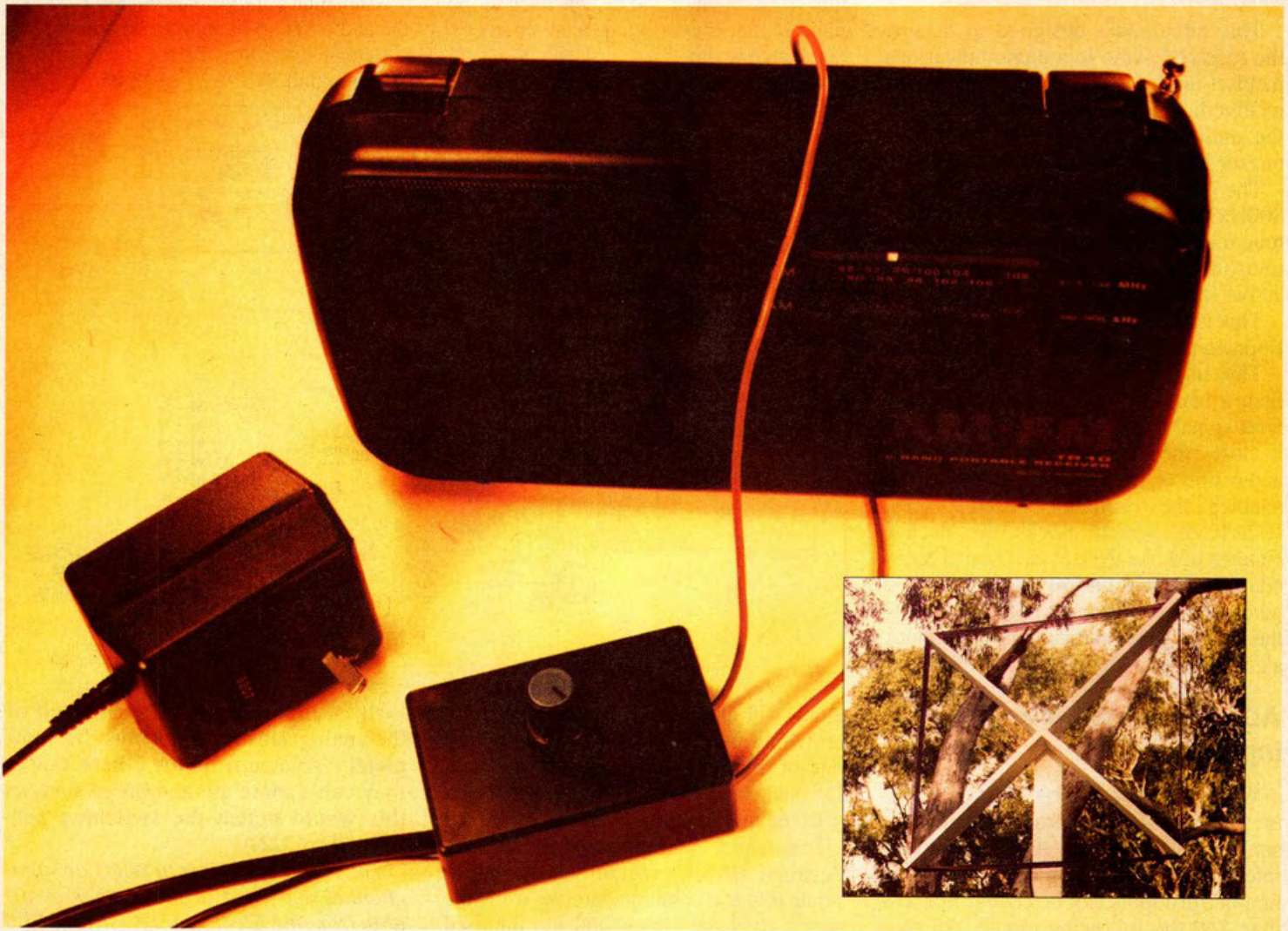


Construction Project:



