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Paper 5.3: Loop Antennas for HF Reception
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Loop Antennas for HF Reception

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INTRODUCTION

In the HF band the sensitivity of a receiving system is limited by ambient noise in the environment. Sensitivity is not increased by increasing the size of the signal provided by the antenna but can only be increased by increasing the directivity of the antenna. It is therefore attractive to consider the possibility of constructing an array comprising a number of small antennas.

1. Choice of Antenna Unit for Array

The characteristics of short dipoles, whips and loops were considered. Each type of antenna has various advantages and disadvantages. To take advantage of being able to use a small antenna element it should be capable of receiving vertically polarised signals, which may be received by an antenna mounted immediately above ground level, rather than horizontally polarised signals whose field strength falls at ground level.

A vertical dipole or whip antenna has a high, capacitive input impedance and an omnidirectional azimuth radiation pattern. The effective height and input impedance may be modified by the addition of a capacity hat to the top of the whip.

A loop—placed in the vertical plane—has a low, inductive input impedance and a figure-of-eight azimuth radiation pattern.

1.1 Input Impedance

If we further examine the input impedance of the two types of antenna we note that a dipole looks like, a slightly lossy capacitor. It does not exhibit resonance phenomena over very wide bands—until its dimensions become a substantial fraction of a wavelength. A small loop looks like a slightly lossy inductor. Unfortunately loops of reasonable size— 0.5 to 1.5m diameter—exhibit resonances in the HF band. The series inductance may be reduced by forming the loop from wide strip and the parallel capacitance may be minimised by careful design of the terminal region.

1.2 Radiation Patterns

As the vertical whip or dipole has an omnidirectional azimuth radiation pattern, all azimuth directivity must be obtained from the arraying of elements. With any array it will be impossible to receive signals arriving from high angles of elevation. This is an unfortunate defect.

A loop antenna normally has a bidirectional azimuth radiation pattern, but is able to receive signals from all angles of elevation. In an endfire array a unidirectionai beam may be formed at any angle of elevation. The null in the basic pattern of the loop may be used to eliminate unwanted signals.

1 .3 Ideal Element

An ideal element would combine a far more constant input impedance than either of the elements discussed, together with a unidirectional radiation pattern. An input impedance close to 50 ohms would be useful, as existing amplifiers and filters could be connected to the element. A unidirectional azimuth radiation pattern would allow endfire, broadside or radial arrays to be constructed.

It did not seem likely that the desired combination of properties could be obtained from a dipole element, so the loop element was further investigated.

2. THE RADIATION PATTERN OF LOOP ANTENNAS

The current which flows in a loop antenna may be represented by a Fourier series of cosine and sine terms. The zero order term represents a constant current flowing around the hop and gives rise to the familiar figure-of-eight radiation pattern typical of a small loop (Fig. 1 A).

The odd order (sine) terms represent the currents which flow in the same direction in both sides of the loop and therefore do not give rise to any output voltage across a balanced terminating impedance. The azimuth radiation pattern associated with this current mode in a small loop is circular. (Fig. 1 B).

When the loop is fed with an unbalanced feed both even and odd modes can exist. The total radiation pattern of the loop will be the sum of those due to the separate modes. The zero order mode predominates in a simple loop; in order to obtain a cardioid radiation pattern the amplitude of the zero order mode current must be reduced relative to the first order mode current, and the relative phase of the currents must be adjusted so that the cancellation obtained in the rearwards direction is complete. This result can be achieved by inserting a suitable impedance in series with the loop at a point diametrically opposite the feedpoint (Fig. 1 C).

The terminated loop exhibits a near cardioidal azimuth radiation pattern for vertically polarised incident energy and an input impedance which may easily be matched to 50 ohms.

3. DESIRED AMPLIFIER CHARACTERISTIC

The effective height of a terminated loop 0.80m in diameter is approximately 0.7m. In order to ensure that the received signal is raised to a level at which it will overcome the internal noise of the receiver and to buffet the output of the loop, a low noise amplifier is connected to the loop output.

The effective height of a halfwave dipole antenna is directly proportional to wavelength—in fact 0.32 wavelengths. Similarly the effective height (or effective area) of any other antenna is proportional to wavelength. By contrast the effective area of a loop increases as the wavelength decreases. Thus if the output of the loop is compared with that from some other broadband antenna such as a log periodic it will be observed that the signal from the loop rises relative to that from the log periodic as the frequency is increased. To provide a constant ratio between the signals from the two antenna the amplifier used with the loop must have a gain which falls with frequency. This is a matter of choice rather than necessity, although in some cases it may avoid blocking of the receiver by signals at the high frequency end of the band.

