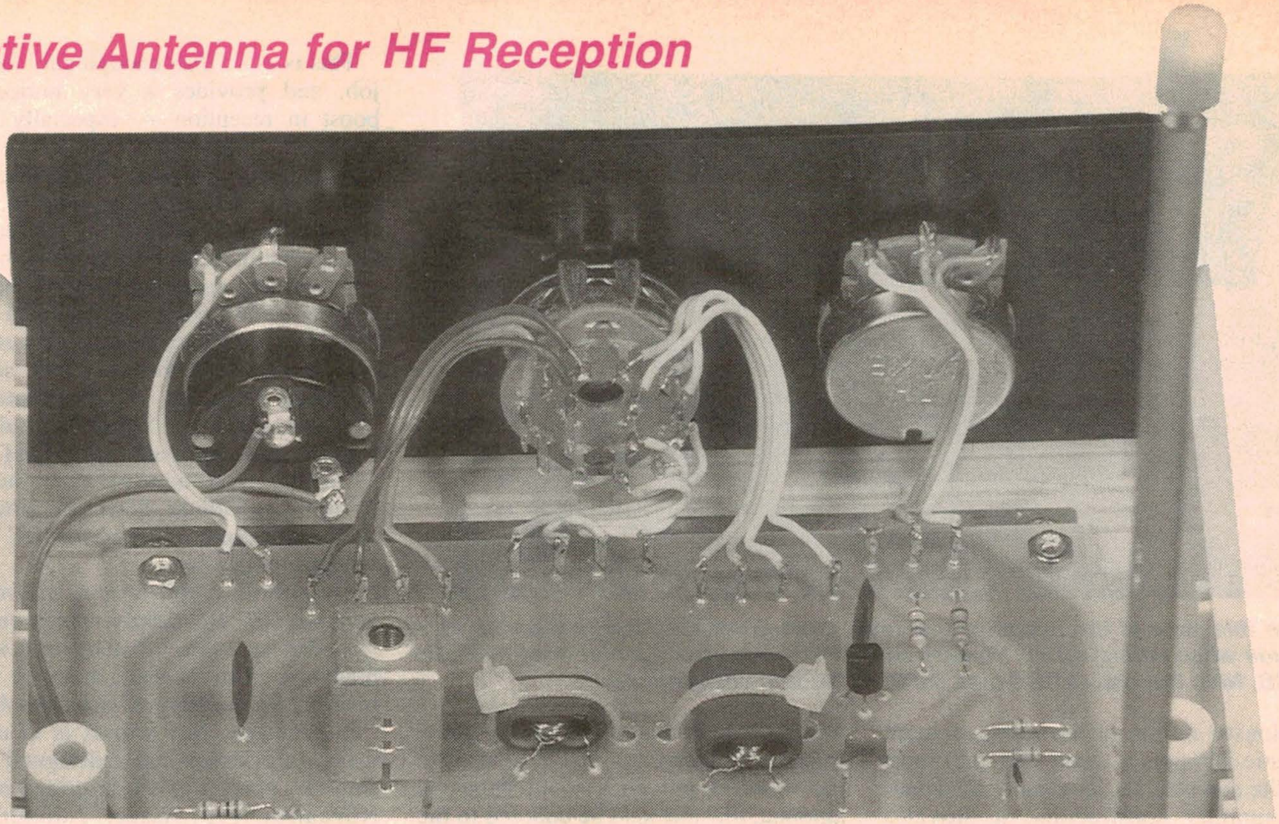
The complete unit is operated from a nominal 12V DC supply, which can be provided by either a battery or a small plugpack. The current drain is very modest, at typically less than 10mA.

Incidentally, this project is in many ways an updated and redesigned version of a similar unit I described in the November 1991 issue. Although it offers a few less 'frills' than the earlier design, it is considerably cheaper and easier to build, and still offers virtually all of the most useful features of its larger predecessor.

In any case the earlier unit is now obsolete, as some of the key parts it used are no longer available.



Dual gate MOSFET Q1 and output buffer Q2 form a wide band amplifier, while coils L1-L3 are tuned by varicap VC1 to form the preselector section. U1 provides voltage regulation for the circuit's 9V supply rail.



Looking towards the back of the front panel, this second internal photo can be used as a guide when you're winding and mounting the coils, and also when you are wiring between the PCB and the front panel controls.

Circuit description

As you can see from the schematic, there isn't a great deal of circuitry involved. Dual-gate MOSFET Q1 is the heart of the RF preamp, providing the wideband gain, with emitter follower Q2 used to provide output buffering so that the preamp can develop full gain but still drive a low impedance receiver input.

