Set up the antennas about 6m apart and at right angles to the direction in which the sharpest nulls are desired. The lengths of coaxial cable joining the antennas to the combiner unit should both be the same, and about 4m is a reasonable compromise and avoids too great a mismatch on either band. (The whips are reactive on both bands – too short on 14MHz and too long on 21MHz – so that the impedance presented to the combiner unit inputs depends on the length of coaxial cable).

The control cables can be any plastic-insulated flexible wire, and two lengths of the grey flat twin cable intended for hi-fi speaker leads have proved satisfactory. There is no restriction on the length of the control cable and coaxial cable running from the combiner unit to the shack – about 17m being used in the present case.

Operation

Directing a null onto a signal requires a little practice, and it is worthwhile to make a table of directions and control settings while doing this. It will be found that there is a definite pattern to settings of the controls so that if it is known which quadrant the signal is in, it can be nulled very easily.

Generally the best nulls will be obtained in a segment about 60° on either side of a line at right angles to the line of the antennas, nulls tending to be poor (or non-existent) along the line of the antennas. (This is mainly due to the 'tuned circuit' phase-shifting circuit having a limited range, though other factors are also involved.)

Before starting, set RV1 for the band in use, RV2 for mid-range ('5' on the scale), and RV3 and RV4 to near the low voltage end of their range (about '8' on the scale). Tune-in a suitable signal on the receiver, and move RV2 slowly off its centre position while swinging RV3 slowly backwards and forwards through its range. If no null is found anywhere in the range of RV3, set RV3 to '8', and repeat the process with RV4. Once a null has been detected it is very easy to tweak the controls to achieve a minimum. It is easier to find the null with the AGC switched off.

Ionospheric signals will be found to have poorer nulls than local signals, due presumably to the vagaries of the propagation path, though the strong (single-hop F2?) signals which are so often a problem to G stations seem to null remarkably well. Where no interference is present the controls can be adjusted for maximum on the wanted signal.

The sharpness of null which can be obtained on local QRN will depend on whether it comes from a well-defined source or not. If all the mains wiring in local houses is radiating interference, so that it appears from the antenna to be coming from a wide angle, then the null will be poor – though by judicious siting of the antennas a worthwhile reduction of the interference may still be obtained. Fortunately if an interference source is too far away to be traced, it is usually far enough away to be in a well defined direction.

Though the main interest has been the amateur bands, an occasional visit to the broadcast bands in the tuning range of RV1 (about 12 to 22MHz) showed that useful results could be obtained on these bands also. There is, of course, a danger to all this – it is easy to spend so much time nulling out unwanted signals, that you never get on the air to work any wanted ones!

References

[1] *Amateur Radio Techniques* 7th edn, p324. RSGB

[2] *Antenna Engineering Handbook*, edited by H Jasik. McGraw-Hill

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A directional active loop receiving antenna system

J A Lambert, G3FNZ

Loop antennas have been used for receiving MF and HF signals for many years. Active systems, in which an electronic amplifier forms an integral part, have not been around so long but are still a recognised tool of the radio systems engineer.

An important use is for direction finding, where the azimuth pattern of a vertically-polarised loop is a figure of eight, thus giving two nulls or minima in received signal strength at 180° to each other (Fig 1). In order to eliminate one of the nulls it was common practice to mount a whip adjacent to the loop and to feed it to one side of the coil that coupled the loop to the tuned RF stage of the receiver. This extra input would unbalance the azimuth pattern to such an extent as to reduce one of the nulls by a significant amount, thus giving an unambiguous directional property to the antenna.

This unbalancing of the output of a loop can be achieved without the use of a separate whip by converting a single-turn loop into two monopoles by inserting a significant impedance in series with the turn diametrically opposite to the feed point (Fig 2). For magnetically induced waves the loop will still operate as a continuous loop with the conventional figure of eight azimuth

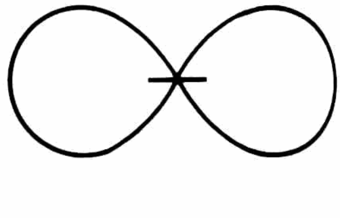


Fig 1. Azimuth pattern of vertically polarised loop

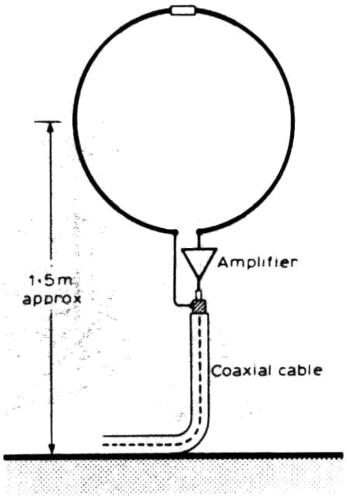


Fig 2. Unbalanced loop achieved by inserting series impedance

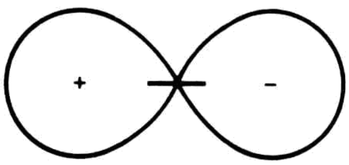


Fig 3. Opposite polarity of the two lobes of the magnetically-induced waves in a continuous loop

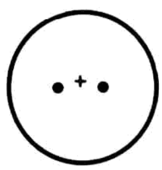
pattern, the two lobes being of opposite electrical polarity (Fig 3).

