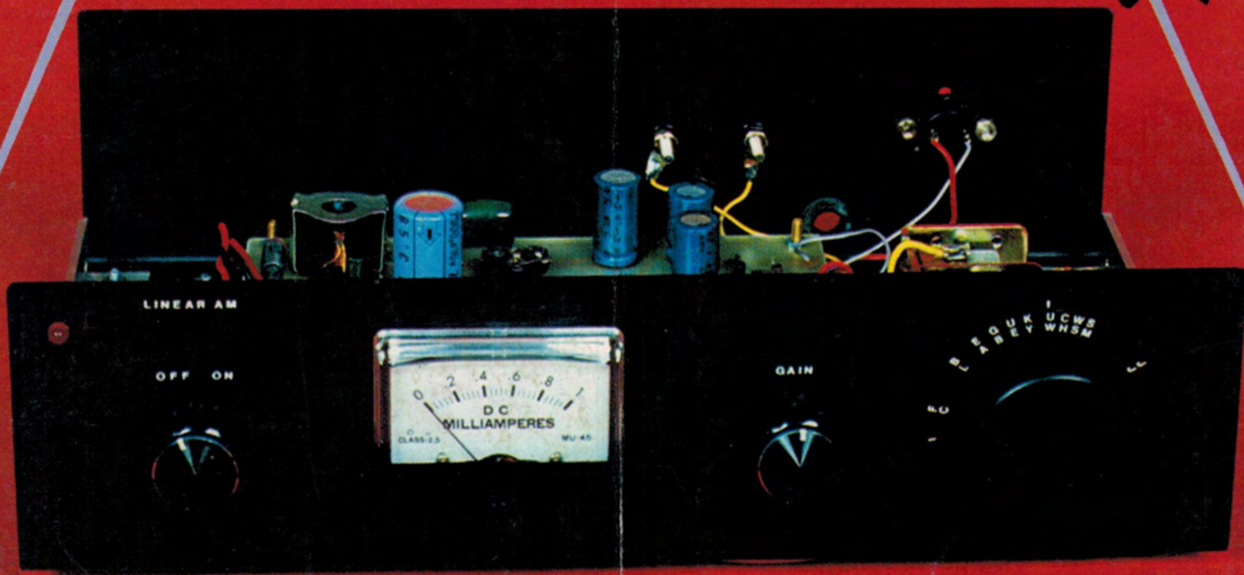
SUPERB AM TUNER

Using the 3080 IC

Win a Dick Smith Computer!



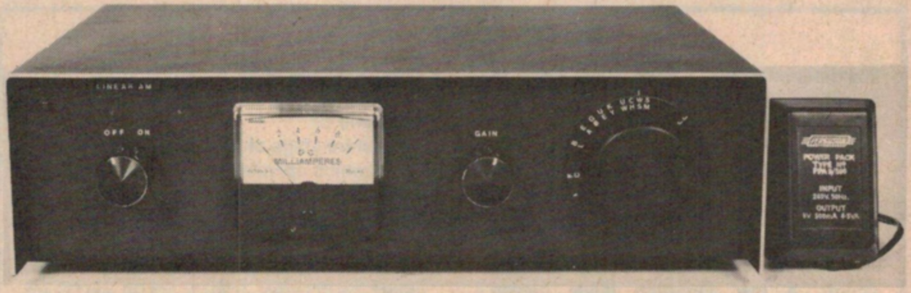
AM Tuner features wide bandwidth and low distortion

Design: Ken Woods
Article: Staff

Now the 'FM boom' has arrived, the AM stations are fighting back with wide bandwidth, good quality sound. This tuner, though simple to build and get going, provides extraordinarily good performance.

WE WERE SURPRISED to learn recently that many of the AM broadcast stations have been transmitting 'full bandwidth' signals for quite some time, it seems they're 'fighting back' at the recent boom in FM with all the new stations coming on to the VHF band.

This tuner has been designed to take advantage of this situation. Broadcast stations are permitted to transmit an audio bandwidth that rolls off at 15 kHz. That means an AM broadcast station will have a nominal bandwidth of 30 kHz. At first glance this seems a little out of kilter as frequency spacing in the 530 - 1650 kHz AM broadcast band is 9 kHz. However, stations serving a particular area are generally allocated frequencies no closer than 54 kHz. Hence, a wideband tuner may be used to exploit the good quality reception possible from stations transmitting 'full bandwidth' programme material.



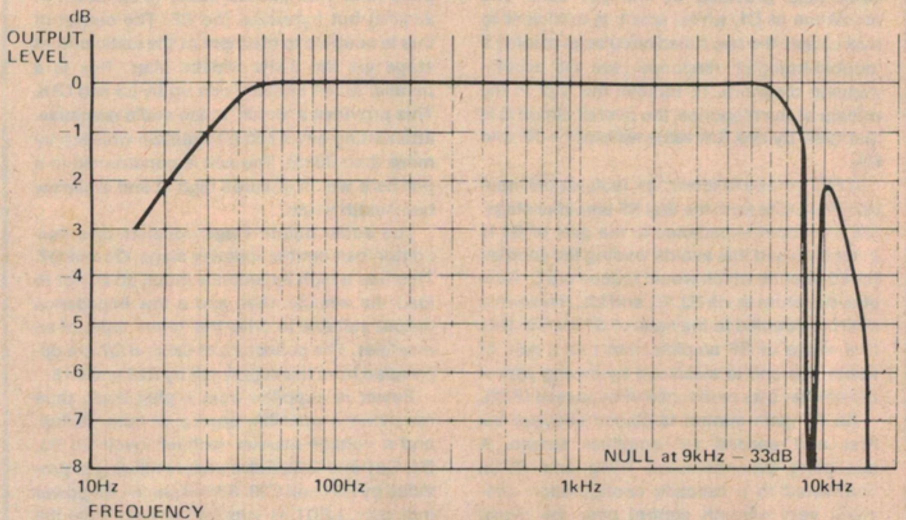
The tuner is housed in a simple, yet attractive, case. A plugpack is used to power the unit.