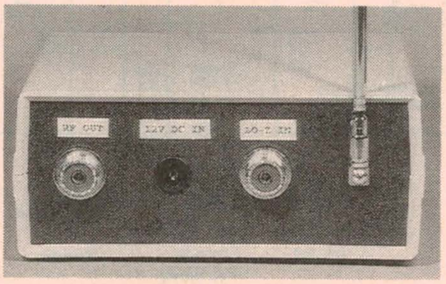
Q1 is a Philips type BF998 surface-mount device, because familiar leaded parts like the MFE131 or BFR84 used in previous designs are no longer available. The BF998 comes in a tiny four-tab SOT143 package (3.0 x 2.5mm overall), and is made for applications such as VHF-UHF TV tuners and cellular radios. Despite its tiny size it offers internal static charge protection, high gain, very low feedback capacitance and very low noise.

Stable biasing of Q1 is achieved by means of source resistor R10, in conjunction with a small amount of forward bias applied to gate 1 via the voltage divider formed by R13 and R14. (The bias is actually injected into the gate circuit through R15, to reduce loading on the tuned circuit.) Resistor R9 forms the drain load, with RF choke L4 providing a small amount of gain lift near the top end of the frequency range.

Variable resistor VR2 allows adjustment of the DC voltage applied to G2 of the MOSFET, from zero to about +4.5V. This provides a very smooth control over its gain, from maximum at the +4.5V end (fully clockwise) to a very low figure at the 0V end. In fact the gain of Q1 near the bottom end is less than one — i.e., it attenuates the input signal rather than amplifying it. This gives a very wide range of control over the signal level fed to the receiver.

Capacitor C9 couples the incoming RF signals to gate 1 of Q1, with low-value resistor R12 used as a 'stopper' to ensure that the MOSFET remains stable even at maximum gain.

As you can see, three pole switch S1 is used to select one of the three input tuning coils which form the heart of the preselector circuit. Only one of these coils, L1 (which covers from 500kHz to a little over 2MHz) is shown in the schematic, but the other two are wired to the switch in the same way. Whichever coil is selected is tuned within its frequency range by means of varicap diode VC1, a readily available BB212 dual type — although here we are only using one half.



This rear view of the unit shows the RF and DC connectors, and also the base of the rod antenna.

(In the old days we would have used a traditional air-dielectric tuning 'gang' capacitor in this sort of unit, but these are so difficult to obtain nowadays that we're forced to use a varicap.)

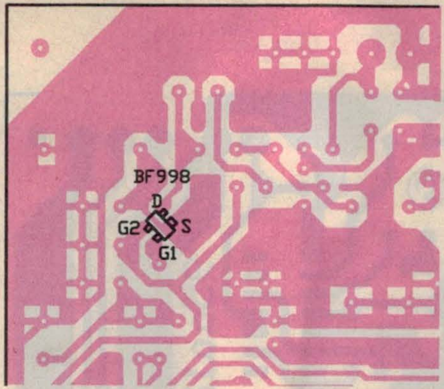
Switch section S1c selects the coil output taps, S1b selects which coil 'top end' is connected to the varicap diode (via DC blocking capacitor C12), while S1a selects the low-impedance coil input taps for the optional low-impedance antenna input. The rod antenna or 'short length of wire' is lightly connected to the 'top' of the selected coil, via coupling capacitor C11. Diodes D1 and D2 are used to limit the amplitude of 'enormous' input signals, and hopefully minimise any risk of gross overload damage.

Varicap VC1 is tuned in the usual way by varying its reverse DC bias, via pot VR1. Decoupling resistor R17 is again used to prevent loading of the tuned circuit, to achieve maximum 'Q' and selectivity. As the varicap is effectively connected between the +9V supply rail and the rotor of VR1, maximum reverse bias and hence minimum diode capacitance is achieved when the pot rotor is at the 'earth' end. This therefore corresponds to the 'top' end of each frequency range, when RV1 is turned fully clockwise.

To ensure that the tuning remains stable, the +9V supply rail for the varicap — which is also the supply rail for the preamp as a whole — is regulated quite 'tightly' via regulator chip U1. This is a time-proven LM723, connected in the standard way with preset pot VR3 used to allow its output to be set to exactly 9.0V. It's U1 that allows the circuit to be powered from virtually any nominal 12V DC source.