In order to avoid disturbance by MF or VHF signals the passband of the amplifier should be restricted by filtering.

The main problem of amplifier design is that of achieving satisfactory intermodulation performance. From work carried out so far it is clear that the performance of any active antenna system will be determined ultimately by intermodulation. The characteristics of transistors which fully determine linearity are unfortunately not well documented. Amplifiers have been made whose 2nd and 3rd order intermodulation products are some 60dB below the outputs for an input signal level of + 80dB (,uV).

4. PRACTICAL LOOP ANTENNA

A practical loop antenna is shown in figure 3. The loop is made from aluminium strip embedded in fibreglass. This construction is light and rigid and gives a low series inductance and shunt capacitance. The amplifier is housed in a cast box at the base of the loop and the terminating components in a recess at the top. Radiation patterns from such a loop are illustrated in figure 2.

5. PRACTICAL COMPARISON OF A LOOP WITH A MONOPOLE

In order to assess the practical performance of a loop and amplifier, a comparison has been made with a conventional quarter wave monopole. The antennas were connected to the two inputs of a dual path diversity receiver which is used to provide two receivers with well balanced characteristics. The output from the receiver, which would receive CW, MCW or FSK signals, was displayed on an oscilloscope and was available on headphones.

Input signals were tuned and the loop aligned for maximum signal. Input and if attenuators were adjusted until the output levels from the two channels were identical. The noise levels on the two channels may then be examined with the oscilloscope. The two antennas cannot generally be distinguished by this test. Signals which are just discernible at low level on the monopole may also be received using the loop.

When comparing the loop or an array of loops with any conventional array great care must be taken that the results are strictly comparable. Mere amplitude of the output signal is of no consequence, for the gain of the amplifier associated with the loop may be changed at will. A comparison between arrays will only be valid if the arrays concerned have closely similar radiation patterns and are properly suited to a propagation path over which they are being tested. Much of the work done in comparing arrays in the past falls down in these respects.

6. PERFORMANCE OF ARRAYS OF LOOPS

The loops may be used in endfire, broadside or radial arrays.

6.1 Endfire Arrays (Fig. 4A)

This type of array is ideal for fixed point-to-point services. An excellent front-to-back ratio can be maintained over a wide frequency band and the angle of elevation of the main beam can be controlled by introducing variable phase shift between elements. They cannot be slewed to fire in different azimuth directions.

6.2 Broadside Arrays (Fig. 4B)

An advantage of using basic elements with a cardioid azimuth radiation pattern is that they can be employed in broadside arrays as well as endfire arrays.

A broadside array has a broad vertical beam which is narrow in the horizontal plane. The vertical beamwidth is not a function of frequency so the array can be used at a variety of frequencies on short circuits. The beam can be slewed over a range of azimuth angles—say +30° from the nominal direction of fire.

6.3 Radial Arrays (Fig. 4C)

If a fully steerable array is required—for example for communication to ships — the conventional solution is to use a rosette of log periodic or rhombic antennas. Such arrays are extremely costly and occupy very large land areas. For this application

loops may be arranged in a number of concentric rings. By suitably matrixing the outputs of the individual loops a number of overlapping beams can be created, available singly or concurrently.

CONCLUSION

A loop element with a cardioidal azimuth radiation patterns has been developed and its performance assessed. Once the problems of intermodulation products have been overcome these elements have wide application for constructing both simple and highly sophisticated arrays.

Acknowledgements

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References

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2. Collin, R.E. and Zucker, F.J., 'Antenna Theory', (Part 1) McGraw Hill 1969.

Antennas embodying the principles described in this paper are the subject of current Patent applications.

