Assembly Manual

Antenna Tuner and RF Pre-amp

K-6100

DICK SMITH ELECTRONICS

ACN 000 445 956

KIT

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Here's a low cost, easy to build unit which can really improve the performance of many elderly shortwave receivers, and give them a new lease of life. It combines an antenna tuner with an RF pre-amp pre-selector - giving the ability to improve both sensitivity and selectivity, at the same time.

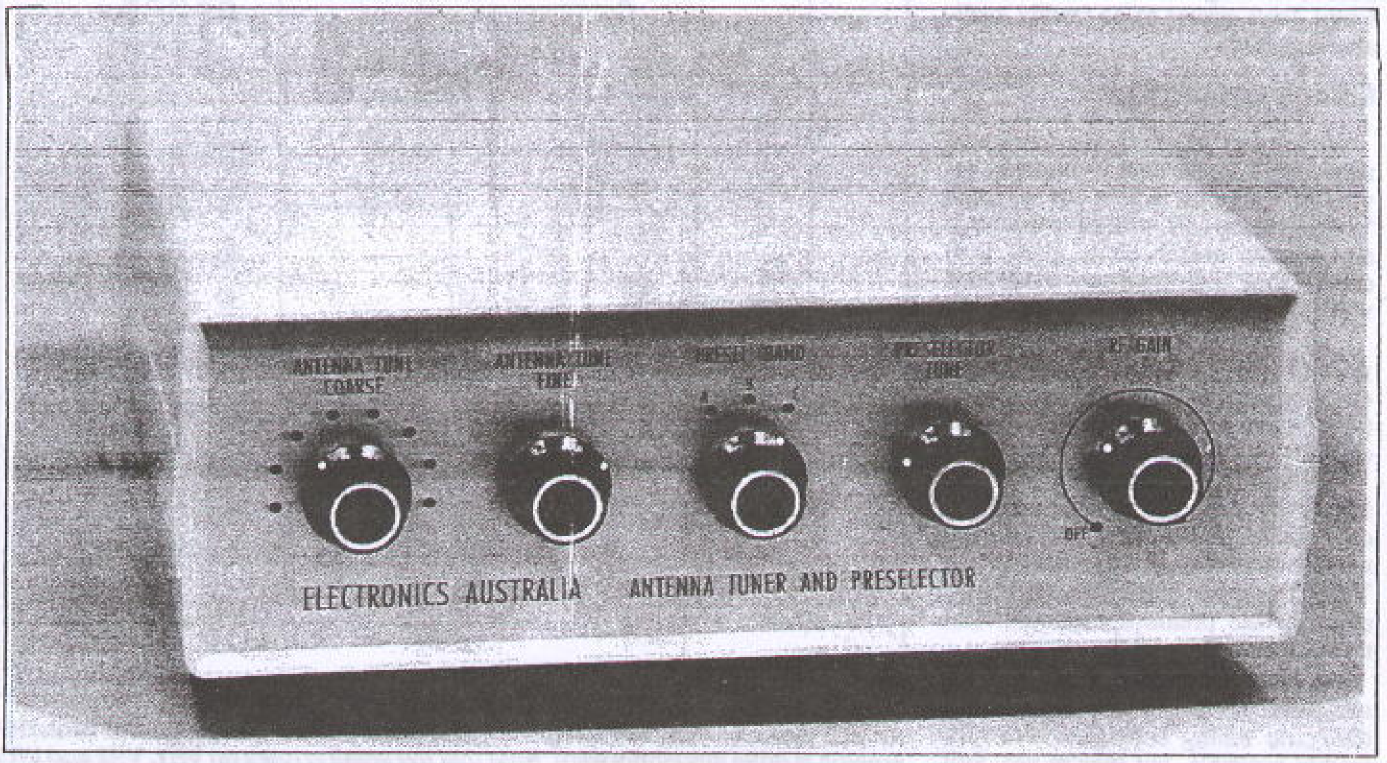
Nowadays most of us live in fairly crowded urban and suburban situations, where it isn't easy to set up an elaborate antenna system for shortwave listening.

As a result many people have to settle for a few metres of wire, either run around a window frame indoors, or perhaps out to a nearby post or tree at best. The results with such a modest antenna system can be fairly disappointing, even with a sensitive modern receiver.

Even going to the trouble of setting up a larger antenna may not achieve a great deal of improvement. There are many sources of noise and interference in our modern society, and a larger antenna may well cause these to 'swamp' the receiver front end. This can cause all kinds of problems, unless your antenna can be tuned to at least a broad resonance at the frequencies you're interested in — to reject a large proportion of the unwanted signals and interference.