The incoming unregulated DC is controlled by a switch fitted to the rear of gain pot VR2, so the complete circuit is turned off when the pot is turned fully anticlockwise.

Incidentally, if you wish to protect the circuit (especially U1) from damage due to accidental polarity reversal of the incoming DC supply, this can easily be achieved by connecting a 1N4001 power diode (or even a 1N4148 signal diode) in series with the unregulated DC input. The only thing to remember if you do this is that the diode's voltage drop will reduce the input voltage reaching U1 by about 0.7V. As the LM723 requires an input voltage at least 3.0V higher than its output, this means that your plugpack or battery will need to provide a minimum of 12.7V for correct operation of the circuit.

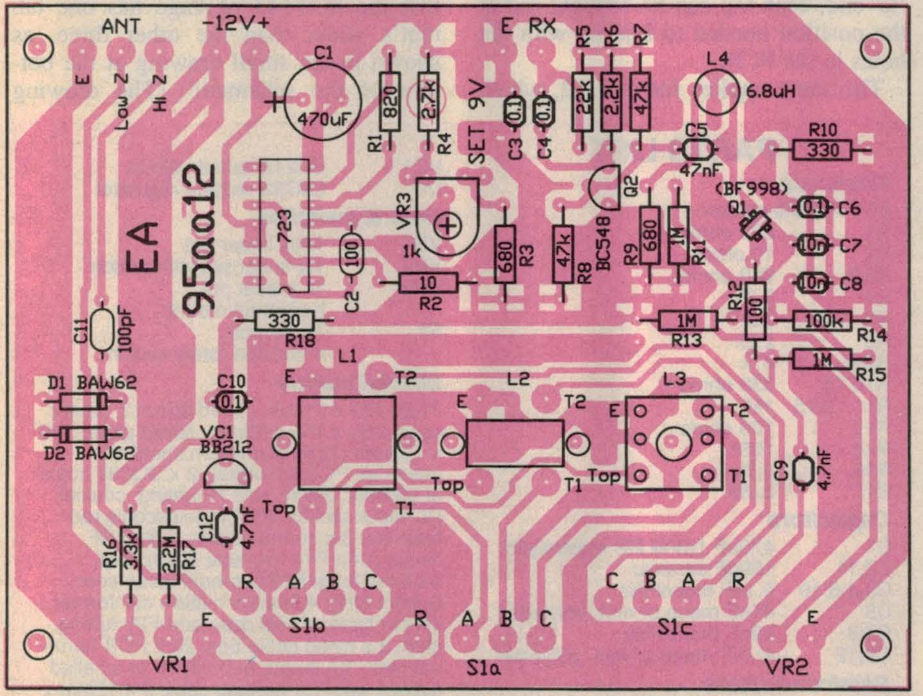


Use this supplementary overlay diagram as a guide when you're fitting the surface mount BF998 to the underside of the PCB.

Decoupling components R18 and C10 are used to ensure overall stability of the preselector-preamp circuit, by preventing any signal coupling via the +9V supply line.

Construction

As noted earlier, the complete circuit is housed in a standard small plastic instrument case. This measures 153 x 158 x 64mm, and is stocked by most of the popular suppliers. Inside all of the components except the three front panel controls and the various input and output connectors (along with the rod antenna) are mounted on a small PCB, measuring 120 x 91mm and coded 95aa12.



And here is the main overlay diagram, showing where all the other components are fitted on the top of the PCB. Also shown are the connections for the three preselector coils L1, L2 and L3 (see text).

As you can see from the photos, the three front panel controls are VR1 the tuning control pot, S1 the band switch and VR2 the RF gain pot (combined with the power switch). On the rear panel, running left to right from the rear are the RF output socket, the DC input jack, the optional low impedance RF input socket and the rod antenna.

For the prototype unit, the rod antenna I used came from Dick Smith Electronics. It has recently been added to DSE's 'spare parts' stock (Cat. No. ZA-4692), and is available from the Kit Department at North Ryde for $3.50 — plus postage if applicable.

It extends to 600mm, has a fold-down 'hinge' about 25mm from the base end and also a milled 'flat' at this end, with a 3.5mm hole to allow convenient mounting. I mounted it to the back panel with a 3mm x 12mm long machine screw, using a nut and star lockwasher to attach the screw to the rod base (and also space it away from the panel), and then a lockwasher, solder lug and final nut on the inside.