Design

The designer, Ken Woods, has chosen to employ a 'tuned radio frequency' design to achieve low intermodulation distortion, low phase distortion and good transient response. There are only two tuned circuits. The overall selectivity is determined solely at the front end, at the frequency selected. The parameters of the input double-tuned circuit have been arranged to provide the required bandpass selectivity with good attenuation outside the passband, to reduce unwanted noise and interference. This circuit arrangement provides low phase distortion as it has a slowly varying phase change across the pass band and no phase reversals. Transient response of this particular arrangement is also good as there is minimum signal delay from input to output and the Q has been carefully 'tailored' to reduce the 'flywheel effect' of multiple tuned circuits (ringing).

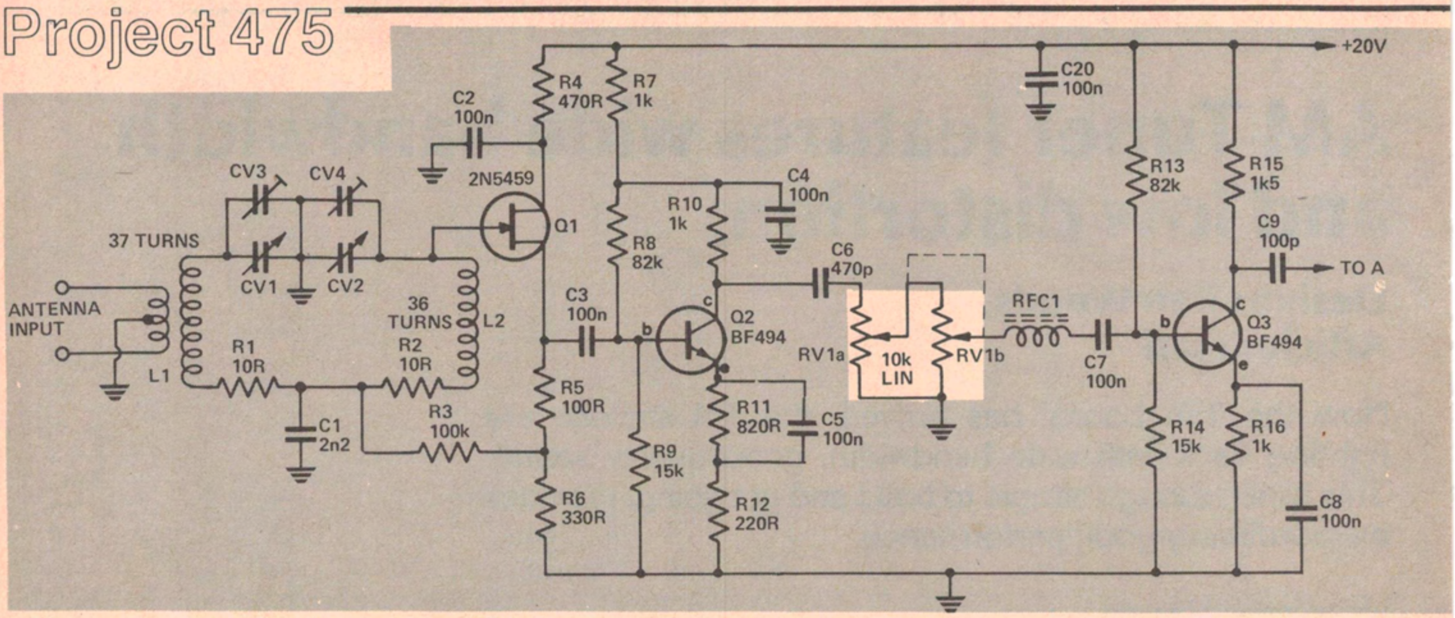
In addition, the circuit has a virtually constant bandwidth characteristic right across its tuning range. It's a little too complex to go into here, but readers looking for a good reference could hardly do better than consult "The Radiotron Designer's Handbook", by F. Langford-Smith, published by AWV-RCA, Chapter 8, section (iii) 'Complex Coupling' (Page 420 in ours, the Fourth Edition).

The tuner has a manual RF gain control and no AGC so that the evil of AGC distortion, prevalent with conventional superhet AM tuners, is eliminated. Actually, rather than varying the gain of one or more of the amplification stages, the RF gain control is an attenuator, ▶



Overall frequency response of the receiver. The response is 3 dB down at 15 Hz and 12 kHz. The whistle filter provides 33 dB of attenuation at 9 kHz and is 3 dB below midband response at just over 8 kHz and just below 10 kHz.

Project 475



HOW IT WORKS — ETI 475

The tuner employs a TRF design where all the amplification and selectivity is achieved at the actual frequency of reception, prior to the detector.

The required selectivity characteristics are provided by the input tuned circuit which is arranged to tune the whole broadcast band, from 530 kHz to 1650 kHz. Several stages of untuned RF amplification follow the tuned circuit. A low distortion diode detector removes the audio programme information from the selected station's RF carrier and this is fed to a 9 kHz whistle filter — which provides a deep 'notch' to remove interstation heterodynes — followed by an audio output stage.

For best, low noise reception, a balanced antenna input is provided. Antennas are discussed in the text. The two tuned circuits, comprising L1, L2 and the dual-gang tuning capacitor CV1/2, are mutually coupled by C1. Individually, each tuned circuit has quite a high Q by virtue of the totally 'closed' magnetic field provided by the pot core. The reactance of C1, whilst small, is sufficient to overcouple the two tuned circuits, providing a 'double-humped' response (see the accompanying diagram). To remove the 'dip' in the middle of the response, the overall circuit Q is 'damped' by two, low value resistors — R1 and R2.

A FET source follower, Q1, isolates the input tuned circuits from the first RF amplifier stage, Q2. The input impedance to the gate of Q1 is quite high and this avoids loading the coupled tuned circuits which would reduce the Q. Gate bias dc return is via R3, R2 and L2. The source of Q1 is coupled to the base of Q2 via C3. This first stage of RF amplification has a gain of about five and is stabilised by having part of the emitter bias resistance unbypassed (R12).