For satisfying reception, then, you often need an antenna tuner. Quite often a further improvement can be obtained by adding a preselector or 'tuned filter' stage as well, to provide further help to the receiver's front end in rejecting unwanted 'rubbish'. And finally, with older receivers in particular, it can be desirable to provide some additional RF gain — if only to compensate for the shortcomings of a modest antenna system.

The unit described here has been designed to provide all of these facilities, in a compact and low-cost



Our kit is supplied with a pre-punched and silk screened front panel and pre-punched rear panel.

form. It's easy to build too, with virtually all of the parts readily available through normal stockists.

Housed in a standard medium-sized plastic case and with most components on a PC board to simplify construction, it provides a simple antenna tuner capable of resonating most typical small- to medium-sized high impedance 'length of wire' antennas, over the frequency range from 500kHz to 30MHz. This makes it suitable for improving broadcast-band performance as well, by the way, which may make it of interest to country listeners.

Along with the antenna tuner, the unit also includes a tuned RF preamp stage, which provides both gain and preselection over the same frequency range as the tuner. The preamp has three tuning bands, and provides a maximum gain which varies typically between about 35dB at 500kHz and 17dB at 30MHz — very worthwhile in boosting the performance of older receivers.

At the same time the preamp has adjustable gain, so that the level provided can be set for optimum reception without producing overload. In fact when the control is turned to the minimum position, the unit actually *attenuates* the incoming signals rather than boosting them — allowing a very wide range of adjustment.

The complete unit is powered from an external 12V DC source, which can either be batteries or a low-cost 'plug pack' power supply. The power drain is very low — less than 10mA.

Incidentally, the unit can also be used as an 'active indoor antenna', simply by fitting it with a small telescopic whip antenna. Provision has actually been made for this on the printed circuit board, although low-cost telescopic whips don't appear to be readily available at present.