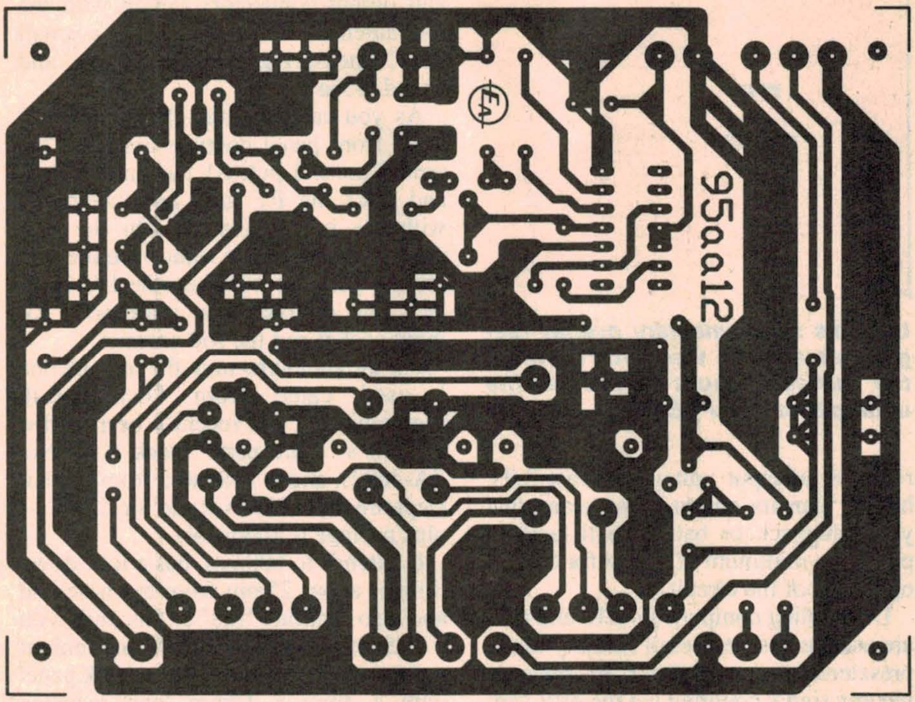
The PC board is not mounted directly inside the lower half of the plastic case, but on a combined mounting/shield plate. This is both to adapt the PCB to the somewhat wider-spaced mounting pillars in the case, and also to provide a worthwhile measure of shielding against noise and EMI. The plate measures 110 x 120mm, and can be made from either 1mm aluminium sheet or unetched PCB laminate. As you can see from the photos, it's connected electrically to the 'earth' lug on the RF output socket.

The PCB is supported about 5mm above the plate by mounting it via four 3mm x 12mm long machine screws, with multiple nuts for spacing.

The location of the smaller components on the PCB should be fairly clear from the photos, and in particular from the overlay diagram. Most are fitted in the usual way, and probably need very little explanation.

I suggest that you begin assembly of the PCB by fitting the terminal pins first, followed by the resistors, capacitors, RF choke L4, diodes D1 and D2, preset pot VR3, varicap diode VC1, transistor Q2 and regulator chip U1. These parts should all be quite straightforward, with little to watch apart from the polarity of the diodes and electrolyt-

Active Antenna for HF Reception



For those who like to etch their own boards, here is the actual size pattern.

ic cap (C1), and the orientation of the varicap and transistor.

Next I suggest that you wind the coils. These have been designed to be relatively easy to wind, so they should involve a minimum of hassle. All three are wound using 0.25mm enamelled copper wire, with the low band coil L1 wound on a two-hole F14 balun core measuring 13.2 x 13.5 x 7.4mm, the middle band coil L2 wound on a two-hole F29 balun core measuring 13.2 x 6.5 x 7.4mm, and the top band coil L3 wound on a standard miniature coil former (nominal 5mm) fitted with the usual six-pin base and shield can. L3 is also fitted with an F29 slug, to allow adjustment of its exact tuning range.

The connections for the three coils are indicated on the PCB overlay diagram, to guide you when winding them and bringing out their taps. All taps are produced by bringing out a loop of wire at the appropriate stage of winding, and then carefully twisting it into a tight 'double thickness lead' before continuing with the coil. Then when the coil is complete and ready to mount on the PCB, the twisted tap leads can be scraped bare ready for soldering, in the same way as the end wires. (Most wire nowadays has enamel which melts during soldering, and acts as a flux — so you generally don't have to be too thorough with the scraping.)

Coil L1 has a total of 15.5 turns, where I'm defining one turn as 'down one hole in the core, and back up the other'. Its first tap T1 is at 2.5 turns, with the second tap T2 at seven turns. So if you start winding at the 'E' end, each tap can be brought out at the position needed to line up with the holes in the PCB.