If we now consider the performance of the loop with respect to electrically induced signals, the two halves of the loop perform as short monopoles closely mounted, each of which will produce like polarity outputs (Fig 4). When combined with the magnetically induced outputs these will add in one instance and subtract in the other, thus producing a cardioid pattern (Fig 5).

The choice of load impedance is important, as it will have a marked effect upon the feed point impedance. If a wideband high performance amplifier is inserted at the feedpoint it is possible to obtain a constant-impedance low-noise output over a wide band of frequencies, eg 2 to 30MHz, and with the very significant capability of being combined into groups to simulate electrically the performance of most HF receiving antenna arrays. An optimum system may therefore be designed for any specific requirement and, if necessary, changes in performance can be easily and rapidly achieved.

Active loop antennas offer many attractive features; for example:

Fig 4. Combined like polarity of two close-coupled monopoles



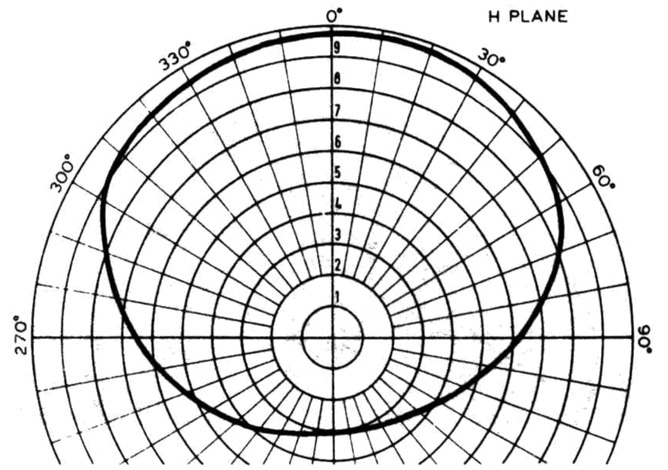


Fig 5. A cardioid horizontal radiation pattern (HRP) is maintained with a consistent front:back ratio – typically 12dB – over a wide band

(a) Simple to install.
(b) Low weight and windloading.
(c) No elaborate structure, concrete foundations etc.
(d) Suitable for permanent, temporary or portable use.
(e) Components immediately reusable in new configurations.
(f) Modules easily stored for emergency operations.
(g) Single flexible cable feeds each loop.
(h) Full control of beamwidths, vertical angle of arrival and null directions.
(i) Loops are normally mounted with their centres about 1.5m above ground – an earthmat is only needed when low-angle reception is required and is in any case considerably smaller than that required for a conventional antenna.

Loop performance

Typical performance figures obtained with a commercial (as opposed to military) loop are as follows:

Frequency range		2-30MHz
Directivity		3dB
Front-to-back ratio		12dB
Amplifier noise factor		5dB
Intermodulation products	2nd order	–30dBm
	3rd order	–18dBm
1dB output compression point		0dBm

The DC power supply is normally mounted adjacent to the receiver, and the DC is fed to the loop amplifier via the coaxial cable in order to reduce cabling, with suitable filters fitted to separate the RF from the DC. However, if the distance from the antenna to the PSU and receiver is short, then for amateur use it may be better to delete L2/C10 and feed DC in via a separate line.

It will be observed that directivity and not gain is given for the loop – this is because system performance is limited by external noise in the HF band. Absolute gain is not the determining factor, as an increase in gain provides more signal but also correspondingly more noise.

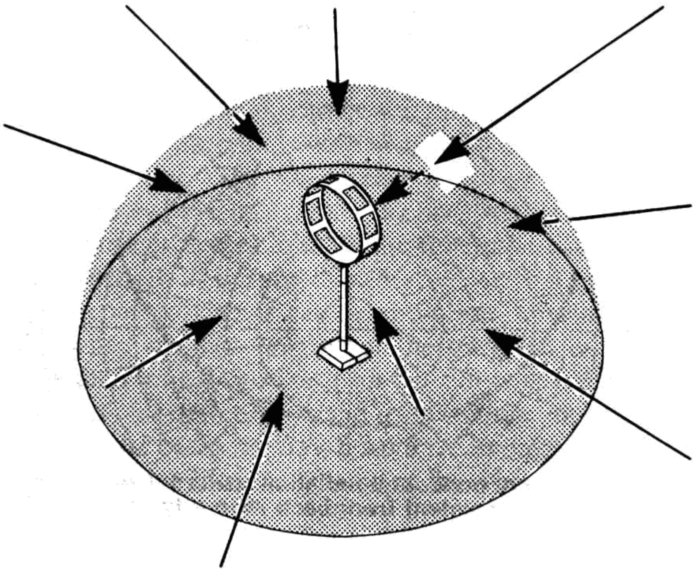


Fig 6. Pictorial representation of arrival of wanted signal and also of unwanted signals, all of which have to be considered when calculating directivity

Directivity is computed from the radiation pattern of an antenna, and relates the response of an antenna to a plane wave arriving from the optimum direction to the average response to signals arriving from all directions (Fig 6).