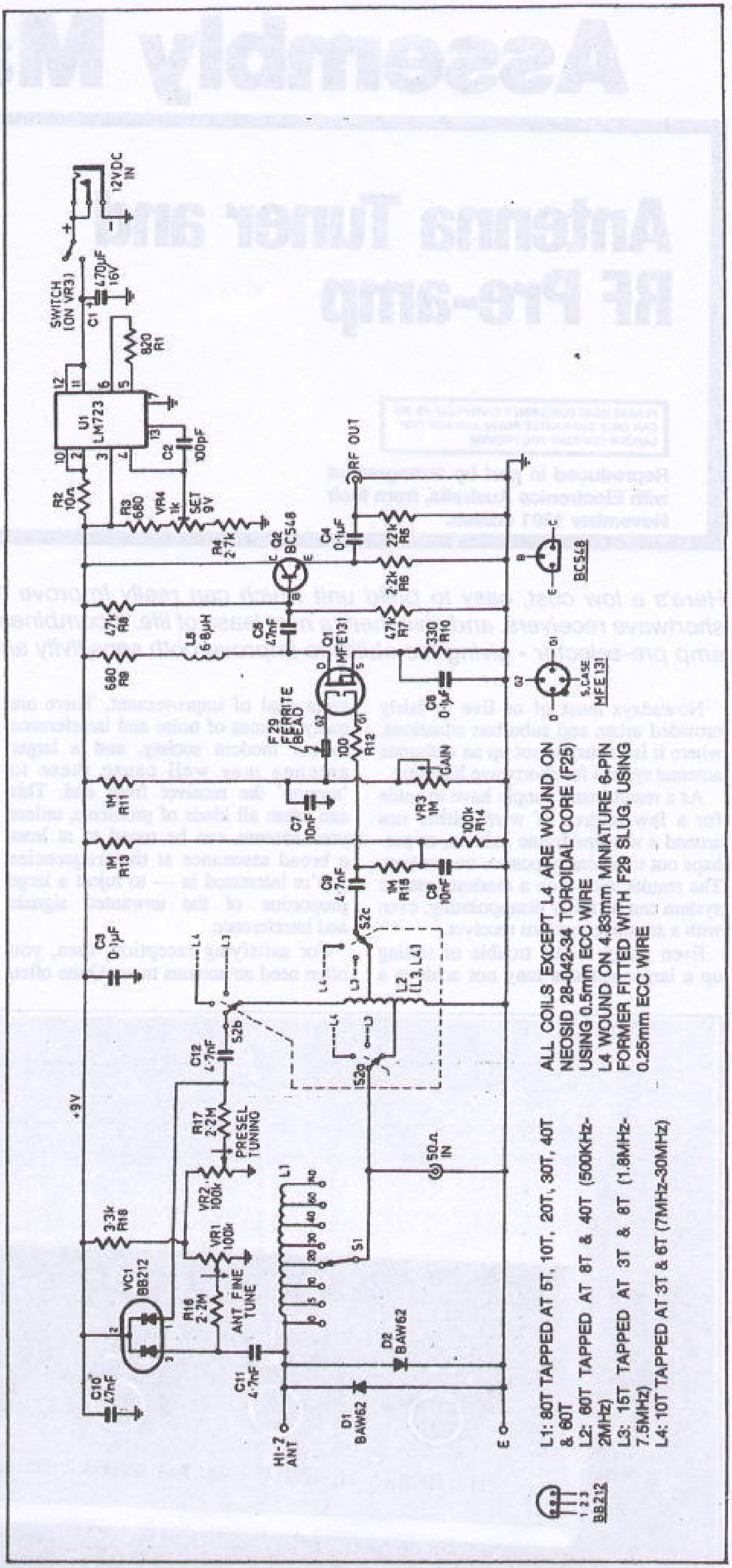
Circuit description

As you can see from the schematic, there isn't a great deal of circuitry involved. Inductor L1 is the antenna 'coarse' tuning coil, with adjustable taps and selector switch S1 to allow it to cope with a wide frequency range and variety of antennas.

Like two of the inductors in the preamp/preselector section, L1 is wound on a Neosid 28-042-34 toroidal ferrite (F25) core, using 0.5mm enamelled copper wire.

Fine control of antenna tuning is performed by one half of VC1, a BB212 dual varicap diode, with its necessary reverse bias voltage adjusted by pot VR1. The other half of the BB212 is used for the preamp/preselector fine tuning, adjusted by VR2.

Fine tuning of both sections would be somewhat simpler if conventional air-dielectric tuning capacitors were still readily available, but they're not. Still, the diodes inside a BB212 have a wide



As you can see from the schematic, the circuit of our new antenna tuner/RF preamp is quite straightforward. Note that the small arrows on VR1, VR2 and VR3 indicate clockwise rotation.

capacitance range (typically 20-550pF), and are smoothly adjustable using a bias range of 8V-0.5V.

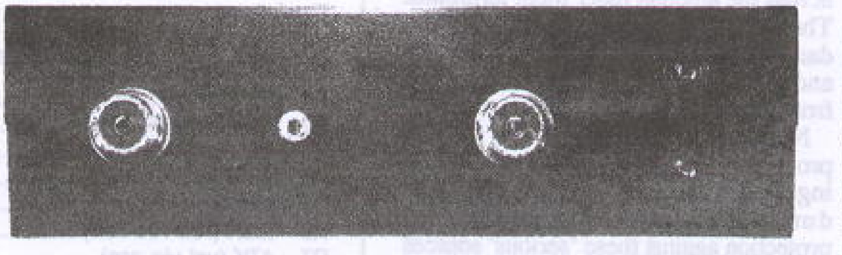
The only real complication with varicap tuning is that the bias voltage must be tightly regulated, to ensure that the tuning is stable. Since the present circuit is intended to be operated from relatively unstable supplies such as batteries or a low-cost plug pack, an LM723 regulator chip (U1) is used to establish a stable and well filtered +9V supply line. The LM723 is cheap and readily available, and needs only a few peripheral components to do the job. Preset pot VR4 is used to set the supply rail to 9V.

At the output of the antenna tuner section, a 50-ohm input is provided. This allows direct input to the preamp/preselector from a resonant 50-ohm antenna, if desired.

The preselector tuned circuit uses three switched coils L2, L3 and L4, selected by band switch S2. Each coil has two taps — one at a fairly low point to match the nominally 50-ohm input from the antenna tuner section, selected by S2a, and the other (selected by S2c) somewhat higher to suit the high impedance input of the RF preamp section. The varicap tuning connects to the top of each coil, via S2b.

L2 tunes from 500kHz to 2MHz, while L3 tunes from 1.8MHz to 7.5MHz and L4 from 7MHz to 30MHz. The first two of these are wound on Neosid 28-042-34 ferrite toroids, like L1, while L4 is wound on a 4.83mm miniature coil former, provided with an F29 ferrite slug.

The RF preamp section of the circuit uses two readily available transistors: an MFE131 dual-gate MOSFET (Q1), and



The rear of the unit is not terribly exciting, to be sure, but it's quite functional. From right to left the connectors are high impedance antenna input, 50-ohm input, 12V DC input and RF output.

a BC548 NPN bipolar (Q2). The MFE131 provides the gain, while the BC548 matches its relatively high impedance output to the low impedance (nominally 50 ohms) of a typical shortwave receiver input. Despite its simple configuration, this preamp circuit gives good results. In fact I was able to optimise its operation quite conveniently using Intusoft's *IsSPICE* analog circuit simulator, during my recent reviews of this and other simulator packages.

The final design needed only a minor adjustment to the value of L5, the peaking choke in the MFE131's drain load (from 4.7uH to 6.8uH), to match the simulated performance. The DC conditions of the MFE131 stage are arranged to be as tolerant as possible of device parameter spread, so that almost any device should give good results without any component changes.