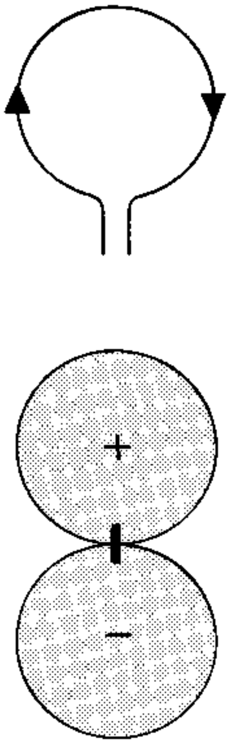


Fig. 1a

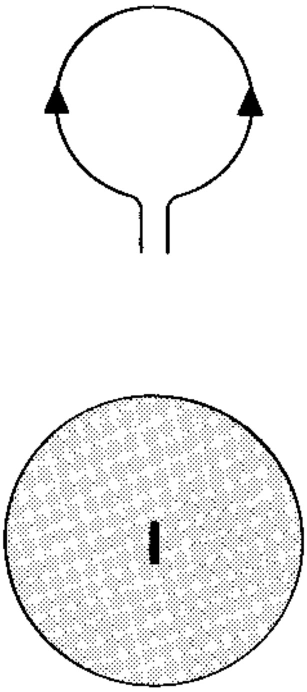


Fig. 1b

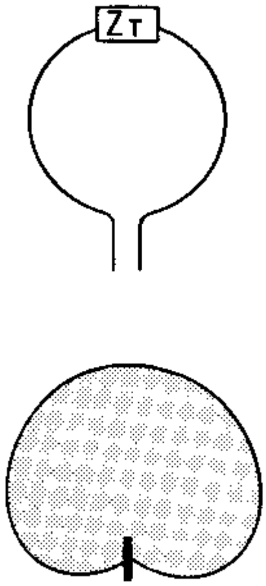
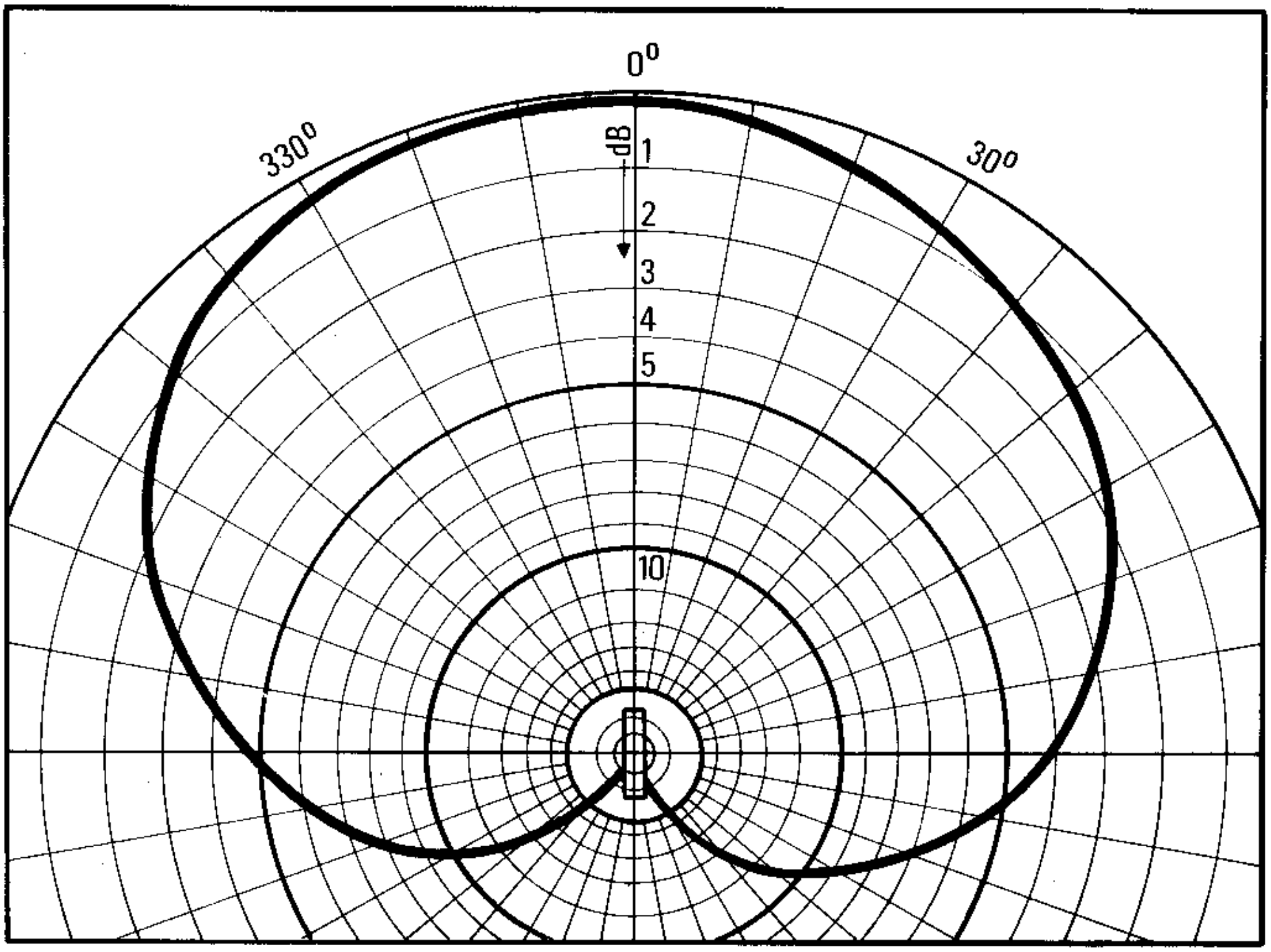