An RF gain control is placed between the first and second RF amplifier stages. A dual-gang potentiometer, RV1a and RV1b, connected in a cascade configuration, provides very smooth control over the signal level.

The input stage FET has its drain decoupled from the supply rail by R4 and C2 while Q2 has its collector circuit and base bias decoupled by R7 and C4.

The third stage of amplification is provided by Q3 which operates at full gain. To prevent VHF parasitic oscillation in this amplifier, a wideband RF choke, RFC1, has been inserted in series with the input to the base.

A further two stages of amplification follow, before the detector. Transistors Q4 and Q5 are direct-coupled and the collector of Q5 drives the diode detector via C11.

The detector is a voltage-doubling type with degeneration to reduce distortion. In addition, there is negative feedback from the detector to the emitter of Q4 via C12, further reducing distortion. A signal strength meter has been provided as a tuning aid. It measures the dc output level from the detector. Capacitor C14 provides smoothing for the meter, removing any audio signal influence.

RF 'smoothing' from the output of the detector is provided by R24 and C15 forming a low pass filter that passes audio (3 dB down at 28 kHz) but bypasses the RF. The output of this is coupled to the input of the audio output stage via the 9 kHz whistle filter. This is a parallel tuned circuit made up by L3 and C16. This provides a 'notch' in the audio response, attenuating any 9 kHz interstation whistles by more than 30 dB. The coil is constructed in a pot core which ensures high Q and a narrow bandwidth notch.

The audio output stage consists of a Darlington pair emitter follower stage, Q6 and Q7. This has a high impedance input, so as not to load the whistle filter, and a low impedance output suitable to drive the 'tuner' input of an amplifier. The collectors of Q6 and Q7 are decoupled from the supply rail by R29 and C18.

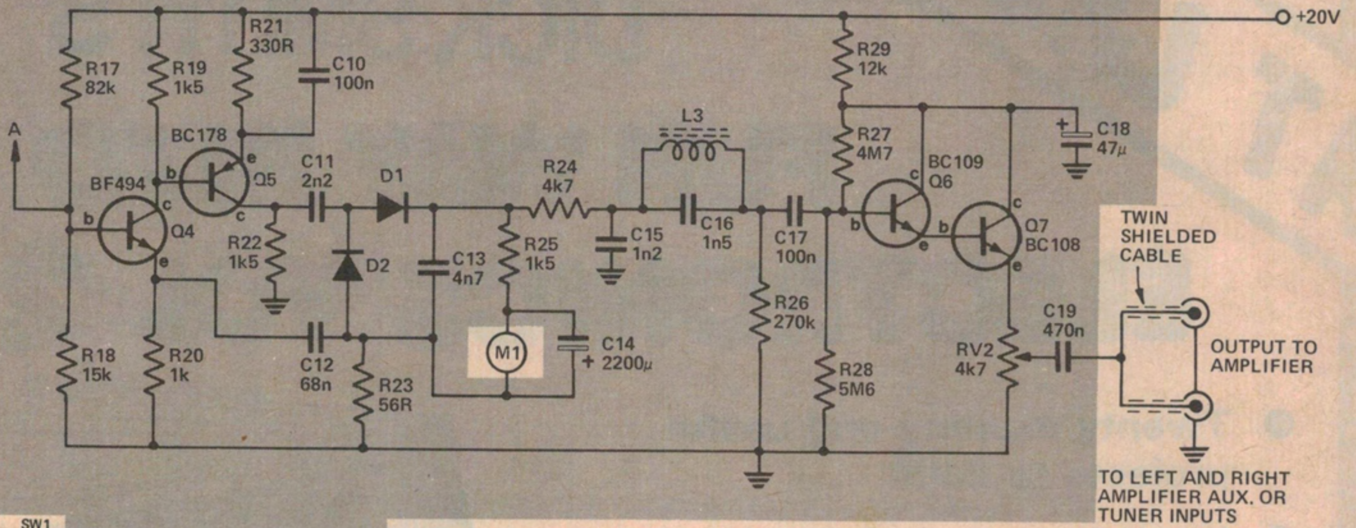
Power is supplied from a plug back, thus removing a possible source of hum pickup, and a voltage-doubler rectifier involving D3, D4, C21 and C22. Extra supply filtering is provided by R31 and C23. A front panel LED power indicator, LED1, is supplied directly from the rectifier output. Switch SW1 is used to turn the tuner on and off.

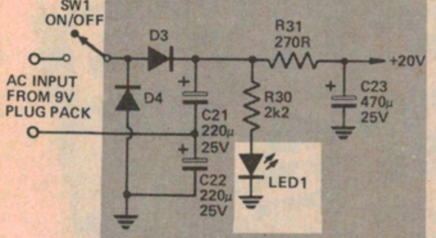
located between the first and second stages of RF amplification. Its purpose is to allow adjustment of the signal level so that at no time is the detector overloaded.

The detector employed features some signal degeneration, via R23, to reduce distortion and negative feedback to one of the RF amplifier stages to further reduce distortion. The overall distortion

PARTS LIST — ETI 475

Resistors	all ½W, 5%
R1,R2	10R
R3	100k
R4	470R
R5	100R
R6,R21	330R
R7,10,16,20	1k
R8,13,17	82k
R9,14,18	15k
R11	820R
R12	220R
R15,19,22,25	1k5
R23	56R
R24	4k7
R26	270k
R27	4M7
R28	5M6
R29	12k
R30	2k2
R31	270R
Potentiometers	
RV1	10k linear dual pot.
RV2	4k7 flat mounting large trimpot.
Capacitors	
C1,C11	2n2 greencap
C2,3,4,5,7, 8,10,17,20	100n greencap
C6	470p ceramic or styroseal
C9	100p ceramic or styroseal
C12	68n greencap
C13	4n7 greencap
C14	2200u/16V electro
C15	1n2 greencap
C16	1n5 see text
C18	47u/25V electro, axial lead type





C19	470n greencap
C21,C22	220u/25V electro
C23	470u/25V electro

Variable Capacitors

CV1,CV2	415p dual gang variable capacitor (Roblyn RMG — 2), see text
CV3,CV4	40p film dielectric trimmer, Philips type 2222 808 01027 (grey case) or similar.
Inductors	see coil winding details

Semiconductors

D1,D2	AA119, OA95, see text
D3,D4	1N4004, A14A or sim.
Q1	2N5459
Q2-Q4	BF494
Q5	BC558, BC178
Q6	BC549, BC109
Q7	BC548, BC108
LED1	red LED, TIL220R or sim.

