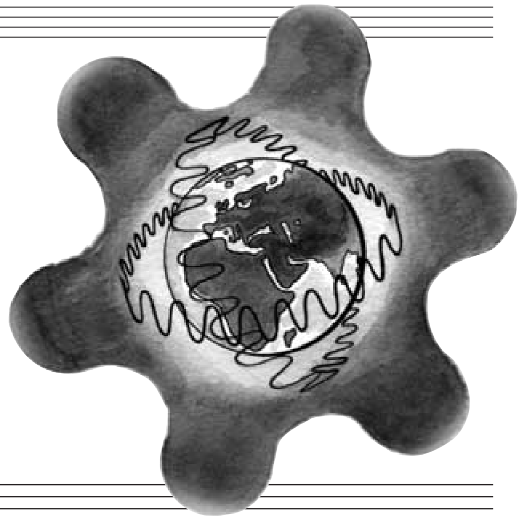
Constructional Project

ACTIVE FERRITE LOOP AERIAL



RAYMOND HAIGH

Whether you're a serious Medium Wave listener or just an inveterate band browser, this compact loop aerial will be an aid to better reception.

LARGE loop or frame aerials were a common part of the 1920s domestic radio scene, but their popularity waned during the thirties when an external wire became the normal means of signal pick-up.

A decade later, improved receiver sensitivity made it possible for small loops to be enclosed within the cabinets of portable and table sets. At the close of the fifties, in the twilight of the valve era, very high permeability ferrites were introduced. Rod-like cores of this material enable a tiny coil to pick up signals better than a small, air-cored loop, and ferrite aerials are now found in most domestic receivers.

TILT AND TURN

When the axis of the loop or coil is pointing towards the transmitter, the induced signal voltage falls, in theory, to zero. The two nulls, 180 degrees apart, are extremely sharp. They enable the operator to prevent interference reaching the receiver, and to separate stations operating on the same frequency.

It is this property which encouraged American Raymond S. Moore to re-introduce the large, air-cored loop, for serious Medium Wave listening, during the 1940s.

The need to rotate the aerial in a horizontal plane to optimise reception is evident to every owner of a transistor portable radio. What is not so widely appreciated is the need to tilt it in the vertical if the deepest possible nulls are to be obtained.

Medium frequency radio waves reach the receiver by line-of-sight (direct waves), travel to it around the curvature of the earth (surface waves), and, at night, are reflected down from the ionosphere (sky waves). The loop must, therefore, tilt as well as turn in order to point its axis precisely at the advancing wave front.

Another American, Gordon Nelson, was probably the first designer to incorporate tilting into his Medium Wave loops.

LOOPS AND WIRES

Transmitting aerials radiate electrostatic and electromagnetic fields which coexist at right angles to one another. Long wire and whip aerials, in conjunction with some form of earthing, are acted upon by the electrostatic field. Signal voltages are induced in loop aerials by the magnetic field.

Signal pick-up by a long (20 metres plus), high (8 metres plus) wire and a decent earth will usually exceed that from even a large loop. A coil wound on a 150mm × 9mm diameter ferrite rod will develop signal voltages around 18dB below those induced in a one metre square air-cored loop.

A loop of these dimensions, mounted so that it can tilt and turn, is cumbersome and more than a little out-of-place in a domestic setting. However, by increasing the size of the ferrite rod, amplifying the output, and multiplying the *Q* of the coil, a ferrite loop can be made to outperform its bigger, air-cored brother.

This approach has been adopted in the design of the very compact unit which is described here.

FERRITE RODS

Because of the high permeability of the ferrite, the magnetic field radiated by the transmitter is concentrated in the rod and the signal induced in the coil wound around it greatly increased.

Bigger rods provide more signal pick-up. Some early ferrite loops produced for Medium Wave listening had rods more than a metre long. This rather defeats the advantage of compactness, and experiments have shown that bundling the rods together to increase the overall diameter is as effective as placing them end-to-end to increase length.

Loops incorporating up to thirty rods have been produced. Signal pick-up increases with each additional rod, but the rate of improvement seems to fall off after about ten or so. Weight and cost are also limiting factors, and this design incorporates seven rods. Fewer or more rods can, of course, be used, and guidance on this is given later.

HIGH-Q

Tuned circuits incorporating coils wound on ferrite rods have a high *Q*. This restricts bandwidth and can result in side-band cutting which reduces treble response.

The application of positive feedback to the tuned circuit increases *Q* and signal output. The price paid for this is a further reduction in bandwidth. Sideband cutting becomes severe and treble response heavily attenuated. Moreover, with high levels of *Q* multiplication, loop tuning becomes critical.

High selectivity ahead of a receiver covering a congested and noisy band can be very useful, however. Careful operation can restore the treble response, and measures can be taken to overcome the problem of critical tuning.