Antenna arrays

Normally the power supply unit would be placed in the receiver building, and the DC to the amplifier fed via the coaxial feed, which could be any 50Ω cable such as UR67 for short or medium runs or 0.5in foam-filled cable for long runs.

A simple beam antenna of two or more loops would use a hybrid combining unit fitted on one of the loop mounting poles. This would be connected to the individual loops by cables of equal length in the case of a broadside array, and cables of different lengths to give the required phase relationship for an endfire array.

When more than one beam is required from an array, this is arranged by dividing the outputs from individual loops with suitable phase differences. Splitting and re-combining is carried out on the signal output from the power supply unit to avoid the complexity of filtering and recombining the DC supply.

As coaxial cables are used to provide path delays for beam forming, directions of fire are maintained over wide bandwidths. Varying elevation angles of endfire arrays and varying slew-angles for broadside arrays may be obtained sequentially by switching or simultaneously using hybrids.

Endfire

An endfire array (Fig 7) provides a single directional

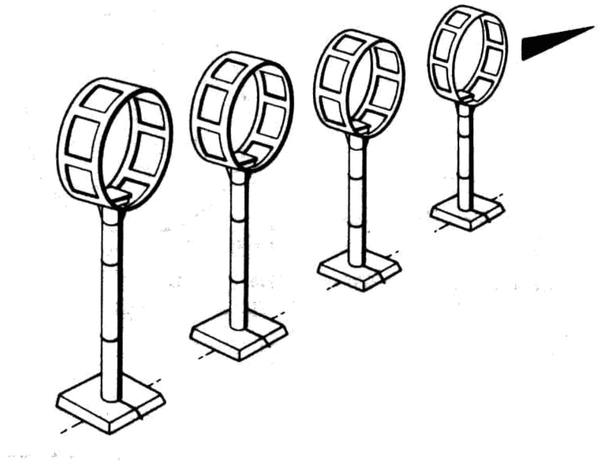


Fig 7. Four-element endfire array

beam with low sidelobe levels and a high back-to-front ratio maintained over a wide frequency band. The radiation patterns, Fig 8, show that as the operating frequency increases, both horizontal and vertical beamwidths decrease. By choosing the correct spacing, the performance of an array can be optimised for the frequency band required. See Table 1.

Table 1. Directivity of loop arrays

Frequency	Number of loops	Directivity (dB) Endfire	Directivity (dB) Broadside
f Max	2	8.1	9.1
f Max/2	2	5.4	6.2
f Max/4	2	4.6	4.3
f Max/8	2	3.9	4.0
f Max/16	2	3.8	3.9
f Max	4	10.9	12.2
f Max/2	4	8.1	9.2
f Max/4	4	5.8	6.3
f Max/8	4	4.4	4.5
f Max/16	4	4.1	4.0
f Max	8	13.5	15.9
f Max/2	8	10.9	12.2
f Max/4	8	8.1	9.3
f Max/8	8	5.8	6.3
f Max/16	8	4.4	4.5

Endfire arrays allow choice of beam elevation angle – from very low angles for long-distance circuits to near-vertical incidence for short circuits. The elevation angle may be fixed or adjustable by switching.

With any of the arrays, unwanted interfering signals

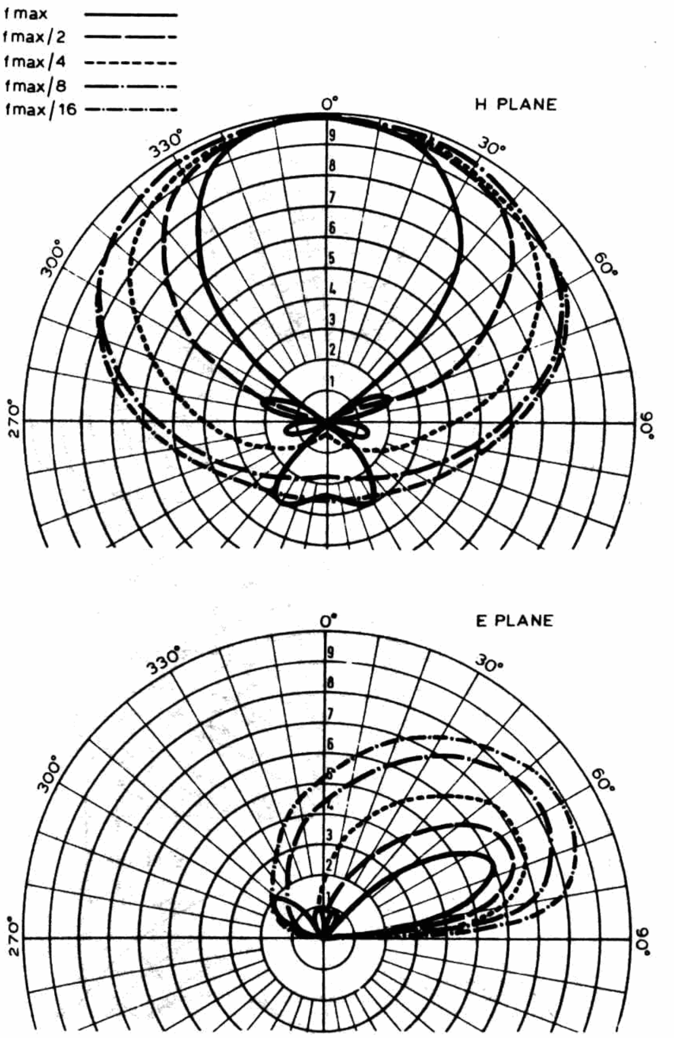


Fig 8. Four loops in endfire is a useful general purpose array which provides an antenna of moderate gain with azimuth and elevation beamwidths which are capable of covering a large area of territory

can be suppressed by designing nulls into the array pattern. The number or bandwidth of the nulls can be greater for the longer arrays (ie arrays with more loops).