'MIRACLE' AM ANTENNA

This antenna system will pull in distant AM stations with amazing results. It has a simple loop antenna that can be 50 metres or more from the radio, connected with inexpensive coax to a loop of wire placed around the radio. Two PCBs, one at the antenna and the other at the radio, do all the work.

by **PETER PHILLIPS**

This project will appeal particularly to country readers, boat owners or anyone wanting to listen to distant AM radio stations. It was designed by Oatley Electronics and features two separate PCBs that link an external antenna to a loop placed around an AM radio. The PCBs are linked with coaxial cable which carries three electrical signals: the AM radio signal, a variable DC tuning voltage and the supply voltage to the PCB at the base of the antenna.

The coax linking the PCBs can be 50 metres or more long. As well, any cheap 50Ω to 75Ω coax cable will do.

Because the antenna can be some distance away from the receiver, it can be placed away from electrostatic signals, and out of sight. As well, the antenna need only be mounted a metre or so above ground level.

The antenna itself is several loops of wire on a one metre square wooden frame. The PCB mounted at the antenna is fitted in a waterproof enclosure, available from Oatley Electronics.

The whole thing is easy to build, as all parts mount on the PCBs. The frame for the antenna is simply an 'X' on a supporting pole, so it too is easy to build.

And as you can see in the price information at the end of the parts list, the whole system is inexpensive.

Operating principle

The antenna consists of eight turns of wire on a timber frame, tuned by two varicap diodes to the station you want to receive. The AM signal is amplified by circuitry on the PCB mounted at the antenna, then sent via the connecting coax to a second PCB near the radio. The inductance of the antenna is about 120uH, and tuning is done by adjusting a pot connected to

the PCB at the radio end.

The radio-end PCB has only a few components, mainly those to regulate the tuning voltage, and the coax connects via two components on this board to a loop of wire. The AM radio is placed inside the loop to give loose coupling between it and the internal antenna of the radio.

There is nothing really critical with the antenna design, or how the radio is placed in the loop. But when the antenna is tuned by the adjustable control voltage to receive the same station as the radio, distant AM stations can be heard almost as though they are close by.

But perhaps the most interesting aspect of this project is how the one coax cable carries the AM signal, the DC tuning voltage and a DC supply voltage. A description of the circuit will explain...

The circuit

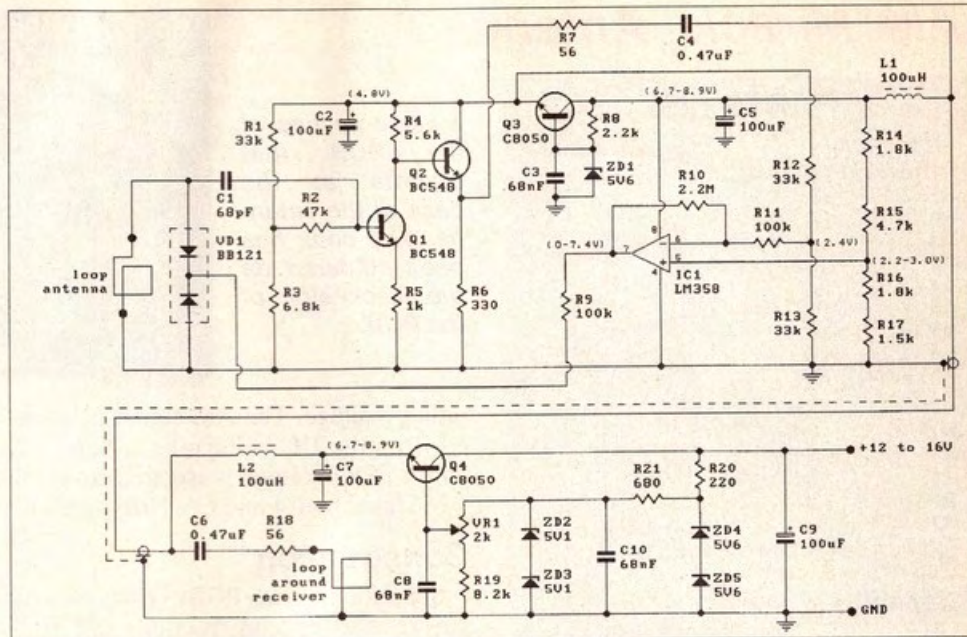
Turning to the schematic, the loop antenna is tuned by VD1, a twin varicap diode. The DC tuning voltage for VD1 comes from the output of IC1, but we'll first trace the path of the AM signal on the assumption that the antenna is tuned correctly.