This is done by the choice of source resistor R10, to give negative current feedback, coupled with a small forward bias applied to G1 via the voltage divider formed from resistors R13 and R14, across the 9V supply.

The gain of the stage is adjusted by pot VR3, which varies the G2 bias voltage between zero and +4.5V. Maximum gain is achieved at around +4.3V for most devices, while the MFE131 is throttled right back and virtually becomes a signal attenuator when the G2 voltage is reduced below about +1V.

VR3 is actually a switch pot, with the switch wired in series with the +12V DC input so that it can be used for on-off switching when a battery is used.

The 100-ohm resistor R12 in series with the MFE131's G1 lead, and the F29 ferrite bead fitted to its G2 lead are both parasitic stoppers, to ensure that the

A view inside the unit, showing the controls behind the front panel and the wiring between them and the PC board. Note that the PC board visible in this picture is slightly different from the final design.

device gives stable amplification.

Probably the only other components which need a mention here are the two BAW62 diodes D1 and D2, connected across the antenna tuner input terminals. These are to protect the circuitry against damage from minor corona discharges, and perhaps also very high-level signals from passing or nearby transceivers.

Note that the diodes will *not* provide protection against damage from lightning strikes, or larger corona discharge during electrical storms. The best protection against these 'serious' sources of damage is to disconnect any outside antenna, during such a storm.

Construction

As noted earlier, the complete unit is housed in a readily available plastic case measuring 200 x 160 x 67mm. With the exception of the control pots and switches, and the various input and output connectors, all remaining components are mounted on a PC board measuring 167 x 114mm and coded 91rfb10.

The control pots and switches are all mounted on the case front panel, and wired to the PCB via short lengths of hookup wire, while the connectors all mount on the rear panel and are wired to the board in the same way.

The position and orientation of virtually all of the parts should be clear from the PCB overlay diagram and the various photographs. Hopefully the connections between the PCB and the controls and connectors should also be quite clear, especially since the over-

PARTS LIST

Resistors

(All 1/4W, 5% types unless stated)

- R1 820R (gry-red-brn)
- R2 10R (brn-blk-blk)
- R3 680R (blu-gry-brn)
- R4 2.7K (red-vio-red)
- R5 22K (red-red-org)
- R6 2.2K (red-red-red)
- R7 47K (yel-vio-org)
- R8 47K (yel-vio-org)
- R9 680R (blu-gry-brn)
- R10 330R (org-org-brn)
- R11 1 meg (brn-blk-grn)
- R12 100R (brn-blk-brn)
- R13 1 meg (brn-blk-grn)
- R14 100K (brn-blk-yel)
- R15 1 meg (brn-blk-grn)
- R16 2.2 meg (red-red-grn)
- R17 2.2 meg (red-red-grn)
- R18 3.3K (org-org-red)

Capacitors

- C1 470uF 16/25V Electro
- C2 100pF Ceramic
- C3 0.1uF Greencap
- C4 0.1uF Greencap
- C5 47nF/0.047uF Greencap
- C6 0.1uF Greencap
- C7 10nF/0.01uF Greencap
- C8 10nF/0.01uF Greencap
- C9 4.7nF/0.0047uF Greencap
- C10 47nF/0.047uF Greencap
- C11 4.7nF/0.0047uF Greencap
- C12 4.7nF/0.0047uF Greencap

Semiconductors

- D1 Baw 62 diode
- D2 Baw 62 diode
- Q1 MFE 131 dual gate Mosfet
- Q2 BC548 NPN Transistor
- V1 LM 723 IC
- VC1 BB 212 varicap diode