Fig. 1c



MEASURED RADIATION PATTERN Fig. 2

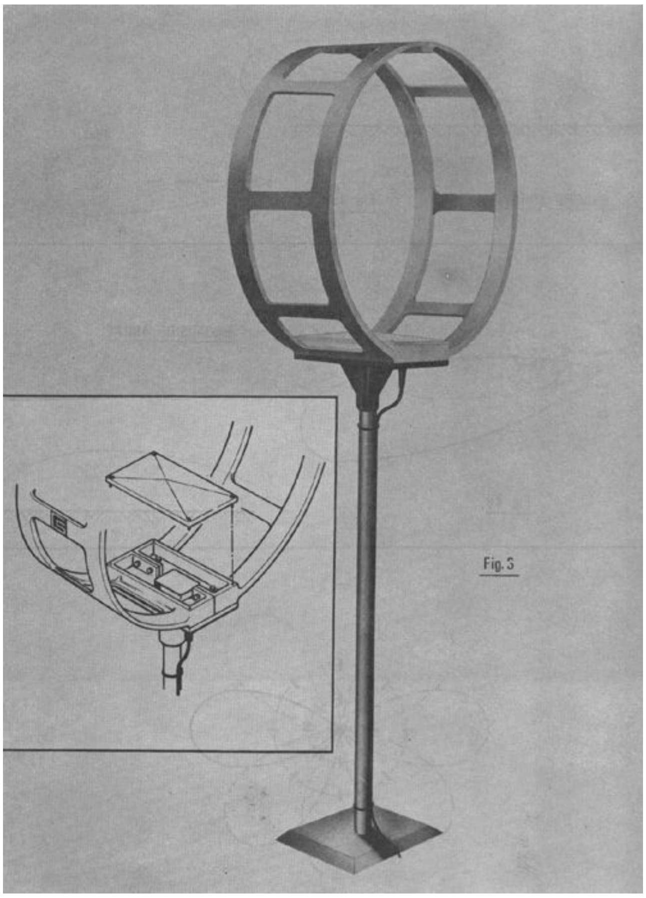
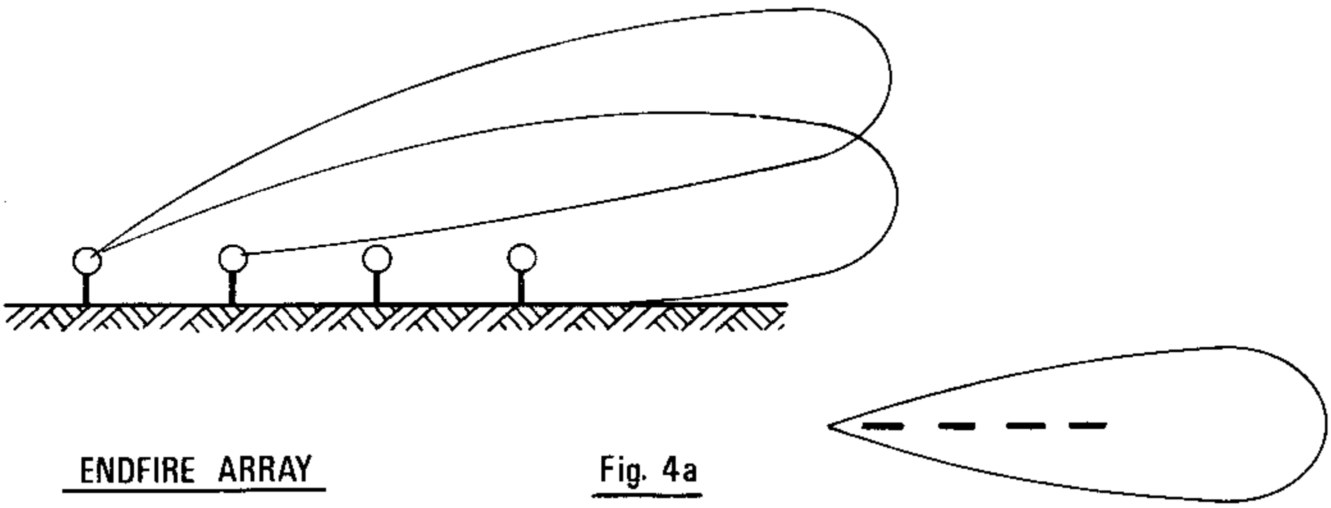
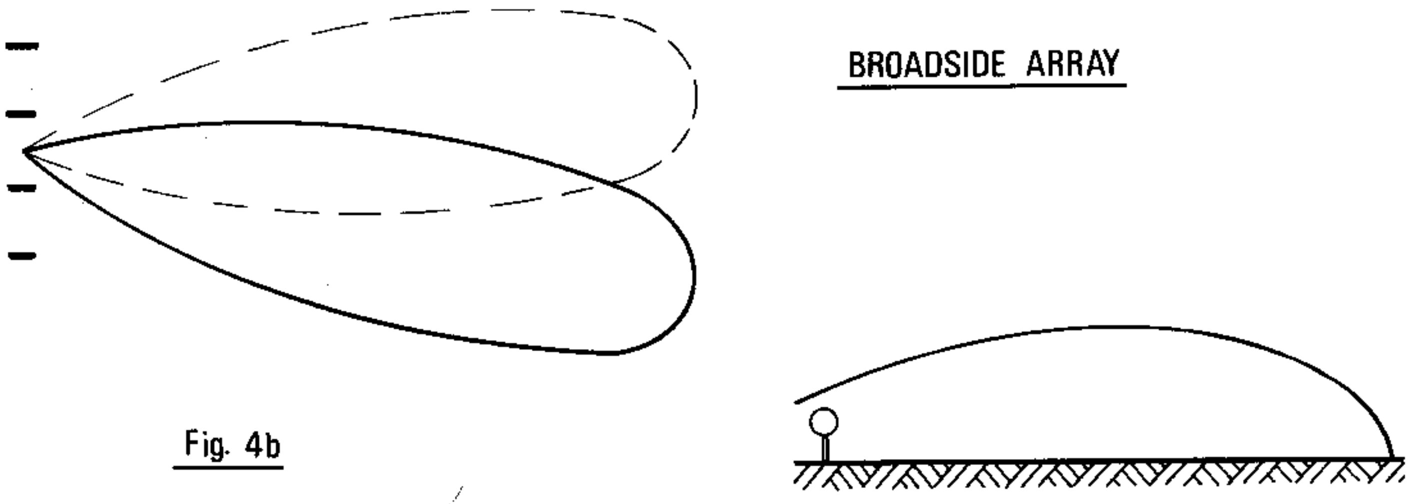