GOING ASTRAY

The Medium Wave band extends from 527kHz to 1620kHz in Europe. In the USA, stations operate up to 1700kHz, and Australia has low-powered transmitters working at 1720kHz.

United Kingdom coverage is from 558kHz to 1602kHz, the region beyond 1602KHz being taken up by cordless 'phone channels. In Europe, Dutch, Greek and Serbian pirate stations invade the segment above 1600kHz.

Stray capacitance can be relatively high with circuits of this kind, and the tuning capacitor should have a swing of at least 10pF to 450pF to ensure coverage from 1720kHz down to 527kHz. Air-spaced variables of this value are no longer readily available and currently listed polythene dielectric types (as used in transistor portables) have a lower value, even when two gangs are connected in parallel.

circuitry avoids any loss of efficiency because of this.

Concern is sometimes expressed at the possibility of strong signal voltages disturbing the diode bias and introducing cross modulation. No problems of this kind have been encountered with the loop design described here.

CIRCUIT DETAILS

The full circuit diagram for the Active Ferrite Loop Aerial is shown in Fig.1. The main components of the circuit are a dual-gate MOSFET (TR1), a field effect transistor (TR2), a varicap diode (D1) and, of course, the multi-rod ferrite "loop'' aerial.

Sockets SK1, SK2 are provided for external aerials and SK3 is the common Earth socket. Switches S1a and S1c permit an instant comparison between loop and wire aerials. Another switch, S1b, connects the battery into circuit. Low current l.e.d. D2 with its dropping resistor R7 forms an economical on/off indicator.

feedback. The gain of TR1, and hence the Q multiplication, is controlled by VR4, which determines the voltage on gate g2.

The stage is decoupled from the supply by preset VR5 and capacitor C5. Making the decoupling resistor variable enables the operating conditions to be adjusted to suit different dual-gate MOSFETs.

Positive feedback is applied, via source bias resistor R4 and its bypass capacitor C4 to coil winding L2.

BUFFER

The impedance of the tuned circuit is very high at resonance and most communications receivers have a low input impedance, typically 50 ohms. Source follower stage TR2, with its high input and low output impedance, matches the loop aerial to the receiver. The voltage gain of a source follower is slightly less than unity. There is, however, a significant power gain.

Decoupling of the source follower stage is provided by resistor R5 and capacitor C7, and the output is developed across source

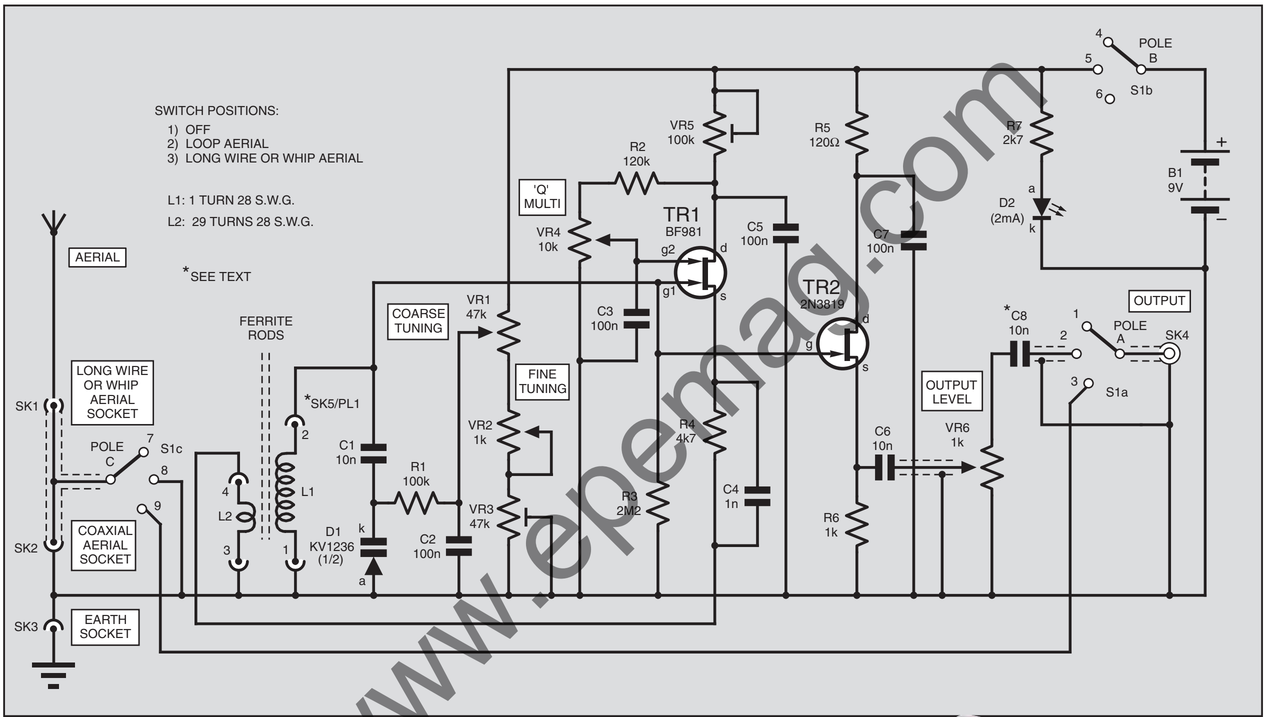


Fig.1. Complete circuit diagram for the Active Ferrite Loop Aerial.