Broadside

The characteristic of broadside arrays (Fig 9) is a beam which is wide in the elevation plane and narrow in the azimuth plane. The vertical radiation pattern is not

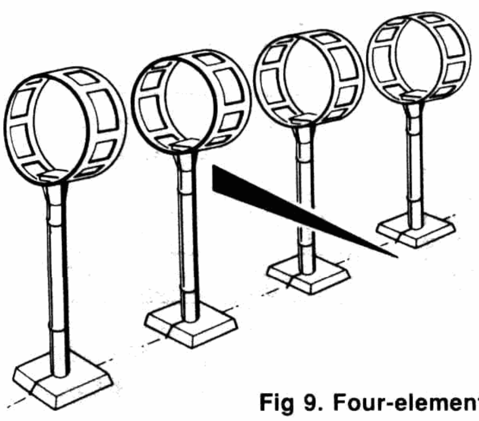


Fig 9. Four-element broadside array

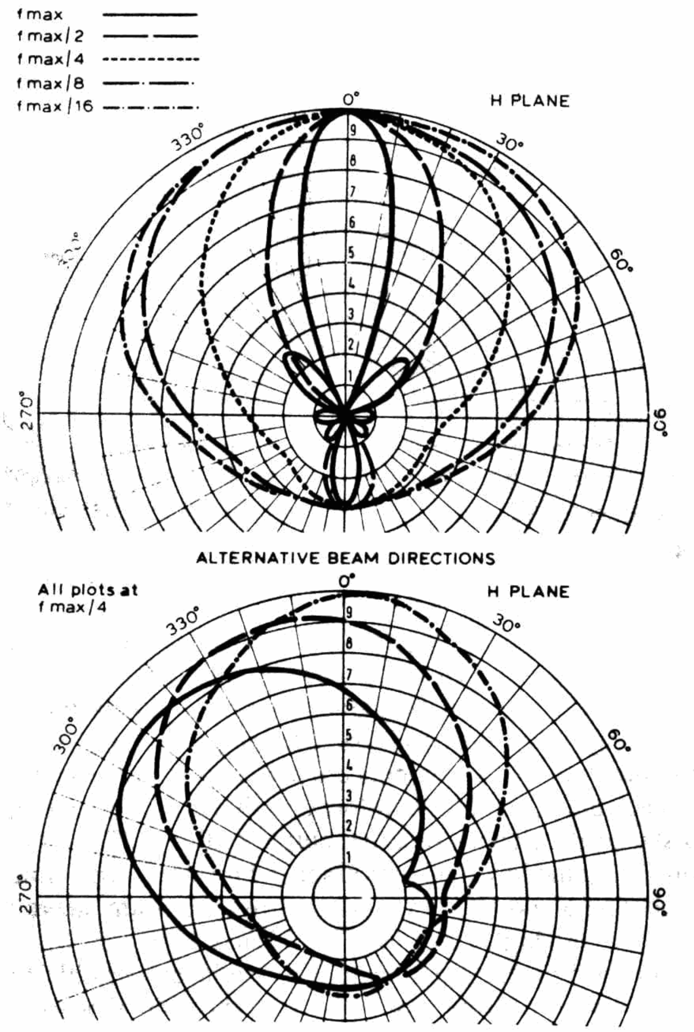


Fig 10. An array of four loops in broadside with its wide fan-shaped beam provides good rejection of unwanted signals. It will accept signals at many angles of arrival, so detailed knowledge of this parameter is not needed

dependent on the number of elements, and its beamwidth changes little with frequency. The horizontal radiation pattern varies widely with frequency; the beamwidth being inversely proportional to frequency (Fig 10).

By suitable array design the beam maximum, usually normal to the line of the elements, can be slewed typically up to 45° from the normal. The design can provide a single slewed beam, switched slew angles or a number of simultaneous outputs to different receivers.

Arrangements in which elements are arrayed in two dimensions – ranks and files – can be designed to combine the properties of broadside and endfire arrays.