Miscellaneous

SW1	one pole, two position rotary switch
M1	1 mA meter, University TD48, Minipa MU45 or similar

Planetary dial drive with flange (Watkin Wynne type 4511 DAF or similar); large black knob 40 mm dia., aluminium disc 55 mm dia. for scale plate (see text); two small black knobs; two antenna terminals: one black, one red; two-pin plug and socket for power input; 9V plug pack, Ferguson type PPA9 - 500 or similar; length of twin shielded cable with two RCA plugs on one end; five pc board standoffs, box to suit (see text); ETI-475 pc board.

of this tuner proved to be significantly lower than that of our Wavetek laboratory signal generator, so we are unable to present a reliable distortion measurement. Listening tests confirm the low distortion characteristic of this tuner.

As some interference may be experienced in particular areas from distant stations propagating via the ionosphere (this generally occurs at night), a 9 kHz whistle filter has been incorporated. It provides an attenuation in excess of 30 dB at 9 kHz and the notch bandwidth is about 2 kHz maximum. If you do not experience any difficulties with this sort of interference, the whistle filter may be dispensed with.

A tuning or signal strength meter has been provided and it has several functions:

(a) To provide a positive tuning indication.
(b) To facilitate optimum signal strength control.
(c) To indicate when signal overload occurs.

It's a very handy aid when adjusting antennas or when setting the RF gain control.

Instruments are not absolutely necessary to align the tuner, although a signal generator makes it somewhat quicker.

An inexpensive plug back is used to provide power to the tuner. This has the advantage of removing the transformer from the tuner's chassis, eliminating a possible source of hum.

Construction

The tuner is housed in a chassis made from a 240 x 290 mm sheet of 16 gauge aluminium bent into a U-shape measuring 290 mm wide by 180 mm deep and 80 mm high. The lid was made from a 205 x 455 mm sheet of 16 gauge aluminium. It is bent and mounted so that it overhangs the front panel of the chassis by 10 mm and the rear by 15 mm. This results in quite a neat, professional-looking unit.

The power switch, power LED, signal strength meter, gain control potentiometer and planetary reduction drive are all mounted on the front panel. The antenna terminals and two-pin power input socket are mounted on the rear panel. The output lead passes through a rubber grommet.

Commence by marking out and drilling the holes in the chassis. This is probably best done before bending it up. Mark out accurately, as per the metalwork drawings. The size of hole required for the meter depends on the meter used. The one on our prototype is a Minipa MU-45 type. It fits neatly on the front panel and has a pleasing appearance. However, other types may be used, such as the University type TD48. This is a little smaller than our meter, but will do equally well.

Two lengths of aluminium angle are bolted to each side of the chassis and the lid is secured to these with either bolts (which mate with tapped holes in the angle pieces) or self-tapping screws. The aluminium brackets are cut from a single 320 mm length of 13 mm (½") angle. This is readily obtainable in hardware stores. Mark and drill the lid, then bend it carefully to shape. The aluminium angle pieces are best marked up and drilled using the chassis, and then the lid, as a template.

At this stage, the chassis and lid could be sprayed matt black inside and out, or anodised — if you're willing to go to that expense. ▶

Project 475

COIL DETAILS ETI-475

L1

Primary: two turns wound bifilar with thin plastic insulated hookup wire (wound last).
Secondary: 37 turns pile wound, 34 SWG enamelled wire (wound first).

L2

36 turns, 34 SWG enamelled wire.
L1 and L2 are wound on Philips P18/11 pot core assemblies, 3D3 material, ue = 68, with adjusters.

Philips part numbers

Pot core	4322/022/24450
Adjuster	4322/021/32170
Former	4322/021/30270
Washer	1811/HWI
Clip	1811/HPC