VARICAPS

Varicap diodes intended for M.W. tuning are widely retailed. Although the minimum capacitance of these devices is higher than that of their mechanical counterparts, they have a big enough maximum capacitance to ensure the required coverage.

Varicaps exhibit a tuning rate which reduces as frequency increases, and this makes loop adjustment easier. Moreover, the provision of vernier or fine tuning involves no more than an additional potentiometer. They are also relatively inexpensive. Quite apart from the question of availability, therefore, electronic tuning has much to recommend it.

These semiconductor devices have a lower Q than a mechanical capacitor, particularly at low bias settings when the capacitance is close to maximum. However, the inclusion of Q-multiplying

TUNING

The loop's main winding L1 is tuned by varicap diode D1, which is connected to it via d.c. blocking capacitor C1. Tuning bias is applied through signal isolating resistor R1.

Potentiometer VR1 adjusts the bias voltage and acts as the Coarse, or main tuning control. Fine tuning is provided by VR2 which produces a much smaller voltage change. Preset potentiometer VR3 sets the minimum bias voltage, fixing the maximum capacitance of the varicap and the low frequency limit of the tuning range. Bypass capacitor C2 eliminates any potentiometer noise.

Q-MULTIPLIER

Dual-gate MOSFET TR1 amplifies the signal voltage developed across coil L1 in order to provide Q enhancing positive

load resistor R6. Output level control VR6 could be connected as the source load. However, the arrangement shown ensures that the impedance presented to the receiver is reasonably constant. Capacitors C6 and C8 block the flow of d.c.

COMPONENTS

Resistors

R1	100k	See SHOP TALK page
R2	120k	
R3	2M2	
R4	4k7	
R5	120Ω	
R6	1k	
R7	2k7	

All 0·25W 5% carbon film

Potentiometers

VR1	47k rotary carbon, lin.
VR2	1k rotary carbon, lin.
VR3	47k enclosed carbon preset, horizontal
VR4	10k rotary carbon
VR5	100k enclosed carbon preset, horizontal
VR6	1k rotary carbon (log law, if obtainable).

Capacitors

C1	10n polycarbonate or Mylar.
C2, C3, C5, C7	100n disc ceramic (4 off)
C4	1n disc ceramic
C6, C8	10n disc ceramic

Semiconductors

D1	KV1236 dual varicap diode (½ of)
D2	3mm or 5mm red l.e.d., low current (2mA)
TR1	BF981 *n*-channel dual-gate MOSFET
TR2	2N3819 *n*-channel field effect transistor

Miscellaneous

L1, L2	ferrite loop aerial, wound using 28s.w.g. enamelled copper wire – see text
S1	3-way 4-pole rotary switch (plastic cased Lorlin)
SK1, SK3	screw terminal post, with 4mm socket top (2 off)
SK2, SK4	coaxial socket, chassis mounting (2 off)
SK5/PL1	stereo jack socket and plug, for linking ferrite aerial to main unit (optional)

Printed circuit board available from the *EPE PCB Service*, code 274; ferrite rod, 9mm dia. at least 150mm long (7-off – see text); instrument case for control unit, size 170mm x 150mm x 50mm; diecast screening box for p.c.b. (optional), size 120mm x 90mm x 30mm; l.e.d. holder; plastic control knob (5 off); 9V battery with connectors and box; single-core screened cable; multistrand connecting wire; plastic pipe for aerial coil former; materials for ferrite loop aerial housing/mounting; fixing nuts and bolts; solder tag; solder etc.

Approx. Cost Guidance Only £35
excl. case and "mechanics"

COMPONENTS

Most dual-gate MOSFETs, including the BF960, BF961, 3SK81, 3SK85, MFE201 and 40673 will prove satisfactory in this circuit. Likewise, most j.f.e.t.s, including the BF244, BF245, J310, MPF102, TIS14 and 2SK168 will be suitable for the source follower stage TR2. Case styles and leadouts vary and must be checked if these and other alternatives are substituted.

Most varicaps designed for Medium Wave tuning with a 9V maximum bias should prove suitable. Plastic pipe for the coil former for L1/L2 is available from DIY outlets, and plastic and metal spindles and bushes for the loop aerial mounting are stocked by model shops.