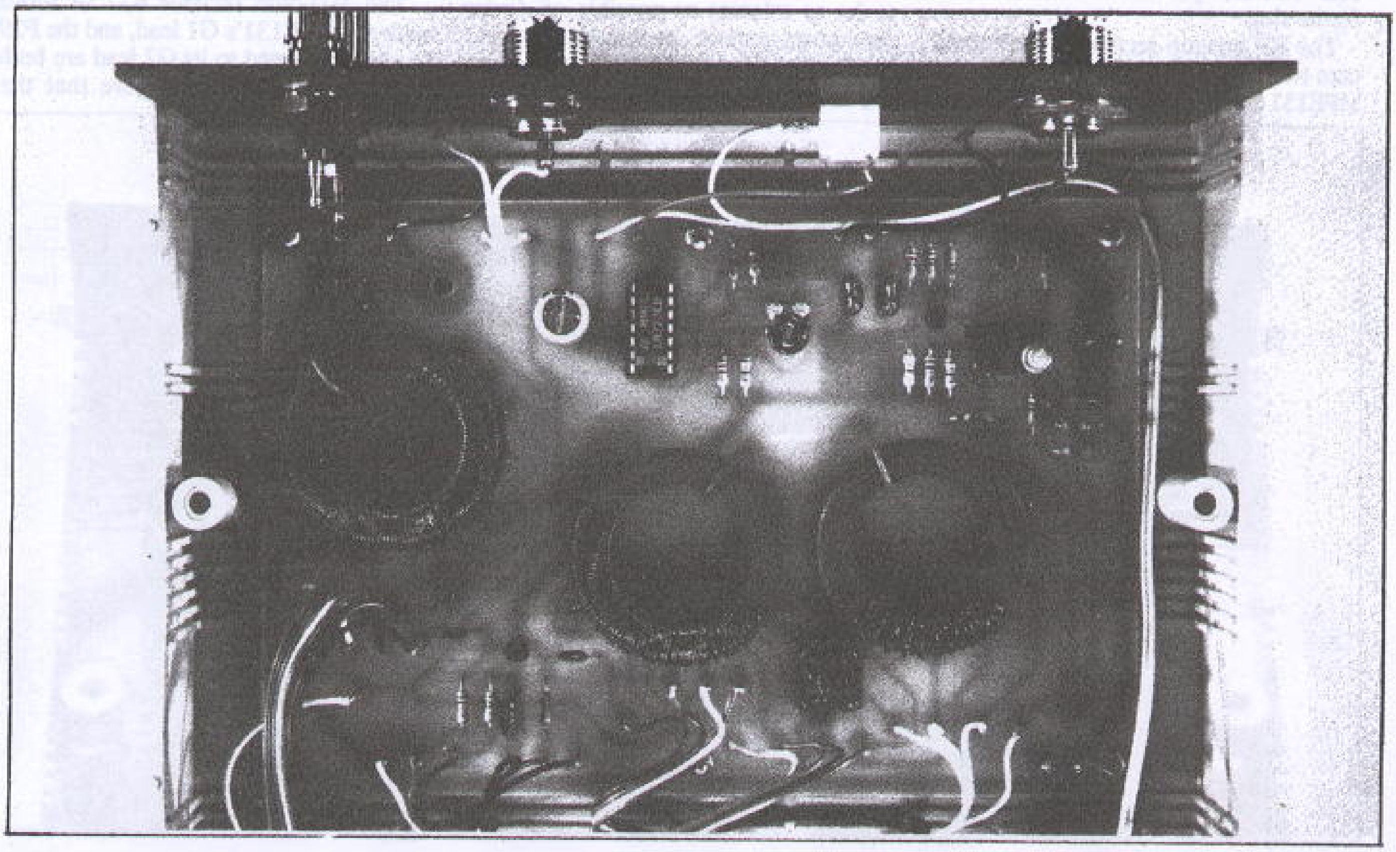
Components

- VR1 100K Linear pot
- VR2 100K Linear pot
- VR3 1 meg Linear pot with switch
- VR4 1K mini trimpot
- L5 6.8uH (6R8K) RF choke
- S1 Rot.sw 1 pole 8 positions
- S2 Rot.sw 3 pole 3 positions

Miscellaneous

- 1 x PCB, 166 x 114, coded 91rfp10
- 1 x Plastic case, 200 x 160 x 67mm
- 1 x Pre-punched & silk screened front panel
- 1 x Pre-punched rear panel
- 3 x Neosid 28-042-34 toroids
- 2 x 50-239 co-axial sockets
- 2 x Plastic binding post, red & black

DC sockets, knobs, IC socket, 4.83mm former & 6 pin base, ferrite bead F29, PCB pins, 0.5mm & 0.25mm En/cw wire, rainbow cable & solder.



And here's a view looking in the opposite direction, showing the rear panel connectors and the wiring from them to the PC board. Also visible are most of the components on the rear half of the board.

lay diagram is provided with detailed legends.

Note that the PCB has been arranged to accept either a horizontal- or vertical-mount miniature preset pot for VR4, to make things easier if one type or the other should become unavailable.

I recommend that you fit PCB pins to the board at all places where wires are used to connect it to either the front-panel controls or the rear-panel connectors. This makes it easy to connect everything up, after the complete PCB assembly is finished and mounted inside the bottom half of the case.

Fitting the PCB pins should in fact be the first step in assembly of the PCB, after you have checked it for any imperfections in etching. After pushing each pin through its hole from the component side, solder it carefully to the surounding copper pad.

As usual the next step is to fit the lower-profile components, such as the resistors and diodes. Then follow the capacitors, taking care with the polarity of electrolytic C1.

Next you can add the regulator chip U1, varicap diode VC1 and the two transistors Q1 and Q2. Note that Q1 has an F29 ferrite bead slipped over its G2 lead before mounting on the board, hence mounts above the board by the length of the bead - 5mm.