Fig. 3



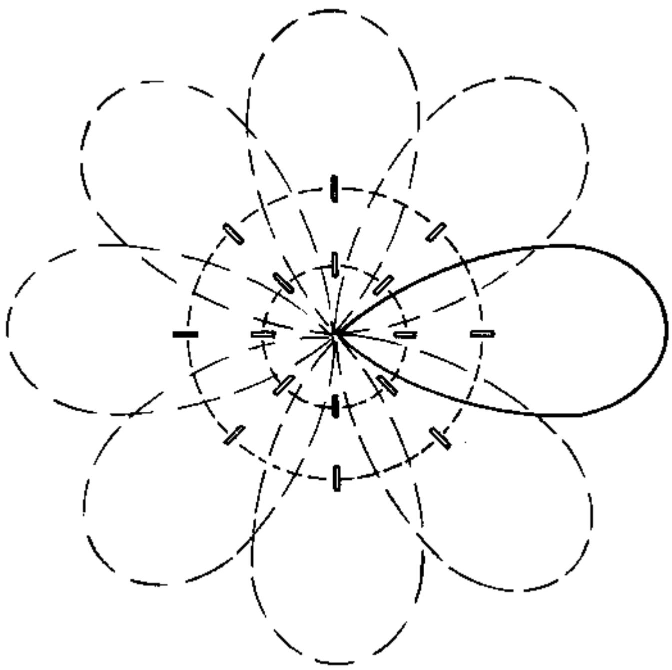
ENDFIRE ARRAY

Fig. 4a



BROADSIDE ARRAY

Fig. 4b



RADIAL ARRAY

Fig. 4c