CONSTRUCTION

Dealing with the control box first. Most parts are assembled on a small printed circuit board (p.c.b.), which is available from the *EPE PCB Service*, code 274.

The topside component layout, off-board wiring and a full-size underside copper foil master pattern are shown in Fig.2. Note that one lead of capacitor C8 is soldered directly on to one tag of VR6 and the other to the solid, centre core, lead of the coax cable running to pin 2 of the rotary switch section S1a. Provision is not made for this component on the p.c.b.

Commence construction by mounting the smallest components first, and solder the semiconductors into circuit last. The use of tweezers or a crocodile clip as a heat shunt is a wise precaution when soldering the f.e.t.s.

Solder pins inserted into the board beneath the specified MOSFET leads will permit TR1 to be mounted on the component side of the board. Pins inserted at the p.c.b. lead-off points will ease the task of interwiring.

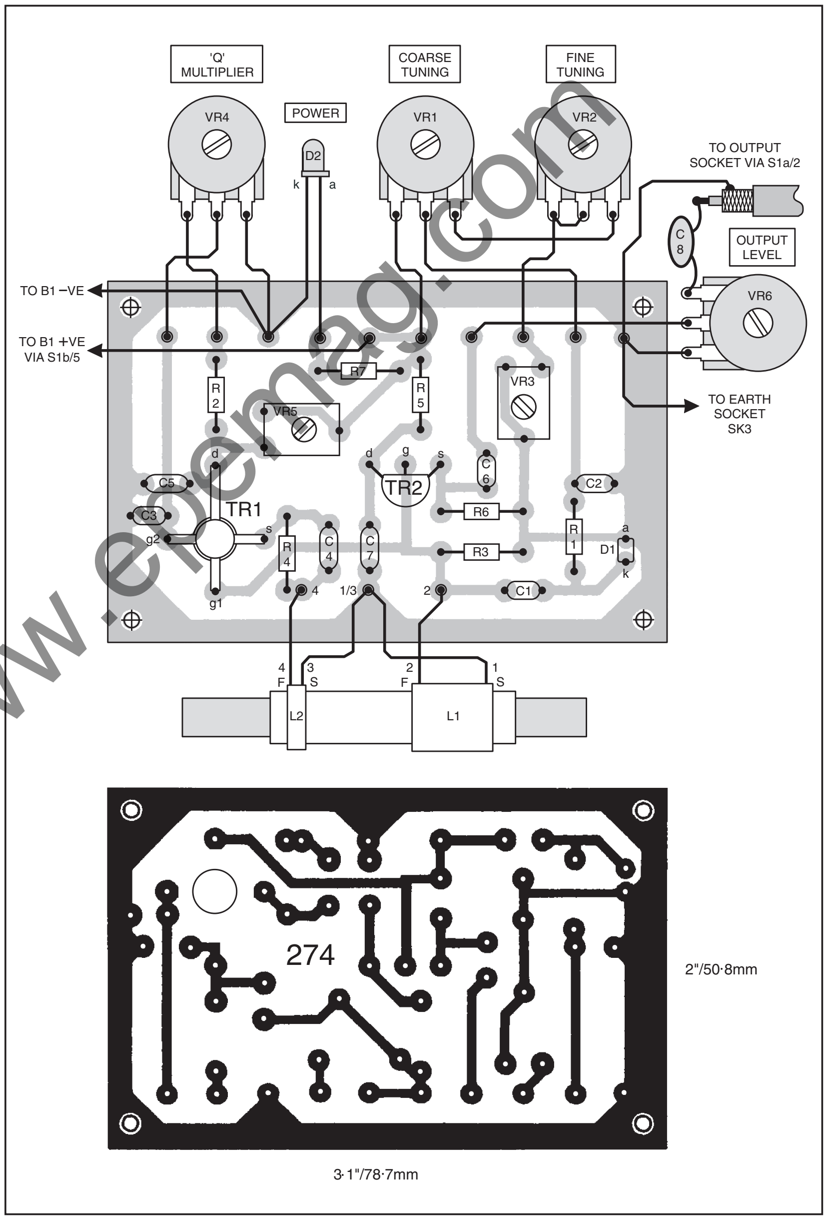


Fig.2. Printed circuit board topside component layout, off-board wiring and full-size copper foil underside master. Note capacitor C8 is mounted directly on one outer tag of VR6 and soldered to the centre core of the output screened lead.