The antenna output connects to the base of transistor Q1, via DC blocking capacitor C1. This transistor presents a high impedance to the signal (50kΩ or more), achieved by the unbypassed emitter resistor R5 and by R2, which connects to biasing resistors R1 and R3. The common emitter amplifier around Q1 has a gain of about five, and its output goes to the emitter follower amplifier of Q2.

The output of this amplifier connects in turn, through R7 and C4, to the coax cable that couples the signal to the loop that fits around the radio. Resistors R7 and R18 give a nominal 56Ω termination for the coax, but as mentioned, the impedance of the coax is not critical. Inductors L1 and L2 isolate the AM signal from the DC side of both PCBs.

You might be surprised to see BC548 transistors as the amplifying devices. However the maximum frequency on the AM radio band is only 1.6MHz, which is well within the capabilities of these transistors.

Now to the DC control voltage, which is set by VR1. The input DC supply voltage for the system goes to the collector of series regulator Q4, and also to a two-stage zener diode regulator. The DC voltage at the base of Q4 determines its emitter voltage, which depending on the setting of VR1, can



The top half of the circuit is on the PCB mount at the antenna end. The bottom half is at the radio. The antenna is tuned by the varicap diodes, whose capacitance varies with the voltage set by VR1.

range from 6.7V to 8.9V. This voltage supplies the PCB at the antenna, and goes via the coax cable (through L2) to the collector of Q3 and to R14. It also supplies op-amp IC1, of course.

The output voltage of series regulator Q3 is determined by ZD1, a 5.6V zener diode which sets the base voltage of Q3 to 5.6V. Therefore the output of Q3 is fixed at nominally 5V, and is the supply voltage to the RF amplifier sections just described. This voltage is also applied to the resistor network of R12 and R13. Because these resistors are equal in value, the voltage at the inverting (-) input of IC1 is therefore fixed at half the output voltage of Q3, or around 2.5V.

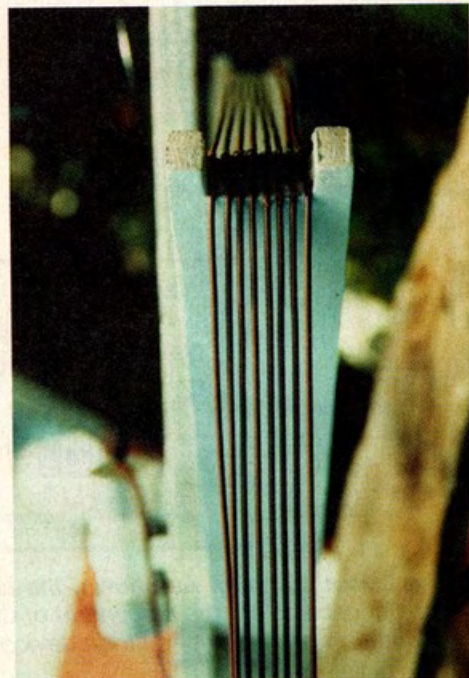
On the other hand the voltage at the non-inverting (+) input of IC1 depends on the output voltage from Q4, which supplies the resistor network R14-17. In fact the voltage at the junction of R15 and R16 varies from 2.2 to 3V, as set by VR1. Because the voltage at the inverting input of IC1 is constant, the output of IC1 will therefore vary with a change in voltage at the other input. For the values shown, the output voltage changes from zero to 7.4V.