The same applies for coil L2, which actually has more turns: a total of 16.5 (because of the lower permeability core), with the L1 tap again at 2.5 turns and the T2 tap at eight turns.

Coil L3, wound on the six-pin former, has a total of only eight turns, with the T1 tap at 1.5 turns and the T2 tap at four turns. All of these turns are tightly wound in a single layer, hard against the base end cheek of the former.

Note that coil L3 is attached to the PCB in the usual way, held in position by both the soldered base pins of the former and the pins of its shield can (which also solder to the PCB). However the other two coils wound on balun cores must be mounted a little differently. As you can see I've provided for 3mm holes in the board on each side of the two former positions, so after you've fitted them they can be held in position using carefully fitted nylon cable ties. This works out fairly neatly, and they're clamped quite securely.

The remaining component to fit to the PCB is the BF998 MOSFET, and I've deliberately left discussing this until now because I recommend that you leave it as the very last part to be fitted to the board. As a surface mount component it must be mounted on the copper side of the board (i.e., underneath), and since it's so tiny it needs special care.

To help you in orientating it correctly on the PCB pads, I'm providing a separate 'closeup' overlay diagram. Note that the SOT143 package has one tab that's wider than the other three, as shown in the small drawing at the bottom of the schematic. (The drawing

PARTS LIST

Resistors

All 1/4W 5% carbon:

R1	820 ohms
R2	10 ohms
R3,9	680 ohms
R4	2.7k
R5	22k
R6	2.2k
R7,8	47k
R10,18	330 ohms
R11,13,15	1M
R12	100 ohms
R14	100k
R16	3.3k
R17	2.2M

Capacitors

C1	470uF 16VW RB electrolytic
C2,11	100pF ceramic
C3,4,6,10	0.1uF monolithic
C5	47nF mono or met. polyester
C7,8	10nF monolithic
C9,12	4.7nF mono or met. polyester

Semiconductors

D1,2	BAW62 or similar
Q1	BF998 dual gate MOSFET
Q2	BC548 NPN silicon
VC1	BB212 varicap diode
U1	LM723 voltage regulator

Pots & switches

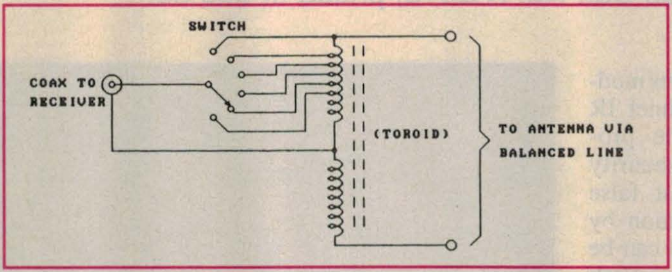
VR1	100k linear pot
VR2	1M linear pot with switch
VR3	1k preset pot, horizontal mount
S1	Three pole, 4 position rotary switch

Miscellaneous

PCB, 120 x 91mm, coded 95aa12; plastic case, 160 x 155 x 65mm; shield plate, 110 x 120mm (1mm aluminium sheet or unetched PCB laminate); 2 x SO239 coaxial sockets, single hole mounting; coaxial DC input socket; 600mm telescopic rod antenna; 3 x control knobs; 6.8uH RF choke (L4); F14 two-hole balun core, 13.5mm long; F29 two-hole balun core, 6.5mm long; 4.8mm miniature coil former, six-pin base, shield case and F29 tuning slug; 2 x nylon cable ties; 24 x PCB terminal pins; 3m length of 0.25mm enamelled copper wire, for winding coils; 5 x 12mm x 3mm machine screws; 14 x 3mm nuts; 2 x solder lugs; 6 x 3mm star lockwashers; hookup wire, solder, etc.

shows the device as seen from its TOP, with the tabs bent down and away from you.) The wider tab is the source connection, and as you can see from the small overlay diagram, the device is orientated on the board with its axis at about 45° to the PCB sides, and with this wide tab soldered to the largest of the four copper pads.

To do this job without damaging the BF998, you're going to need a soldering iron with a very fine chisel-pointed bit — well tinned, and very clean. The iron should also be reliably earthed, to ensure that there are no leakage currents to damage the device when you solder it in place.



If you would like to use a balanced antenna, here is the schematic for an adjustable ratio balun transformer. The text explains how to wind one.