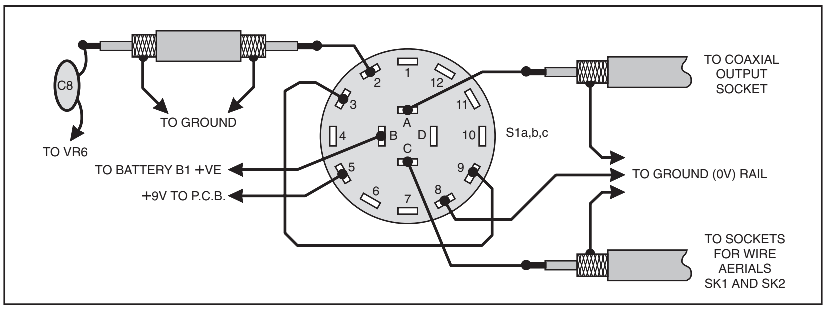


Fig.3. Wiring to the on/off and aerial selector switch. Pole letters and tag numbers match specified switch.

Use screened cable (ordinary audio type cable will suffice for this purpose) between the wire aerial input sockets, the rotary switch, and the loop output socket. Connect the metal cases of the potentiometers to ground (0V rail). Details of the Selector switch wiring are given in Fig.3.

HOUSING THE CONTROLS

The photographs show how the controls and p.c.b. are housed in a plastic instrument case which also acts as the base of the unit. The p.c.b. and jack socket SK5 are screened within a diecast box which also strengthens the case beneath the loop. Screening the p.c.b. is not essential; the entire enclosure can be of wood or plastic.

RODS AND TURNS

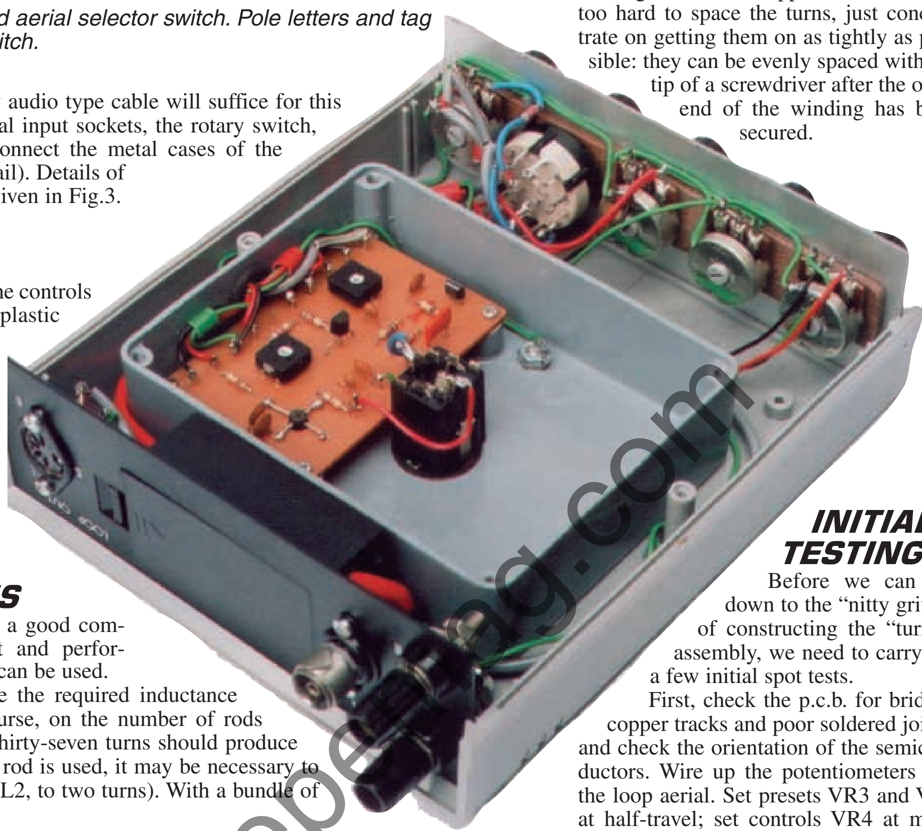
Seven ferrite rods represents a good compromise between cost, weight and performance, but fewer or more rods can be used.

The number of turns to give the required inductance (about 160μH) depends, of course, on the number of rods finally used. For a single rod, thirty-seven turns should produce the required value. (If only one rod is used, it may be necessary to increase the feedback winding, L2, to two turns). With a bundle of thirty rods, twenty turns will be about right.

FERRITE LOOP

Moving on to the loop assembly, Fig.5, tightly bind the seven ferrite rods together with masking tape, winding on sufficient material to ensure that the plastic coil former is a tight sliding fit.

Secure the wire to the former with a narrow strip of tape and wind on the specified number of turns – 29 turns of 28s.w.g. enamelled copper wire. Don't try too hard to space the turns, just concentrate on getting them on as tightly as possible: they can be evenly spaced with the tip of a screwdriver after the other end of the winding has been secured.



INITIAL TESTING

Before we can get down to the "nitty gritty" of constructing the "turret" assembly, we need to carry out a few initial spot tests.