Dual beam

It has previously been mentioned that it is possible, in the case of an endfire array, to steer the elevation pattern – and, similarly, the azimuth pattern in a broadside array. In systems engineering it is sometimes found to be desirable to have both high and low angles of elevation covered or to receive simultaneous circuits from different azimuth bearings. To meet such requirements it is

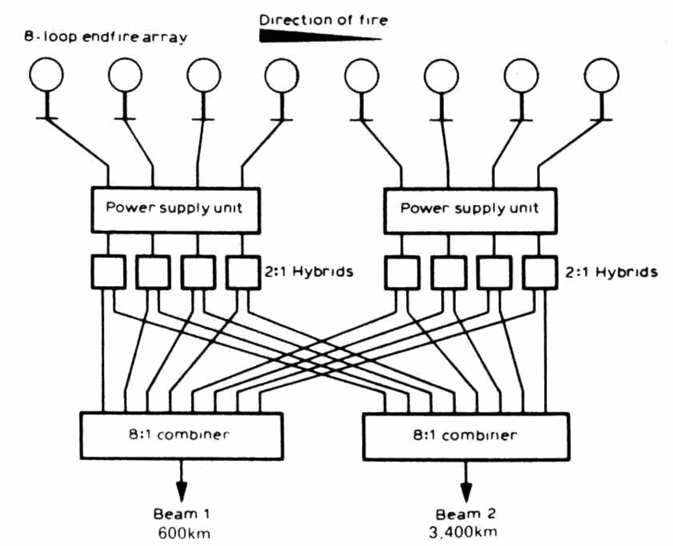


Fig 11. Block diagram of an eight-loop endfire array with dual beams to receive simultaneous signals from two circuits at distances of 600 and 3,400km

possible to provide equipment to enable two distinct beams to be received independently from one array.

The design of the individual array is identical to that for covering endfire and broadside arrays. It is important to note that the two outputs are completely independent of each other, and it is therefore possible to receive a long distance HF signal using that output of the endfire array providing the low-angle coverage, while at the same time receiving a short-distance signal from the beam steered to cover the higher angles (Figs 11 and 12).

In the broadside application it would be possible to receive a signal from, say, 30° east of the normal bearing and at the same time receive another circuit coming, say, from 30° west from the other output, (Figs 13 and 14). It must be remembered when deciding to use a two-beam array that the array beams must be within the limits of the beam of a single loop, ie it would be unwise to steer a beam in elevation by more than 50° or performance will fall off considerably. In the same way, when steering the broadside array it is necessary to stay within the azimuth beamwidth of a single loop.

A further restraint on beam steering is the appearance of large side lobes when the beam is steered over a wide angle. The appearance of these lobes limits the steering of the beam of high-directivity arrays to around ±3 beamwidths.

It will be noted that for this type of system it is necessary to bring back an individual cable from each of the loops to the receiver room.

Other configurations

There are many more configurations possible, such as constant-performance arrays of loops in log-periodic form to give a constant-azimuth beamwidth over a wide frequency band, or sector arrays where loops are mounted in a ring and adjacent loop groups switched into use to give azimuth beam selection.

The constant-performance array of loops placed in

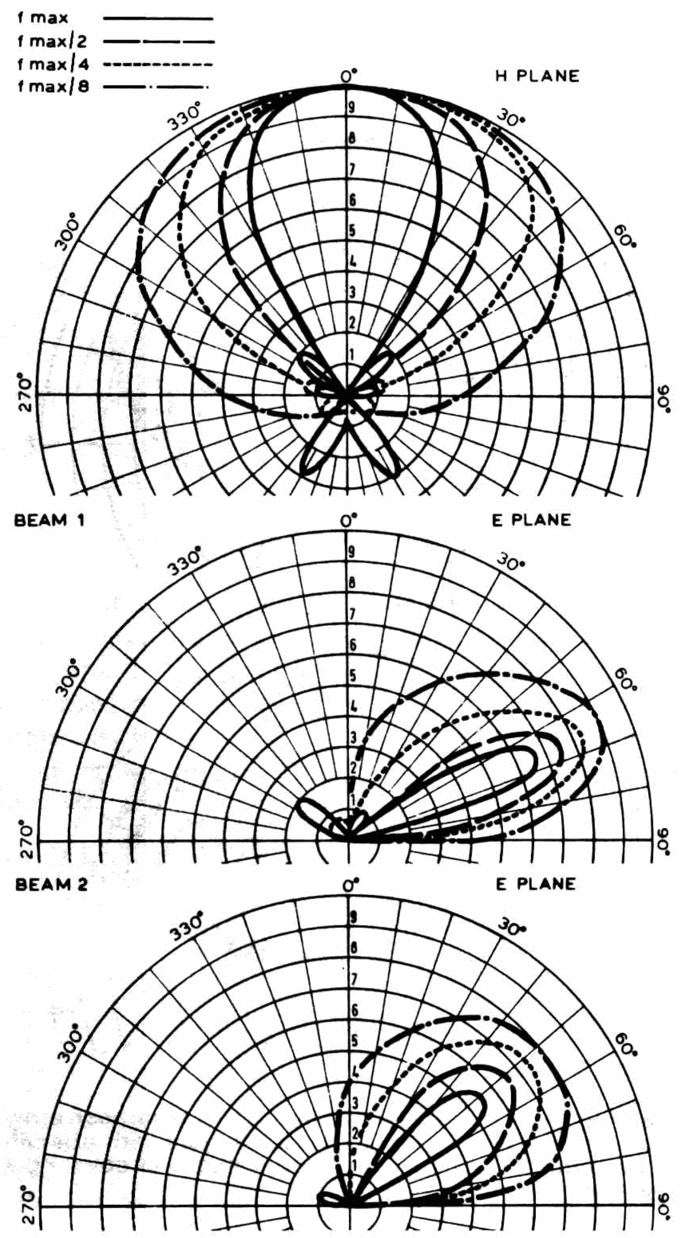


Fig 12. Beam patterns of the eight-loop endfire array with dual beams shown in Fig 11