Don't mount it any higher than this, however; push it down so that its body is hard against the top of the bead. Q2 and VC1 can also be mounted about 5mm above the board.

Preset pot VR4 can now be mounted, with its pins pushed as far into the board as possible before soldering. Also RF choke L5 can be added as well, with its body again about 4-5mm above the board.

At this stage your board assembly will be complete apart from the coils, and the next step is to wind these. The easiest is L4, which winds on one of the miniature 4.83mm formers which mates with a 6-pin base

As you can see from the schematic, this has a total of only 10 turns, with the T1 tap at 3T and the T2 tap at 6T. The pins on the former used for the four connections are shown in the PCB overlay diagram (viewed from above).

I suggest you wind each section of L4 in turn, soldering its 'start' end to the appropriate pin before winding, and then its 'end' to the next pin afterwards. This works out rather more conveniently than trying to wind the whole thing and then soldering everything to the pins afterwards. Don't forget to wind each section in the same direction, though.

The three other coils are all wound on the Neosid toroids, using a slightly different technique. Here since the coils are mounted directly on the PCB, with their connections made directly to it, the easiest way is to wind them completely first.

Capacitor Codes

Value	Alt value	IEC value	EIA code
0.0047uF	4.7nF	4.7n	472K
0.01uF	10nF	10n	103K
0.047uF	47nF	47n	473K
0.1uF	100nF	100n	104K
100pF		100p	101K

This is done using a single length of wire for L3, bringing the taps out as you go by leaving a short loop or 'doubled back' section, and twisting it around tightly to strengthen it before proceeding with the next part of the winding.

After the complete winding is finished, the twisted 'tap leads' can then be scraped and tinned with a hot iron, to burn off the enamel and make them ready to pass through the PCB holes for soldering.

The same basic technique is used for L1 and L2, but as these require longer lengths of wire, and toroids are not easy to wind with such longer lengths, you can actually use shorter lengths and make joins at one or more of the tapping points. As before this is done simply by twisting the 'start' of one wire tightly to the 'end' of the previous length, at the tapping point, and then soldering the two together later when the total winding is completed. As with L4 the main thing to watch is that all sections of each coil are wound on the toroid in the same sense — i.e., either all clockwise or all anticlockwise.

When you're winding each of the toroid coils, work slowly and carefully so that your windings are fairly tightly wound around the core. Loose windings will give poorer 'Q', and hence less effective tuning. Also keep an eye on the PCB, so you can see the locations provided for each of the tapping points on each coil.

When all of the coils are finished, the next step is to mount them on the PCB. With L4 this is again very simple — you merely push the former's pins through the appropriate holes (note the polarised spacing), and then solder them to the pad underneath.

The three toroidal coils involve a little more fiddling, as you have to form each of the leads and persuade them to pass through the appropriate PCB holes.

Note that all three toroidal coils also have an additional 'U-shaped' link fitted over them, roughly opposite the winding, to help secure them to the PCB. These links can be made from short lengths of hookup wire, which is soldered to isolated pads under the board. (Don't link the pads together underneath, by the way — this would make the wires into shorted turns, and ruin the performance of the coils.)

The completed board assembly can now be mounted inside the lower half of the case, and you can turn your attention to the front and rear panels. Both panels have been supplied pre-punched, with the front panel silk screened.

The rear-panel connectors scarcely need lettering as they are normally only seen on rare occasions.

Check that the two rotary switches are configured for the correct number of positions (Eight for S1 and three for S2).

When the controls and connectors are all mounted on their respective panels, the final step is to connect them up to the appropriate PCB pins via short lengths of insulated hookup wire.