First, check the p.c.b. for bridged copper tracks and poor soldered joints, and check the orientation of the semiconductors. Wire up the potentiometers and the loop aerial. Set presets VR3 and VR5 at half-travel; set controls VR4 at minimum and VR6 at maximum.

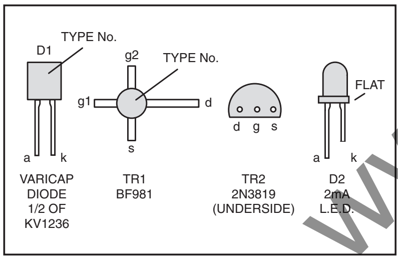
Connect the unit to the receiver by a short length of coaxial cable, then connect a 9V battery. Current consumption should be approximately 5mA.

Assuming you are using a receiver with an in-built signal strength meter, proceed as follows. With receiver and loop tuned to a strong transmission, the receiver's signal strength meter should be driven hard over. Turn down Level control VR6 until the signal strength meter reads about half-scale. Advancing the Q-multiplier control VR4 should now drive the pointer hard over again.

Loop tuning has to be very precise at high Q levels, and it may be necessary to use Fine tuning control VR2 to bring loop and receiver into perfect alignment.

Check that the loop can be tuned over the required frequency range, and adjust preset VR3 until the low frequency limit is reached with VR2 at minimum resistance. Set preset VR5 so that the loop just glides into oscillation, with Q-control VR4 at maximum, when tuned to a station near the low frequency end of the band.

Sliding the coil along the ferrite rods will change its inductance, and coverage can be adjusted in this way. If it has to be located very close to the end, remove a



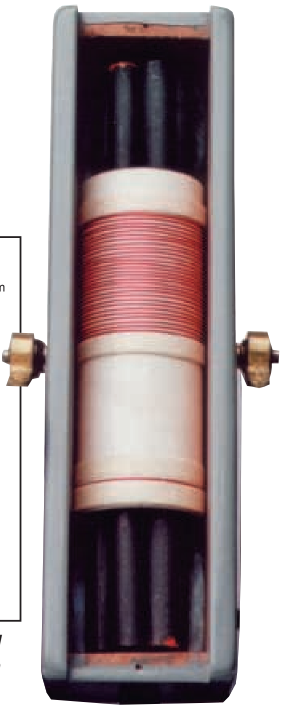


Fig.4 (left). Semiconductor pinout details. (Right) Completed ferrite loop aerial housed in a pivot box.

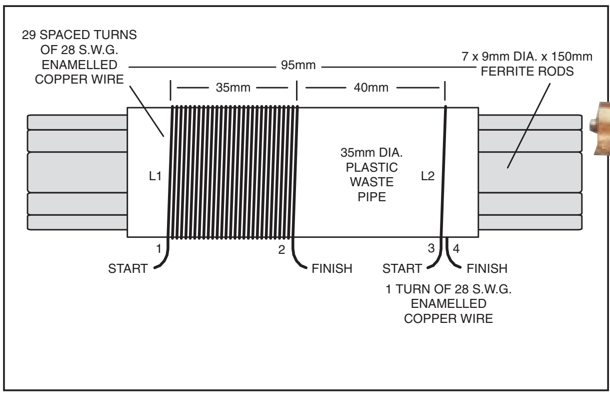


Fig.5. Ferrite rod (7 off) loop aerial winding details and dimensions. The coil former is made from a piece of 35mm outside diameter plastic waste pipe.