This voltage connects via R9 to the cathodes of the varicap diodes, and reverse biases the diodes. When this voltage increases, the capacitance of the diodes drops.



Above: A close-up of the completed antenna. The waterproof enclosure is available from Oatley Electronics and is used here to house the PCB that mounts at the antenna.

Right: As shown in this close-up, each turn of wire on the antenna is separated by about 5mm. Use silicone glue to hold the loops in place, with a cutout in the frame to help locate the loops.



AM 'Miracle' Antenna

PARTS LIST

Resistors

(All resistors 1/4W)

R1,12,13	33k
R2	47k
R3	6.8k
R4	5.6k
R5	1k
R6	330
R7,18	56
R8	2.2k
R9,11	100k
R10	2.2M
R14,16	1.8k
R15	4.7k
R17	1.5k
R19	8.2k
R20	220
R21	680
VR1	2k panel mount pot

Capacitors

C1	68pF ceramic
C2,5,7	
C9	100uF electrolytic
C3,8,10	68nF polyester
C4,6	0.47uF monolithic

Inductors

L1,2	100uH
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Semiconductors

IC1	LM358 dual op-amp
Q1,2	BC548 NPN transistor
Q3,4	C8050 NPN transistor
VD1	BB212 dual varicap diode
ZD1,4,5	5.6V 330mW zener
ZD2,3	5.1 330mW zener

Miscellaneous

PC board, 113 x 373mm; 25m length of insulated wire for antenna and loop; length of 50Ω or 75Ω cable to suit; 12V DC 300mA plugpack; plastic utility case 82 x 30 x 53mm; knob; waterproof plastic case.

Kit available

A kit of parts for this project is available from Oatley Electronics, of PO Box 89, Oatley NSW 2233. Phone (02) 9579 4985, fax (02) 9570 7910.

Price of the kit, including both PCBs and all on-board components, is \$24.

Waterproof plastic case to suit... \$2.50

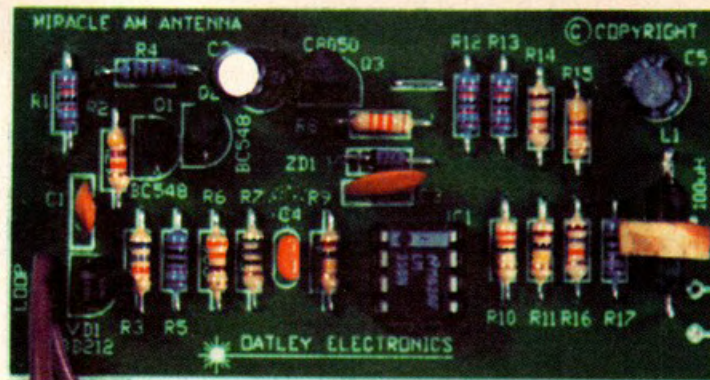
Plastic utility case, waterproof case & knob... \$5

Suitable 12V plugpack... \$13

Both PC boards only (silk screened)... \$8

Packing and postage... \$5.

A close-up view of the PCB that mounts at the base of the antenna. The coax has been soldered on the track side of the PCB.



tuning voltage. The AM signal is isolated from the DC voltage by L1 and L2, and the DC voltage is isolated from the AM signal by C4 and C6. Nifty, isn't it?

Construction

Separate the two PCBs (if necessary) before starting construction, and confirm that the PCBs are free of any manufacturing faults. The photos and layout diagram show where the components go, and if you buy a kit of parts from Oatley Electronics, you'll get silk-screened PCBs also showing component placement.

Mount the resistors, inductors, capacitors and zener diodes first. Make sure you correctly identify the 5.6V zeners and 5.1V zeners. Also check the orientation of the zener diodes and the electrolytic capacitors. Note that there's one wire link required on the antenna PCB. Next fit the transistors and IC socket. Again, make sure you correctly identify each transistor before fitting it in place.