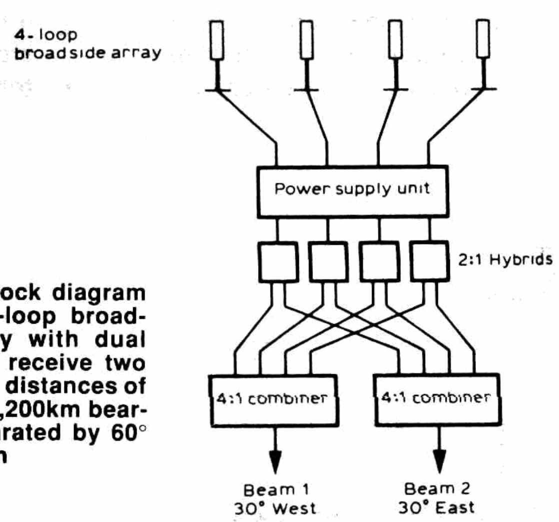


Fig 13. Block diagram of a four-loop broadside array with dual beams to receive two circuits at distances of 800 and 1,200km bearings separated by 60° in azimuth

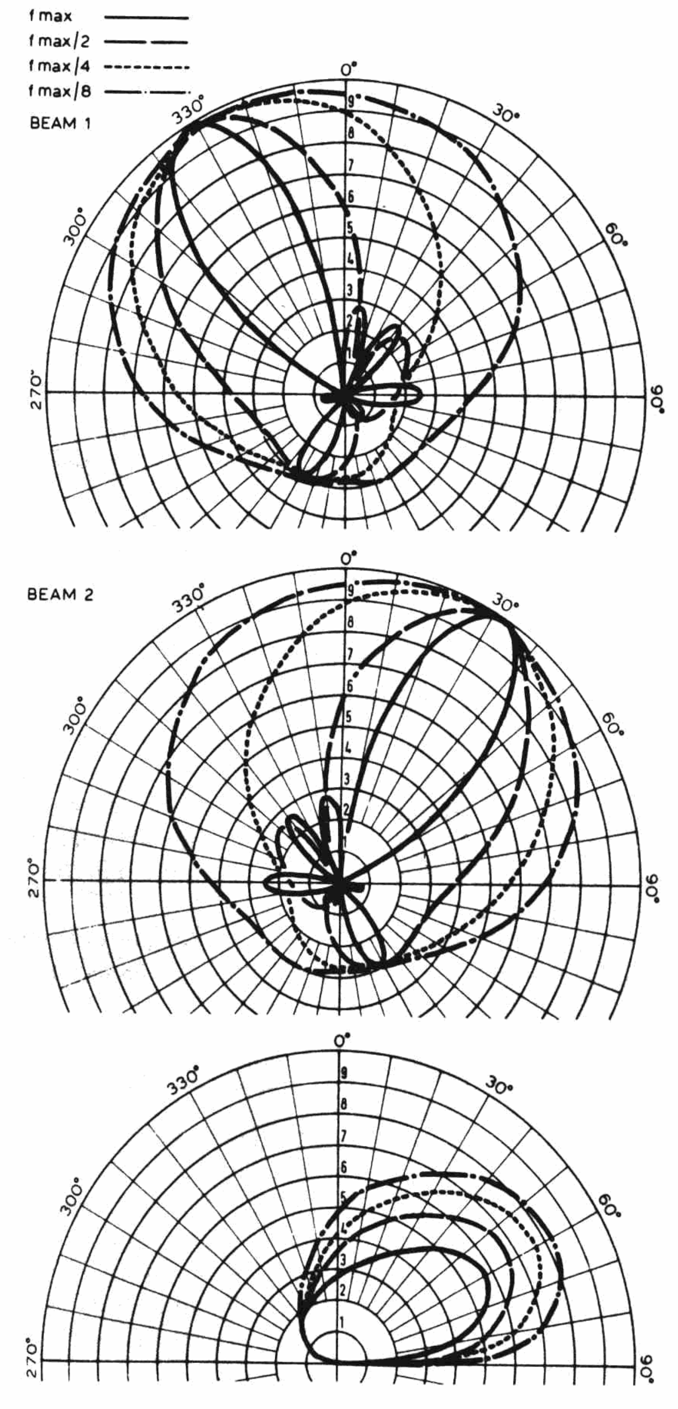


Fig 14. Beam patterns of the four-loop broadside array with dual beams shown in Fig 13.

log-periodic form may also be utilised to form an azimuth sector coverage antenna by placing log arrays in the form of a rosette; by combining adjacent arrays a constant beamwidth is achieved in both azimuth and elevation over a wide frequency range of up to 2-30MHz. The composite antenna may be designed to meet the exact requirements of the system engineer.