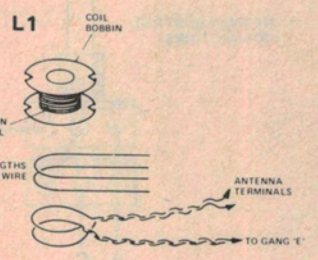
L3

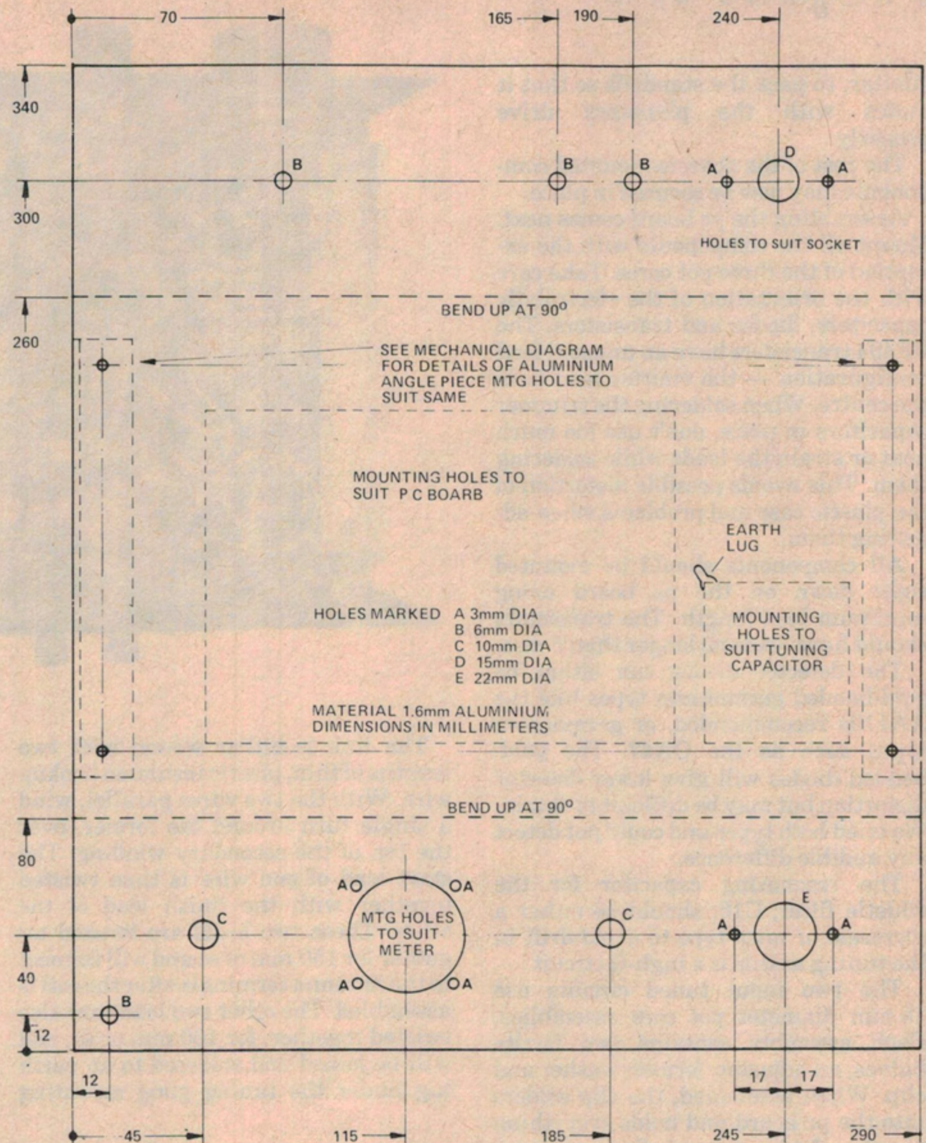
540 turns, 34SWG enamelled wire.
L3 is wound on Philips P26/16 pot core assemblies, 3B7 material ue = 220, with an adjuster.

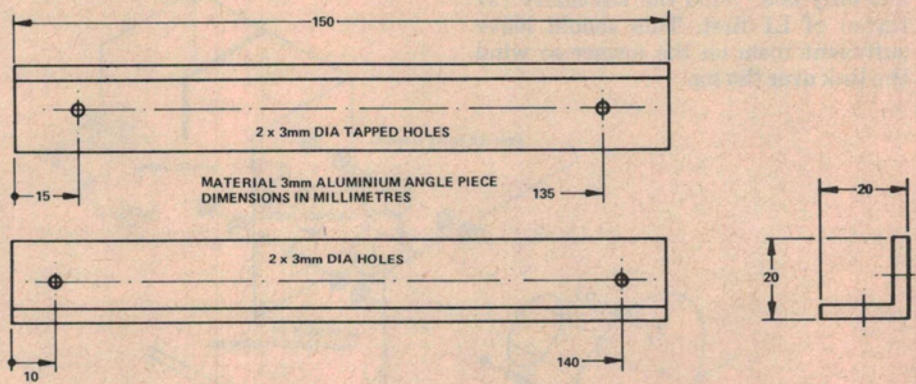
Philips part numbers

Pot core	4322/022/28080
Adjuster	4322/021/30810
Former	4322/021/30330
Clip	2616/HPC

No washer is used with the large pot core.







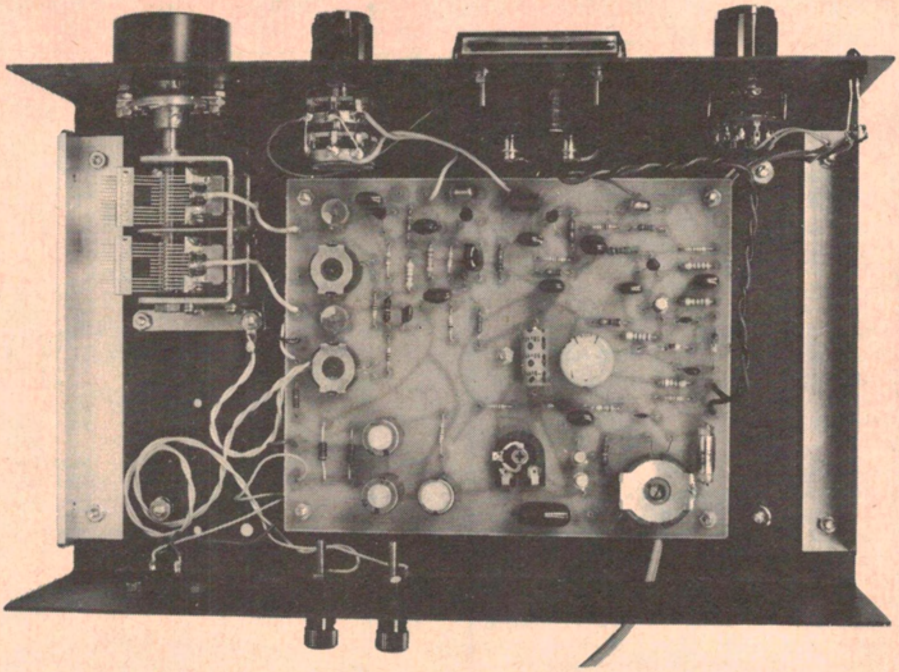
When the chassis is completely prepared, the major components can be mounted on it. The planetary drive should be mounted first. It is best to mount it on adjustable standoff pillars, as shown in the photographs, to allow the position of the dial flange to be adjusted. This should protrude from the front panel about one or two millimetres.