Although the PCB at the radio end will accept a PCB mount potentiometer for VR1, a panel mount type is much easier to use. As shown in the photos this is connected to the PCB with three wires. Drill a hole in the centre of the bottom of the plastic case for the pot.

Now for the antenna. As you can see in the photos, the antenna used with the prototype is eight loops of insulated wire wound around a wooden framework. The framework is made with 75 x

20mm Oregon pine, well painted to protect it from the weather. The two cross members are one metre long, with a 40mm deep cutout at each end as a guide for the wire. These members are attached to the support pole (also a length of 75 x 50mm Oregon pine), positioned at right angles to each other to give a distance of about 700mm between adjacent extremities. That is, you end up with a square antenna measuring 700 x 700mm.

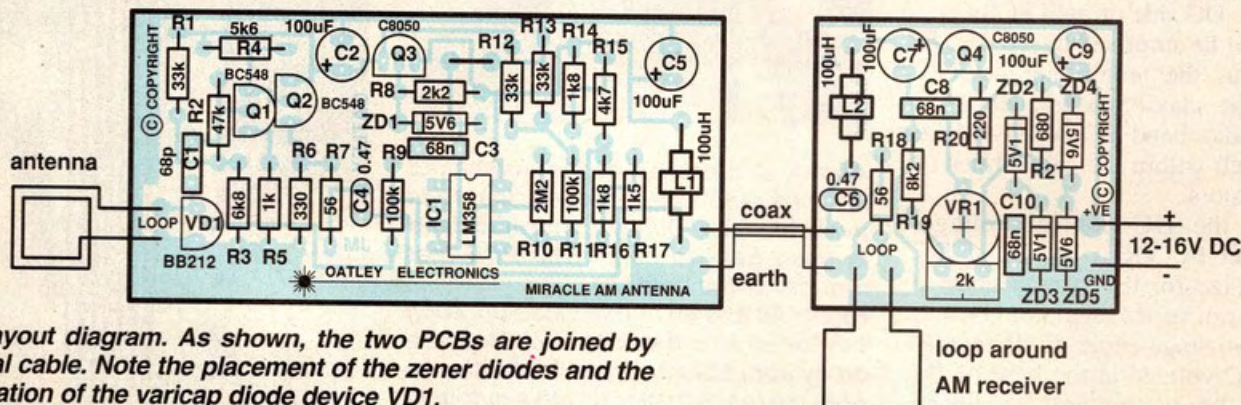
The wire is wound around the assembly so each loop is spaced about 5mm from adjacent loops. This is necessary to minimise the capacitance of the antenna. Don't make each loop too tight, to allow for expansion and contraction with ambient temperature. When the loops are all in place secure them with dabs of silicone glue where they contact the framework, as shown in the photos.

Testing

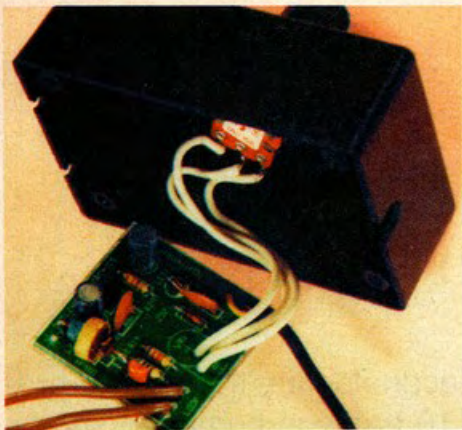
Before final installation, test the system first, in case you need to alter the inductance of the antenna. To do this, connect the two PCBs with a length of coax cable. Connect the antenna to its PCB and, to the other PCB, connect the loop of wire that will wrap around the radio. Then with the plugpack also connected, apply power.