Construction

The construction of loops for experimental purposes, HF band monitoring, Intruder Watch etc, should present no problems. The loop itself is 1m in diameter and, in order to achieve a substantially constant match to the amplifier

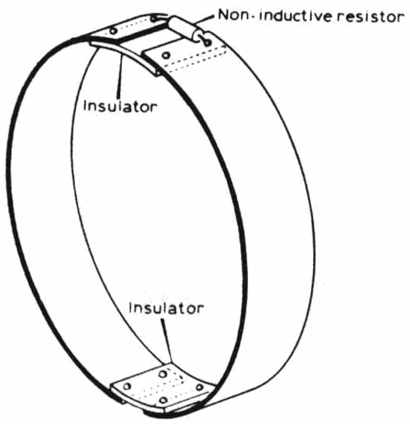
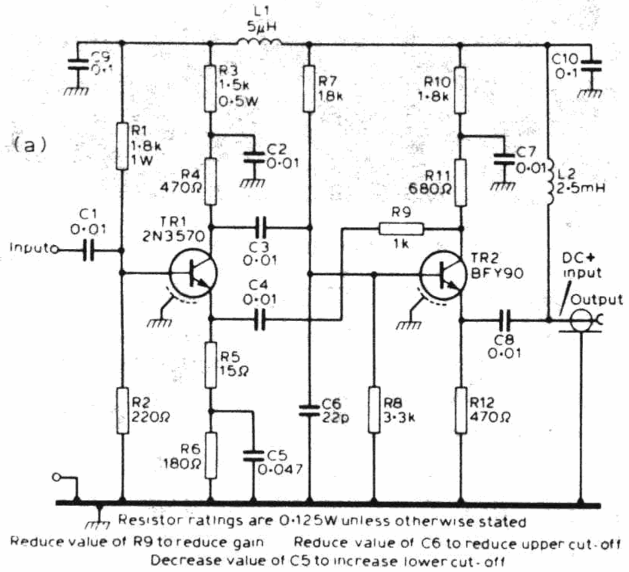


Fig 15. Suggested construction of an experimental loop antenna, the amplifier being connected across the lower insulator

together with structural stability, it is suggested that it be made from a 15cm-wide strip of 16swg (1.6mm thick) aluminium. Having formed the loop it should be cut into two equal parts (Fig 15) and then rejoined, utilising two blocks of insulating material, thus resulting in a firm 360° loop separated into two electrically equal parts.

A 0.5W carbon non-inductive resistor of a value between 47 and 100Ω is then connected across one of the loop junctions, and a broadband low-gain amplifier across



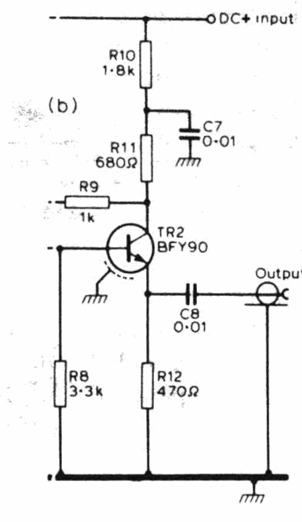


Fig 16. Amplifier circuit diagram: (a) shows the normal arrangement for feeding the DC input via the coaxial cable; (b) shows the alternative arrangement for a separate DC input