The dial was made up from a disc of 18 gauge aluminium (though 16 gauge or even a thinner gauge would be OK. The local stations were marked on the dial with white rub-down lettering (such as Letraset or Geotype). This disc is attached to the planetary dial flange by two screws supplied with the dial drive. The complete assembly is shown in the exploded-view diagram.

Since it will probably be difficult for most readers to cut a clean circle from aluminium, without the facilities of a machine shop, we have reproduced a suitable dial from which a Scotchcal copy may be made. If you use the metal Scotchcal, you can leave the backing paper on it and attach that as your dial.

The tuning knob on the prototype is a little special. It consists of a large diameter knob with a turned-up aluminium 'cup' pushed over it (the inside diameter forms a snug fit to the knob). We'll leave the knob to your ingenuity. A large knob is recommended as it provides smooth control of the tuning, a good grip and enhances the appearance.

The next step is to mount the tuning gang. It is very important that no strain is placed on the planetary drive from the shaft of the tuning gang. Careful, correct alignment will ensure this. The tuning capacitor is mounted on small standoff nuts and the shaft is carefully aligned, using washers or something ▶



similar, to pack the standoffs so that it mates with the planetary drive properly.

The rest of the chassis-mounted components may now be secured in place.

Assembling the pc board comes next. Mount all the components with the exception of the three pot cores. Take care with the orientation of the electrolytic capacitors, diodes and transistors. The BF494 transistors have an unusual lead configuration — the emitter lead is in the centre. When soldering the trimmer capacitors in place, don't use too much heat or strain the leads while soldering them. This avoids possible distortion of the plastic case and problems when adjusting them.

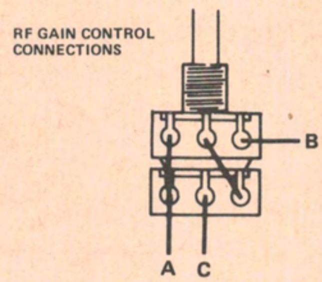
All components should be mounted right down on the pc board using minimum lead length. The transistors should have leads no longer than 5 mm.

The detector diodes can either be gold-bonded germanium types like the AA119s recommended, or germanium types such as the OA47. The gold-bonded diodes will give lower detector distortion but may be difficult to obtain. We tried both types and could not detect any audible difference.

The resonating capacitor for the whistle filter, C16, should be either a styroseal or mica type to avoid drift in the tuning as this is a high-Q circuit.

The two input tuned circuits use 18 mm diameter pot core assemblies. Each assembly contains two ferrite halves, an adjustor, former, washer and clip. When assembled, the clip solders into the pc board and holds everything together. L1 has two windings while L2 has only one. Wind the secondary (37 turns) of L1 first. This should leave sufficient room on the former so wind the link over the top.

The link is bifilar wound with two lengths of thin, plastic insulated hookup wire. With the two wires parallel, wind a single turn around the former, over the top of the secondary winding. The start lead of one wire is then twisted together with the finish lead of the other. These two leads are twisted together for 150 mm or so and will connect to the antenna terminals after the coil is assembled. The other two leads are also twisted together, for 100 mm or so, and will be joined and soldered to an earth lug under the tuning gang mounting bolt adjacent to the coil locations on the pc board.



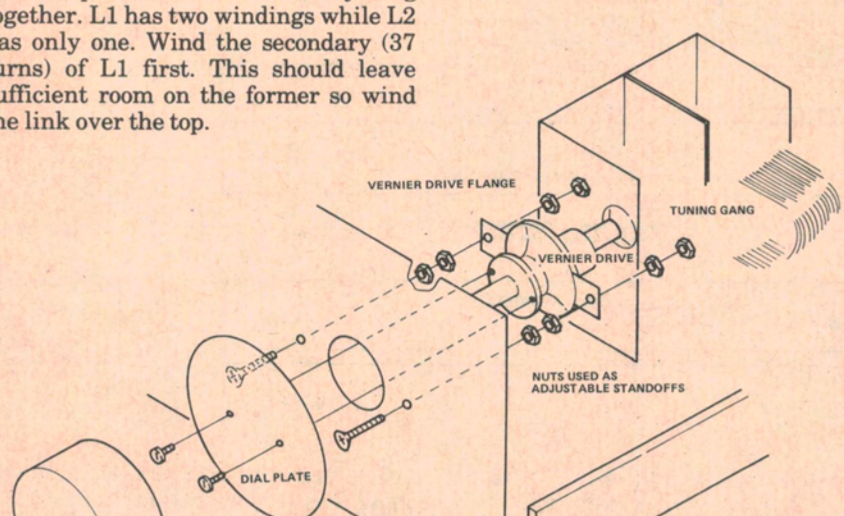
The accompanying exploded diagram should make the assembly of this link winding clear.

Arrange the wires so that all the link wires come out one side of the bobbin and the secondary wires come out the other.