ACTIVE FERRITE LOOP AERIAL

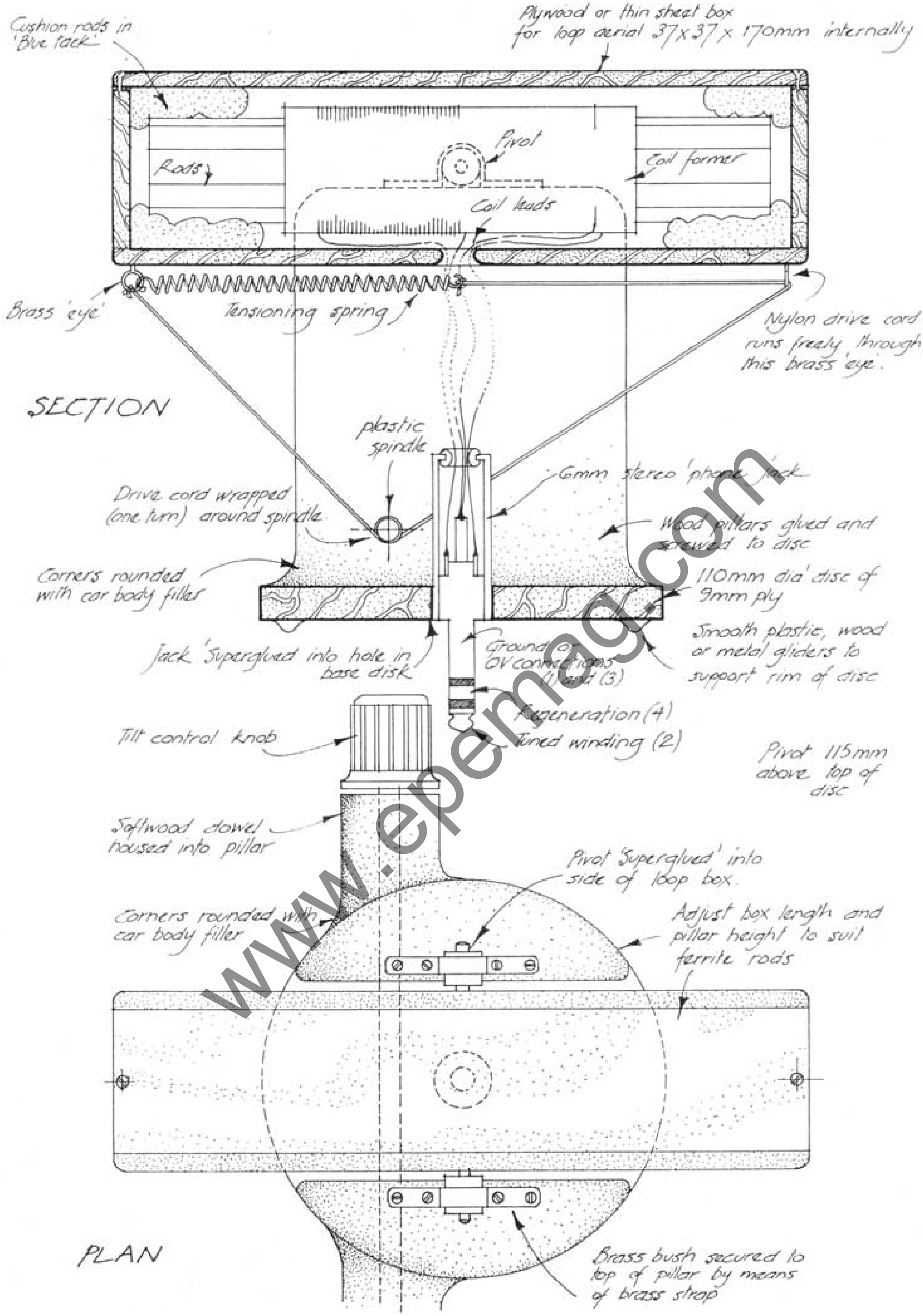
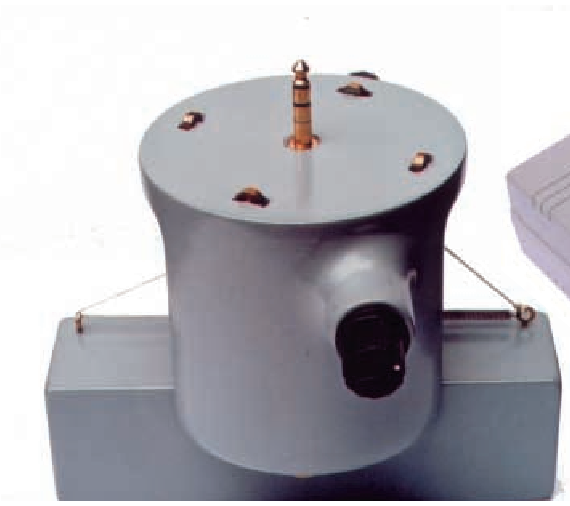
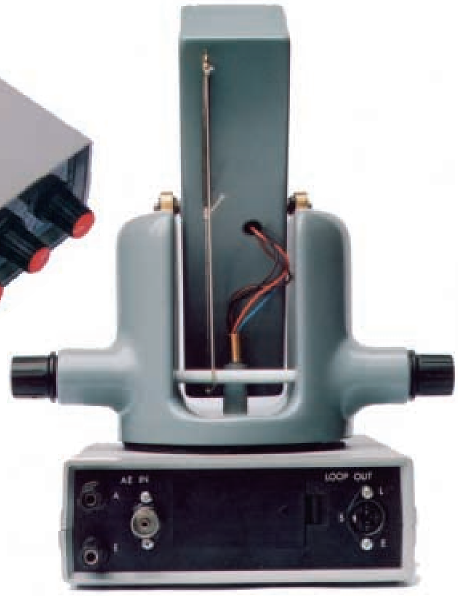


Fig.6. Details of the tilt and turn assembly.



Underside of the "turret" assembly showing four wheels set in the plywood base to relieve the strain on the jack plug. The wheels are taken from curtain runners and mounted on spindles cut from a wire coat hanger. The wheels are cushioned on a disc of thin leather, above right, to allow the turret to glide around freely and silently.