Tune your radio to the required station, then place it inside the loop, as in the lead photo. Adjust VR1 so the antenna is also tuned to this station. You will soon know

So, the DC voltage fed along the coax cable is both the supply voltage and the



The layout diagram. As shown, the two PCBs are joined by coaxial cable. Note the placement of the zener diodes and the orientation of the varicap diode device VD1.



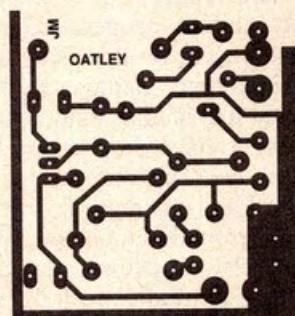
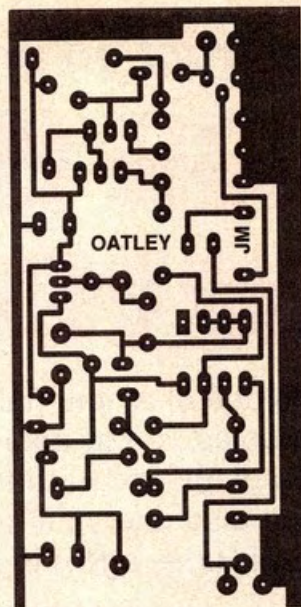
Left: This is the PCB that sits near the radio. The pot is fixed to the plastic box, rather than being mounted on the board. Note that changes have been made to the PCB design since this shot was taken. See the layout diagram for final component placement.

Right: The artwork for the PCB, for those who prefer to make their own.

a waterproof enclosure, which can be attached to the antenna support pole. All wiring (leads from the antenna coil and the coax cable) should enter at the bottom of the enclosure. Form the leads from the antenna coil to give a 'drip loop', so water will drip off instead of running into the enclosure.

The coax cable can be run as required, even buried in the ground if you wish. Note that shielded cable is not suitable, as it is designed for audio applications only, not for RF.

You might find that you don't need to place the radio inside the coupling loop. Instead, depending on the signal strength, reception might be good enough by placing the loop near the radio, rather than around it. Like anything, it's worth experimenting to get the best results. ♦



when the antenna is tuned, as the reception will improve markedly.

If you cannot get the antenna to tune correctly, you might need to add or delete turns, depending on which end of the AM RF spectrum you are trying to tune to. However before doing this, confirm that the voltage readings in your circuit agree (approximately) with those shown on the circuit diagram. These voltages are from the prototype with VR1 set first to one end of its travel, then the other.

If you want to receive a frequency at the low end of the spectrum, and can't tune the antenna to this frequency, try adding a turn to increase the inductance of the antenna. The opposite applies for frequencies at the high end of the spectrum — that is remove a turn, or make the antenna smaller. The aim here is to reduce the inductance.

The antenna orientation is not critical, but try different placements and directions for best reception. If you want to receive signals from a range of radio stations, compromise the position of the antenna to give the best overall effect. Note that the antenna should be 'side on' to the transmission.

Final details

The antenna dimensions given here are those for the prototype. However different designs are possible, providing the inductance of the antenna is similar to that of the prototype. You could try a smaller antenna with more turns, or a larger antenna with less turns. A possible design that should work is to wind 16 turns (spaced 5mm apart) wound on a square frame measuring 355 x 355mm.

Once you're satisfied with the tuning, it remains to position the antenna properly and to run the coax to the receiver. As already mentioned, there is no need to mount the antenna more than a few metres above the ground. However make sure you place it so it's away from any sources of interference.

The antenna PCB should be housed in

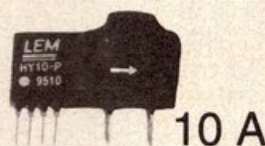
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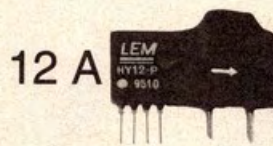
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10 A



12 A

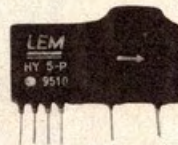


15 A

20 A

25 A

5 A



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