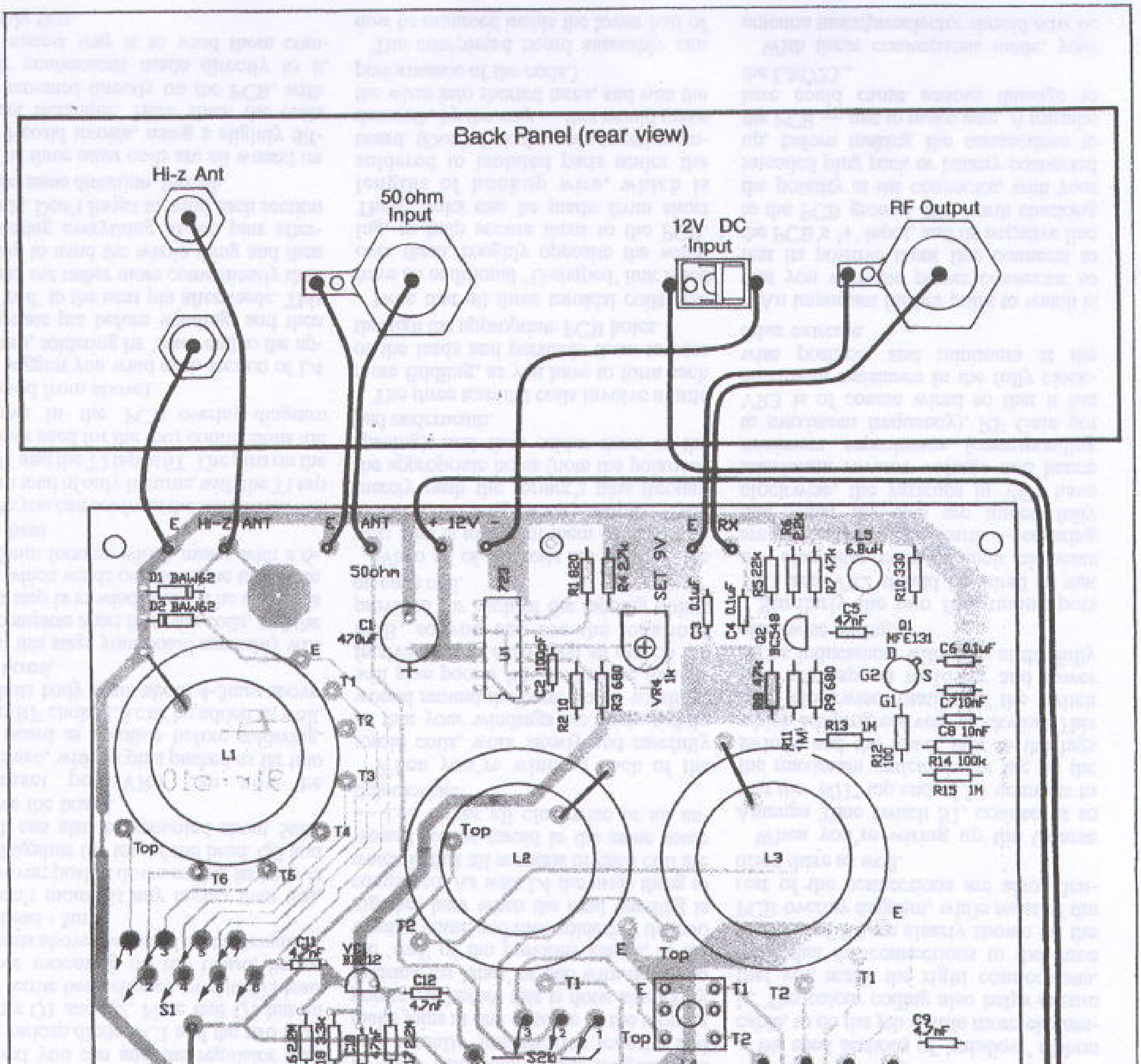
We used sections of 'rainbow' ribbon cable, to do the job a little more elegantly. The colour coding also helps ensure that you make the right connections. Note that the connections to the three sections of S2 are clearly shown on the PCB overlay diagram, while most of the rest of the connections are also identified there as well.

When you're wiring up the Coarse Antenna Tune switch S1, connect it so that the '80T' top end of L1 connects to the maximum *anticlockwise* lug on the switch, and the lower taps to the lugs which are progressively clockwise. This way, clockwise rotation of the switch will correspond to lower and lower series inductance, with zero at the fully clockwise setting.

Similarly the two fine tuning pots VR1 and VR2 should be wired so that the *clockwise* ends of their elements are connected to PCB earth — ensuring that when the pots are turned fully clockwise, the varicaps in VC1 have maximum reverse voltage and hence minimum capacitance (corresponding to maximum frequency). RF Gain pot VR3 is of course wired so that it has maximum resistance in the fully clockwise position, and minimum at the other extreme.

An important further point to watch is that you wire the power connector so that its positive input line connects to the PCB's '+' input, and its negative line to the PCB ground. It's worth checking the polarity at the connector, with your intended plug pack or battery connected up, before making the connections to the PCB — just to make sure. A mistake here could cause serious damage to the LM723...

With these connections made, your antenna tuner/preselector should now be



Here's the PCB overlay diagram for the antenna tuner/RF preamp. Note that the connections for L2, L3 and L4 are indicated as well, along with the connections for the three sections of band switch S2.

complete, and ready for testing.

Testing & adjustment

There's very little to do to the completed project, before it's ready for use. The first thing is to set the internal regulated supply rail to +9V, using VR4.

To do this, set the rotor of VR4 initially to a point halfway around the track, and then connect a source of 12V DC to the power connector. Make sure the RF gain control pot is turned 'on', and then check the voltage between the regulated rail and PCB ground, using a DMM or analog multimeter. A convenient place to check the rail is at the end of R3 nearer to coil L2, or at the end of R18 nearer to VC1.