Rear of the prototype model, showing the tilt drive-cord arrangement.

turn. If the lowest frequencies cannot be covered even when the coil is central, a turn or two should be added.

LOOP MOUNTING

Now for the task of putting everything together to give a neat finish. Two suggestions are put forward, one fairly basic and the other almost a professional "work-of-art", but not so hard to achieve as it looks.

Simple System

The mounting of the aerial section must allow the loop to rotate and tilt, and readers will have their own ideas for this.

It can consist simply of a 25mm square wooden post, secured by a screw driven through the top of the control unit case, and free to rotate. The bundle of ferrite rods can then be attached with rubber bands to a cross arm, fixed by a central screw, close to the top of the post and, again, free to rotate. The coil leads are taken through a hole in the top of the case.

Although extremely basic, this arrangement works quite well, especially if a few washers are used to make the pivots turn smoothly.

Prototype System

A more complicated mounting, and the one adopted by the author, is shown in Fig.6 and the photographs. Built up from ply and wood blocks, the internal angles are rounded with car body filler and the unit is finished with "spray-can" paints.

The rods are enclosed in a pivoted box and tilt is controlled by a cord drive. A spring keeps the cord under constant tension.

The plastic spindle which drives the cord is extended a little beyond the body of the unit in order to minimise hand capacity effects. This problem is experienced with *all* loops when critical null adjustments are being made.

A 6mm stereo 'phone jack plug and socket form the vertical pivot and connects the aerial loop leads to the p.c.b.

Coil connections 1 and 3 go to the jack shank, 2 is wired to the tip, and 4 to the jack's centre band. This arrangement minimises stray capacitance.

OPERATING THE LOOP

Communications receivers and, indeed, any Medium Wave receiver with aerial and earth sockets can be used with the loop. (Salvaged car radios often perform extremely well). Connection between the Active Ferrite Loop Aerial and receiver should be by means of a length of coaxial cable.

This loop is not balanced with respect to ground, and the two nulls are not equal or symmetrical. The unit cannot, therefore, be used for direction finding. There is one position for maximum signal, and one for the deepest null, not two 180 degrees apart, as is the case with balanced loops.

The a.g.c. (automatic gain control) system of a sensitive radio will tend to mask the null, but turning loop output well down will usually expose it. Bearing and tilt can then be adjusted until the null is as deep as possible.

Null depth will vary from station to station and from time to time. Some programmes are transmitted from different locations on the same frequency, and a combination of ground and sky waves also results in multi-path reception, making it impossible to achieve deep nulls.

Notwithstanding this, interference from unwanted stations, and man-made electrical interference, can always be greatly reduced and usually eliminated. To have one station completely disappear and be replaced by another as the loop is rotated can be magical. It certainly makes the construction of the unit very worthwhile.

Advancing the *Q*-control (VR4) will dramatically increase sensitivity at the expense of bandwidth. At high settings the audio quality is muffled, and the loop can be tuned across the received signal and centred on one or other of its sidebands. Not only will this restore the treble response, it can also shift the tuning to the side of the signal furthest from a source of interference.

The Selector switch S1 permits an instant comparison between the loop and the other aerial available at the listening station. Band searching is best carried out with some form of wire aerial. The loop can then be switched in for comparison when the station has been located. This avoids the need to keep loop and receiver tuning in step.

PERFORMANCE

Performance was assessed by comparing the seven-rod active loop with other aerials. The receiver used for the test has a large signal strength meter, and its a.g.c. system was switched out.

The aerials used were as follows:

(1) A long (20 metres), high (10 metres) wire aerial with impedance matching transformer and screened downlead. The receiver was earthed when this aerial was in use.

(2) A passive, one metre diameter air-cored loop with a single turn coupling winding and no provision for tilting; i.e., a traditional loop or frame aerial.

(3) A thirty-rod version of the ferrite loop described here.

The test was carried out, during daylight, in a room "caged" by the usual house-wiring and plumbing (this distorts nulls). It involved ten stations spread across the Medium Wave band. Loop output was set at maximum, and the *Q*-multiplier control at zero.

CONCLUSIONS

Results were as follows:

With the exception of one station, the signal level from the seven-rod loop always matched that from the long wire.

The seven-rod Active Ferrite Loop Aerial consistently outperformed the air-cored passive loop, the signal delivered being from 3dB to 6dB stronger. The tilt facility made the nulls with the ferrite loop deeper than those displayed by the air-cored model; in some instances a decent null could be obtained with the ferrite aerial when the null with the traditional loop was barely discernible.

Output from the thirty rod loop was some 3dB greater than that from the seven-rod version.

The application of a modest amount of *Q* multiplication dramatically increased the output of the ferrite loops at the expense of bandwidth. For a given output, bandwidth with thirty rods was always greater than with seven. □