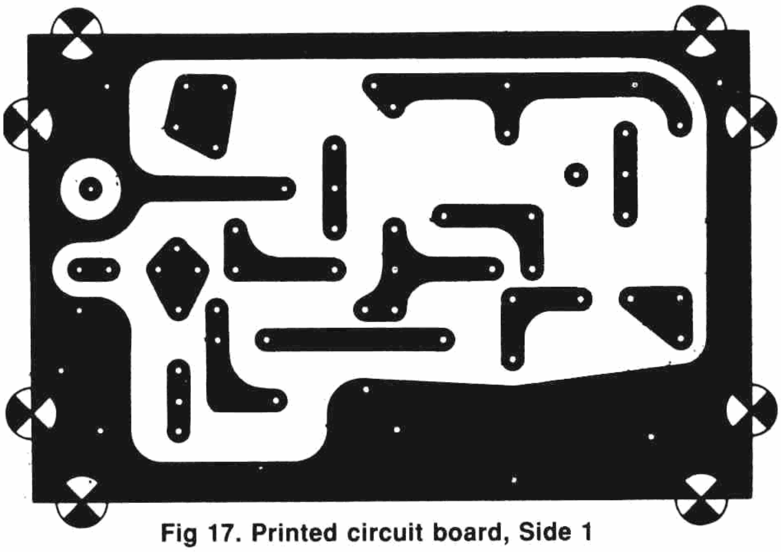


Fig 17. Printed circuit board, Side 1

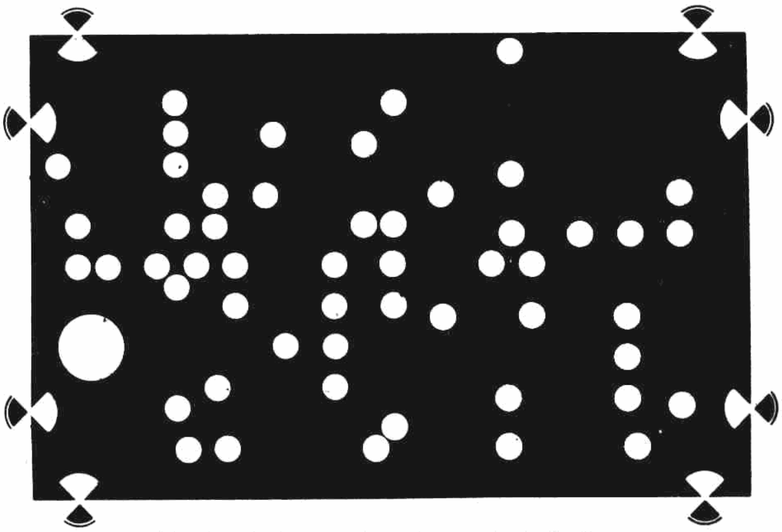
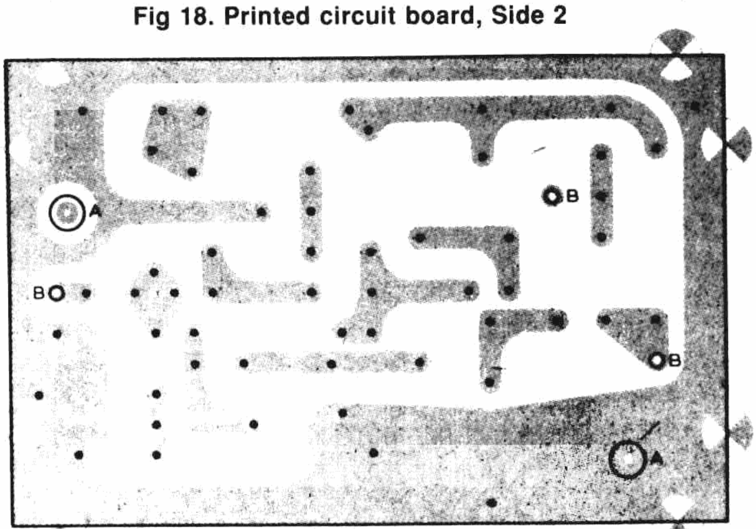


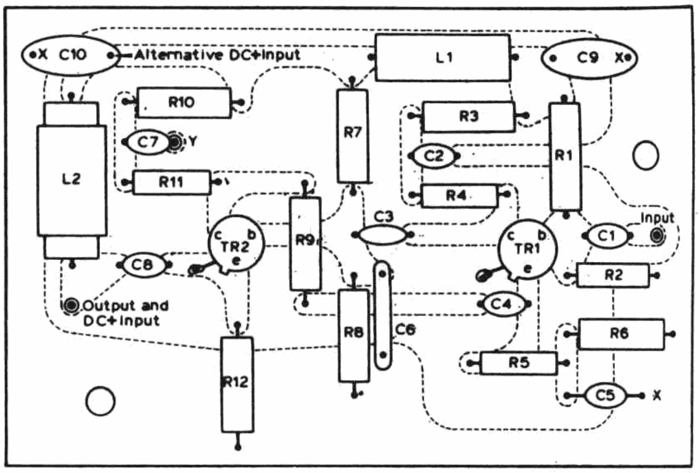
Fig 18. Printed circuit board, Side 2



2 holes 'A' 3·2mm dia 3 holes 'B' 1·3mm dia
54 unmarked holes 1·0mm dia

Fig 19. Printed circuit board drilling data

the other. The amplifier should be broadband from 2 to 30MHz with low noise and low level of intermodulation products. The design of a suitable amplifier is shown in Figs 16-20, and it will be noted that it incorporates a filter to separate the RF from the DC supply. It will be necessary to provide a 24V DC supply capable of providing 30mA, and this unit will also require a filter to enable the RF only to be connected to the station receiver.



◉ indicates terminal pin

Fig 20. Printed circuit board component layout

1. All components to be spaced approximately 0.06in (1.5mm) from face of board.
2. Earth leads of transistors to be soldered to component side of board as shown.
3. Connections at points marked 'X' to be soldered on both sides of board.
4. Pin marked 'Y' to be soldered to component side of board

It has been stated that optimum performance is obtained when the loop is 1.5m above ground, and although the professional version of the loop utilises a custom-produced casting, the amateur constructor will find that an electrical conduit flange plus 1.5m of conduit to be a satisfactory method of mounting.

An interesting series of experiments may comprise varying the loop height and altering the value of the element-joining resistor.

Components list

R1	1.8k 1W RS
R2	220 0.125W RS
R3	1.5k 0.5W RS
R4, 12	470 0.125W RS
R5	15 0.125W RS
R6	180 0.125W RS
R7	18k 0.125W RS
R8	3.3k 0.125W RS
R9	1k 0.125W RS
R10	1.8k 0.125W RS
R11	680 0.125W RS
Terminal pins	Type SS 3-off RS
C1,2,3,4,7,8	0.01μF min ceramic plate 40V DC Sasco
C5	0.47μF silvered mica RS
C6	22pF silvered mica RS
C9,10	0.1μF mico-min plaquette RS
L1	5μH 1A RS238-255 or equiv
L2	2.5mH Home Radio
TR1	2N3570 Fairchild Micro Marketing
TR2	BFY90 Farnell
PCB	FR4GID double-sided 1.5 by 46 by 72.6mm

Acknowledgement

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RadCom, November 1982