The voltage should measure close to 9V, but will probably be a little higher or lower. It should be a simple matter of adjusting VR4 slightly one way or the other, to set it to the correct figure.

While you have the DMM or multimeter at hand, you can quickly check a couple of circuit voltages to make sure that everything is in order. The voltage across R6 should be close to 3.9V, while that across R10 should be around 1V — but this will vary a bit, depending upon the parameters of your particular MFE131. A bit of variation here is of no great concern.

If these two voltages seem OK, your circuit is probably operating correctly. The only other adjustment which needs to be made is setting the tuning slug in L4 to its correct position, so the tuning range for preselector band C is the desired 7-30MHz.

This is done most easily when the unit is connected to your shortwave receiver, using a signal generator set to 30MHz. With the preselector fine tuning pot VR2 set to its fully clockwise limit, the slug is then adjusted for a peak in the received signal — as indicated by the receiver's S meter.

If you don't have a signal generator, a reasonably strong and steady off-air signal near 30MHz can be used in much the same way. Again set VR2 to its top end, and set L4's slug for a peak. If the only signal that you can find is significantly below 30MHz, turn VR2 a little back from the clockwise limit to allow for this.

Using it

Using the unit is quite straightforward. With the RF gain pot set at about '12 o'clock' and the preselector band switch S2 set for the correct band for the signal you wish to receive, the receiver should be able to locate your signal and tune it in normally.

After you've adjusted the receiver controls for best reception in this situation, you can then manipulate the tuner/preselector's controls to achieve improved results. In each case, the receiver's S meter and your own ear will be the best guide to the correct control settings.

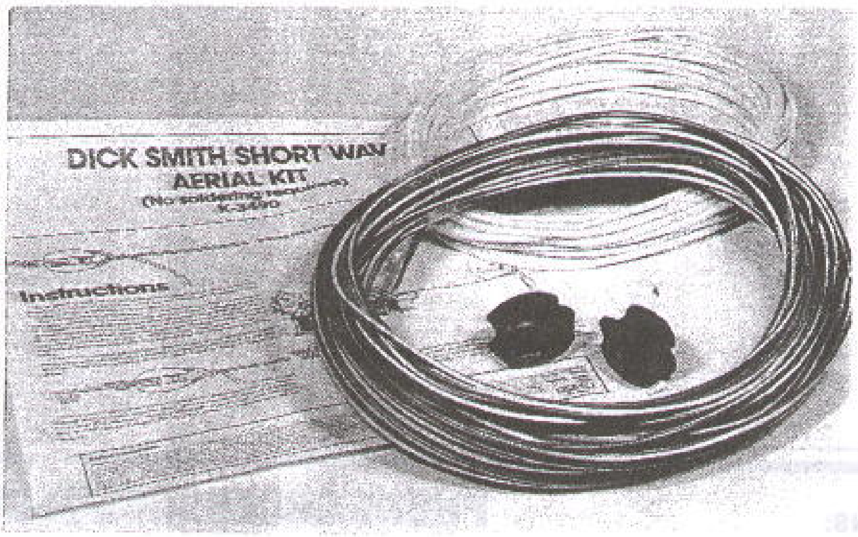
The first step is to try adjusting the coarse antenna tuning switch S1, to find the setting which gives the best results. As a guide, the positions nearer the clockwise end (minimum inductance) will tend to get best results at higher frequencies, while those nearer the anticlockwise end will be better for low frequencies — with the exact setting depending upon your antenna, or course.

Once you've found the best position for S1, then you can adjust the 'Antenna Fine Tune' pot VR1 for a peak in signal strength. This done, you can swing over to the 'Preselector Tune' pot VR2, and again tune for a peak.

Finally, you can adjust the RF Gain pot for the strongest signal that the receiver can handle, before any overload is evident. Needless to say if overload occurs, this control should be wound back until it disappears.

And that's really all there is to it. You'll find the unit can make a big difference to the reception with an elderly shortwave set, and can also help a modern set cope when your antenna setup leaves a good deal to be desired. Happy DXing!

SHORTWAVE ANTENNA KIT FROM DSE



Readers building our new Antenna Tuner and RF Pre-amp project may also be interested in a kit being marketed by Dick Smith Electronics: the K-3490 Shortwave Aerial Kit. This contains virtually all of the main items needed to build a standard 'inverted L' outdoor antenna, for shortwave reception - about 25m of multi-stranded and insulated copper wire, about 10m of weatherproof plastic rope, and a couple of 'egg' type insulators. It also comes with full assembly instructions. For price and availability please check with your local Dick Smith retail outlet.