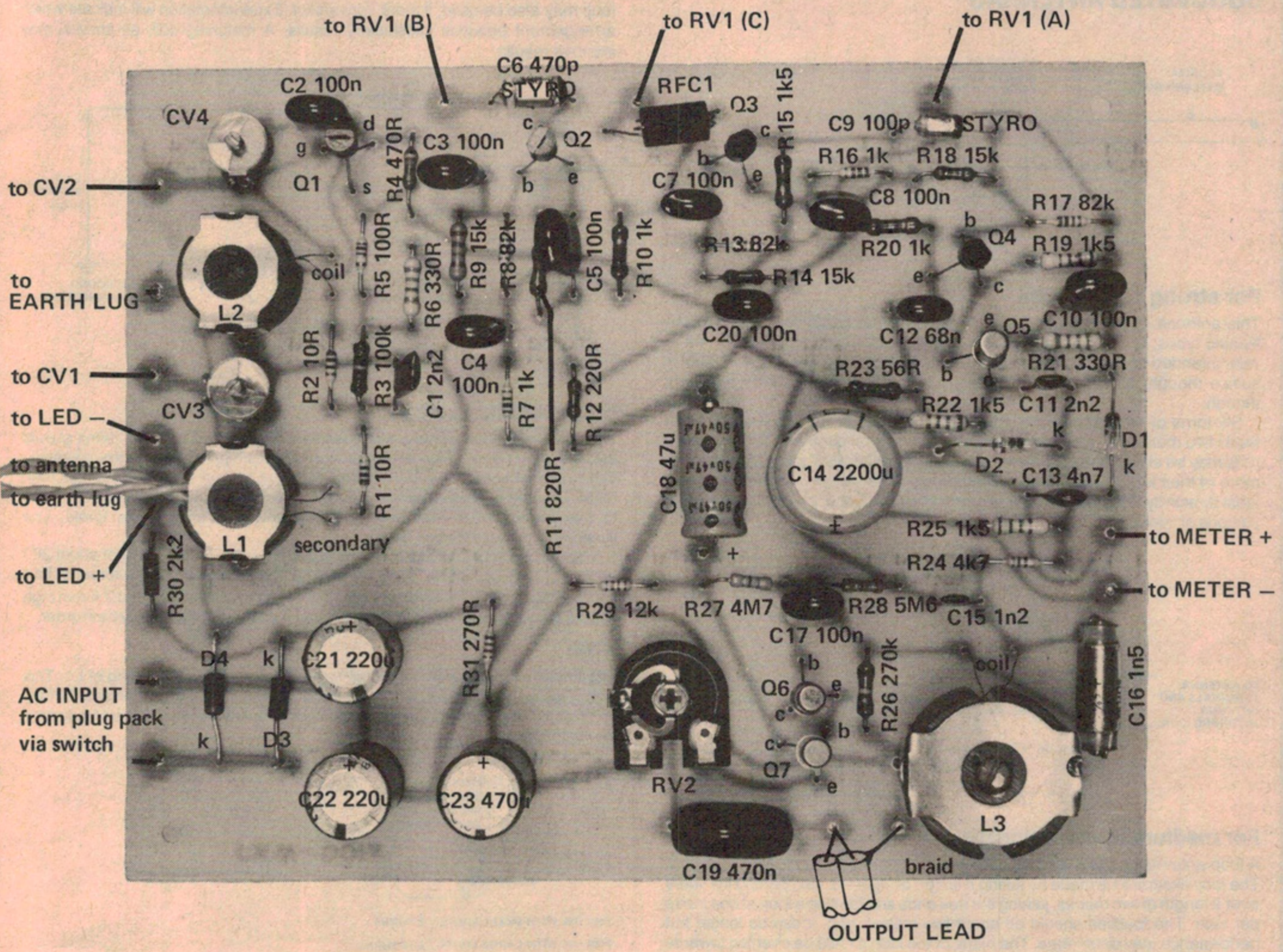
Assemble the two ferrite pot core halves over the former, place the washer on top of the assembly and slip on the clip. The washer ensures an even pressure is transmitted from the clip to the ferrite assembly and should always be used with these small pot cores. Insert the adjuster carefully into the centre hole of the core using a small aligning tool. Take care as it cuts its own thread in the nylon insert and any forcing can damage this.

Solder the complete assembly into the pc board (before everything falls apart!) orienting the assembly with the link connections facing the edge of the board and the secondary connections toward the centre.

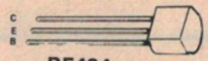
The second front end pot core, L2, is assembled in a similar way but note



EXPLODED DIAGRAM OF VERNIER DRIVE AND DIAL ASSEMBLY

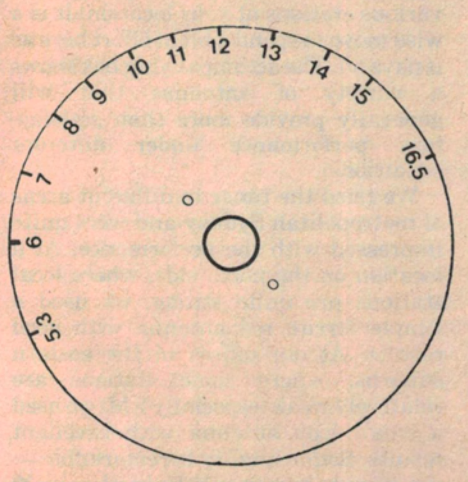


NOTE: Space problems prevent us publishing the pc board pattern this month. A good quality photostat may be obtained by sending a large, stamped-addressed envelope to 'AM Tuner PCB' c/o the magazine. We will endeavour to publish the pc board next month.



BF494

BC109



Full-size reproduction (negative) of the dial.

that it has no link.

The whistle filter, L3, uses a 26 mm diameter pot core which is assembled in a similar fashion to the other two except that it does not require a washer under the clip. Wind the wire on the bobbin as detailed in the accompanying box. The wire should almost fill the former, so be careful to wind it firmly, laying the turns neatly on the bobbin.

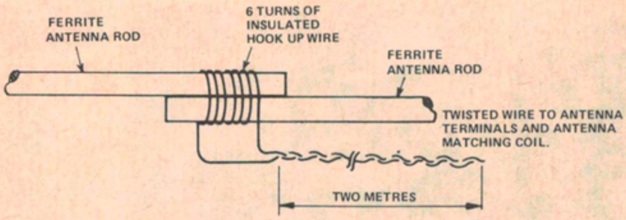
Tuning up

Turn the unit on and connect it to your stereo amp. Turn trimpot RV2 on the pc board fully clockwise. Connect an antenna and turn the RF gain control fully clockwise. Set the two trimmer capacitors at mid range (you can see the plates), and the ferrite adjusters in L1 and L2 at half depth. Tune over the range and you should hear some stations. Select a station at the high frequency end of the range. By adjusting the two trimmers in turn, and the tuning capacitor, bring the station to its correct position on the dial. This requires a little juggling with the three adjustments. Next, find a station at the low frequency end of the dial and repeat the procedure, this time tuning in the station using the two ferrite pot core adjusters and the tuning capacitor. You now have the receiver roughly aligned.