I suggest that you *very lightly* tin the PCB pads first, if they haven't already been pre-tinned by the manufacturer. Then place the BF998 carefully in position, and hold it place using a toothpick while you quickly tack-solder the source tab to its pad. Then you can solder the remaining tabs, and finally resolder the source connection if you're not entirely happy with it.

The main things to ensure are that (a) you don't overheat the BF998, during the soldering process; (b) you don't apply too much solder, and create 'bridges' to short between the pads or device tabs. The space between the pads is very small, so you need to be particularly careful.

Once the BF998 is in place, your PCB assembly should be complete and ready to mount in the case (assuming you've already fitted the shield plate, with its PCB mounting screws). Then, once you've mounted the controls on the front panel, and the connectors on the rear panel, the final step is to make the various connections between all of these off-board components and the PCB. You should find these all pretty straightforward from the internal photos and the PCB overlay, which has labels for all of the terminal pins.

Adjustments

Once the unit is complete, there are really only two adjustments to be made. One is the setting for preset pot VR3, which is simply adjusted until the regulated supply rail measures as close as possible to +9V. A DMM can be used to monitor the voltage for this adjustment, connected between say pin 3 of U1 and the earthy side of the RF output socket.

The other adjustment involves the tuning slug of L3, the coil for the 8 - 30MHz band. It's the position of this slug that determines the bottom limit of this top band, and hence whether or not it correctly overlaps (slightly) the top of the middle band.

The best way of setting the slug is to use an RF signal generator, set to 7.8MHz. The output of the Active Antenna — switched to the top band (C) and with the tuning pot turned fully anticlockwise — is then fed to your receiver, which is also tuned to 7.8MHz. The output of the generator is then increased until the signal can be heard, and the slug in L3 adjusted until you achieve a 'peak', indicating that resonance has been reached. (You may need to reduce the generator output as the peak is reached, to prevent receiver overload.)

If you don't have access to an RF generator, an alternative approach would be to set the Active Antenna to the top of the middle (B) band, and tune your receiver to an easily recognisable station close to 8MHz.

Then switch the Active Antenna to band C, turn VR1 down almost fully anticlockwise, and adjust the slug in L3 until the signal reaches a peak again. In the absence of a generator, this should give the best result possible.

Balanced antenna

As mentioned earlier, a balanced antenna tends to give the best results in a noisy urban environment, especially when used with a 'balun' or balanced-to-unbalanced matching transformer. So if you have the room to use one, the results are generally worth the additional effort.

The basic idea is that you use *two* lengths of wire, arranged so that they assist each other in terms of picking up the wanted signals, but at the same time can be connected to the balun so that they cancel out each other's noise pickup.

The key points are that the two wires should be of the same length, be at close to the same height above the ground and share close to the same axis, but ideally run in opposite directions away from the balun. In other words, they should form a small dipole, with the balun in the centre. A short length of coaxial cable then runs from the balun to the low impedance input of the Active Antenna.

A loop of wire can be connected to the balun in the same way, to form a 'folded' dipole.

As the impedance of a small balanced dipole or loop will vary quite widely over the HF spectrum, for the best results the balun should be adjustable in terms of its primary to secondary ratio. Tom Moffat described a suitable multi-tapped adjustable balun in the May 1991 issue, and its schematic is shown in the diagram. Tom used a 500mm length of 24SWG enamelled copper wire, bent into a 250mm bifilar pair and carefully wound on a small HF ferrite toroid. They were then cut apart at the 'bend' end, and connected head-to-tail to form a centre-tapped balanced winding. He then made taps on one side, as shown, and wired the taps to the switch so that when receiving, it is possible to select the tap that gives the best reception at any particular frequency.

Tom used a small toroid measuring about 10mm OD, but is no longer able to supply them. DSE has a somewhat larger and more expensive toroid, available in its D-5350 Balun Kit, while Jaycar has a 20mm OD toroid (LF-1241) which would probably be suitable although we haven't tried it.

The balun can be housed in a small plastic utility box, with the switch fitted with a suitable knob for convenient adjustment. If you can't fit the balun at the centre of the antenna and still get easy access for adjustment, you can have the balun near the Active Antenna unit and couple its input to the antenna using a short length of 300Ω ribbon cable (as used for TV antennas).

In fact you could even make a small loop antenna out of the same cable, if you wish — soldering the conductors together at the far ends, just as if you were making an indoor folded dipole for TV or FM reception. The only difference is that in this case, you don't need to cut the dipole to any specific length; just make it as long as you can, for the best HF reception.

Happy listening! ❖