Repeat the process but this time you can set the dial to where a station should be located on the dial (according to the markings) and tune the two trimmers for maximum signal on the meter. Repeat for a low frequency station, adjusting the pot cores.

Repeat once more, just to make sure, ▶

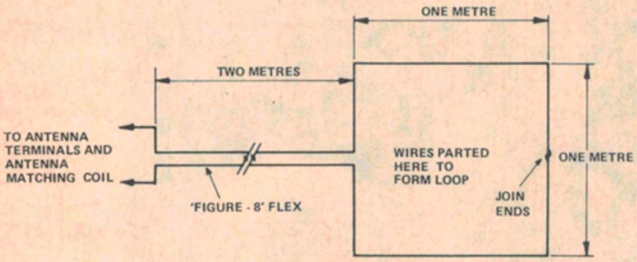
SUGGESTED ANTENNAS



For strong signal areas

This antenna is constructed of two 13 mm diameter ferrite rods. We suggest Neosid types, of F8 material, 12.7 mm diameter by 100 mm long. Most ferrite rods intended for broadcast band 'loopstick' antenna applications will probably suffice though, as construction is not all that critical; performance may vary though.

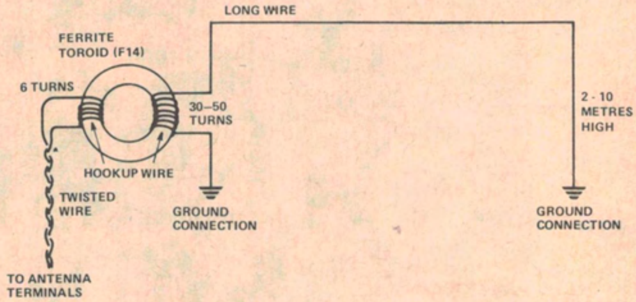
Six turns of hookup wire are wound firmly around the two rods and twisted leads two metres long connect to the tuner's antenna terminals. The two ferrite rods may be extended as illustrated or pushed together so that they overlap over more of their length. As shown, the antenna provides maximum sensitivity and least directivity. The rods should be oriented for best reception for the station or stations of interest.



For medium to weak signal areas

A loop antenna can provide very good results where signals are not too strong. The loop illustrated is made by taking a length of 'figure-8' flex, parting the wires over a length of two metres, joining the free ends and forming a loop of one metre per side. The feedline should be about two metres long. It can be longer but performance may deteriorate. The plane of the loop should be oriented towards the transmitters for best results.

A larger loop may be constructed to improve pickup. Note that a rectangular loop may also be used, if more convenient. Experimentation will indicate which arrangement provides satisfactory results. A matching coil, as shown, may improve results.



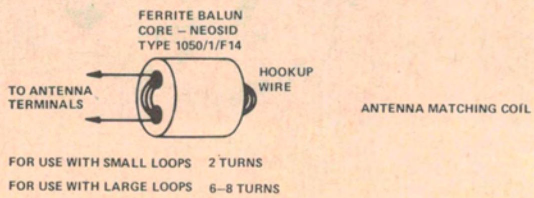
For weak signal areas

If you live in a weak signal area, or want to 'chase the DX', this antenna should provide good results. Run a long, straight wire as high above the ground as you can reasonably manage ánd as long as will fit in your property (but less than 5 km !). Connect the furthest end to a ground stake. The opposite end connects to the primary of a 'matching' transformer wound on a ferrite toroid. The illustration shows the main details.

The toroid should be of a material having an initial permeability of about 200 to 300, t least, and an A_L factor of around 100 to 150. A Neosid toroid of F14 material, 25.4 mm outside diameter, 19.05 mm inside diameter and 9.5 mm high should do nicely. It's not too critical, and some experimentation may be in order.

Note

The impedance of the antenna will have some effect on the tuning of L1. This may necessitate minor re-alignment of the adjuster in L1 if you change antennas or change the position of the antenna. Check the alignment at the low frequency end of the band.



and you should notice that all the stations are in their correct positions on the dial. If you change antennas you may need to make a slight re-adjustment to L1.

The whistle filter can be adjusted by tuning across the dial until you find a 9 kHz whistle between two stations. Wind the ferrite adjuster on L3 in until the tone disappears. If no whistles are found, wind the adjuster all the way out.

An alternative method is to use a signal generator with external AM modulation. Set the modulation to 9 kHz, at about 80%, and tune in the signal. Use the ferrite adjuster on L3 to null the audio from the speaker.

Always use proper adjusting tools (these are available from most suppliers) to avoid breaking the adjusters or affecting their correct operation. The pot core adjusters are delicate and should be treated with kindness. Overzealously screwing them in and out will almost certainly result in permanent damage.

This fairly simple alignment technique yielded an overall bandwidth, at the −3 dB points, extending from 15 Hz to 12 kHz. For those readers with a little more perseverance, this can be improved with judicious adjustment of the tuned circuits.

Operation

With the unit aligned you can connect an antenna and enjoy sounds from an AM tuner you never thought possible!

The output level to your stereo amplifier may be set by adjusting RV2, a trimpot on the pc board. The setting will depend on the signal strengths of the different stations at your location and the tuner input sensitivity of your amplifier. It is best set by experiment.

The antenna required will depend, again, on the signal strengths of the various stations at your location. It is a wise move to spend a bit of effort here as it pays off. The accompanying box shows a variety of antennas that will generally provide more than satisfactory performance under different conditions.

We tried the tuner in different areas of metropolitan Sydney and were quite impressed with the performance. At a location on the north side, where local stations are quite strong, we used a simple ferrite rod antenna with good results. At our offices in the eastern suburbs, where some stations are relatively weak (especially 2JJ) we used a small loop antenna with excellent results. Sound quality is remarkable — you have to hear it to believe it! ●