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FREQUENCY INDEPENDENT UNIDIRECTIONAL ANTENNAS

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2 Sheets-Sheet 1

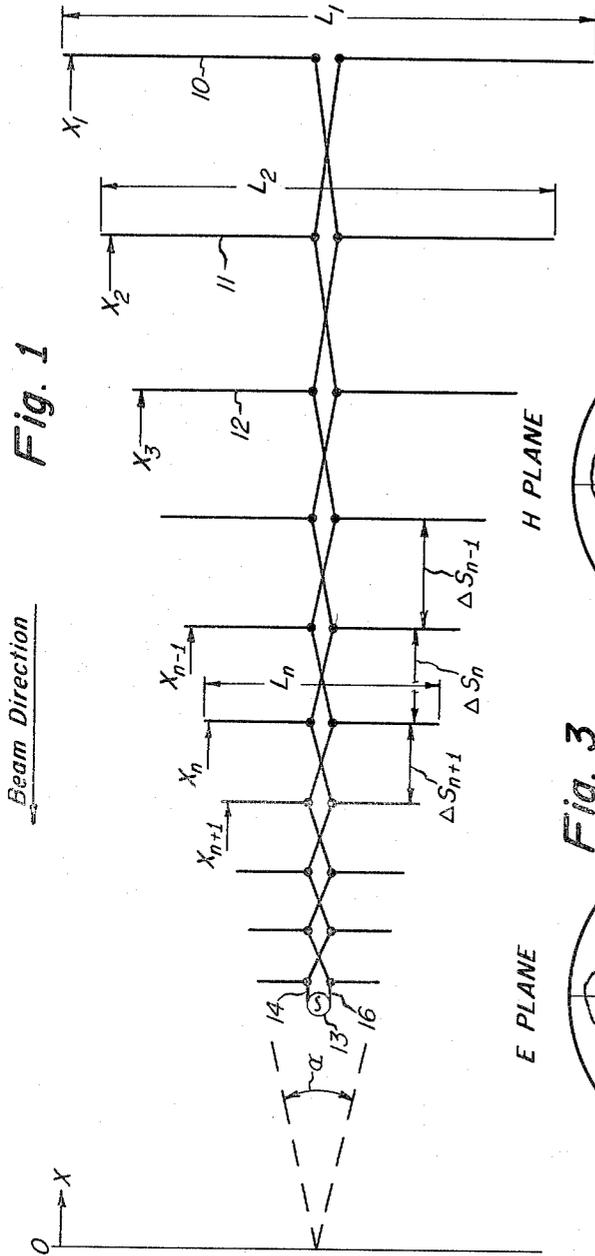


Fig. 1

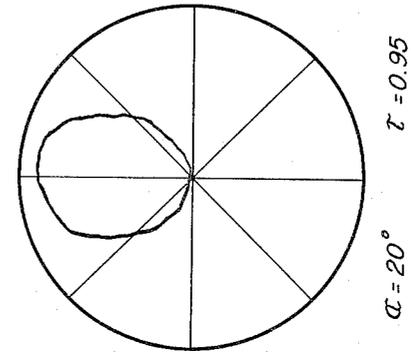


Fig. 4

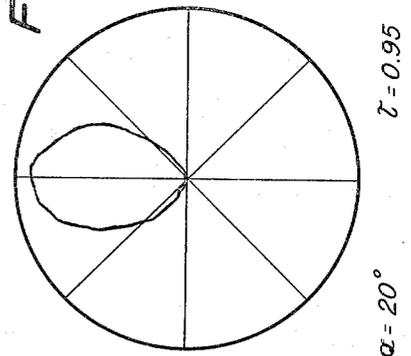


Fig. 3

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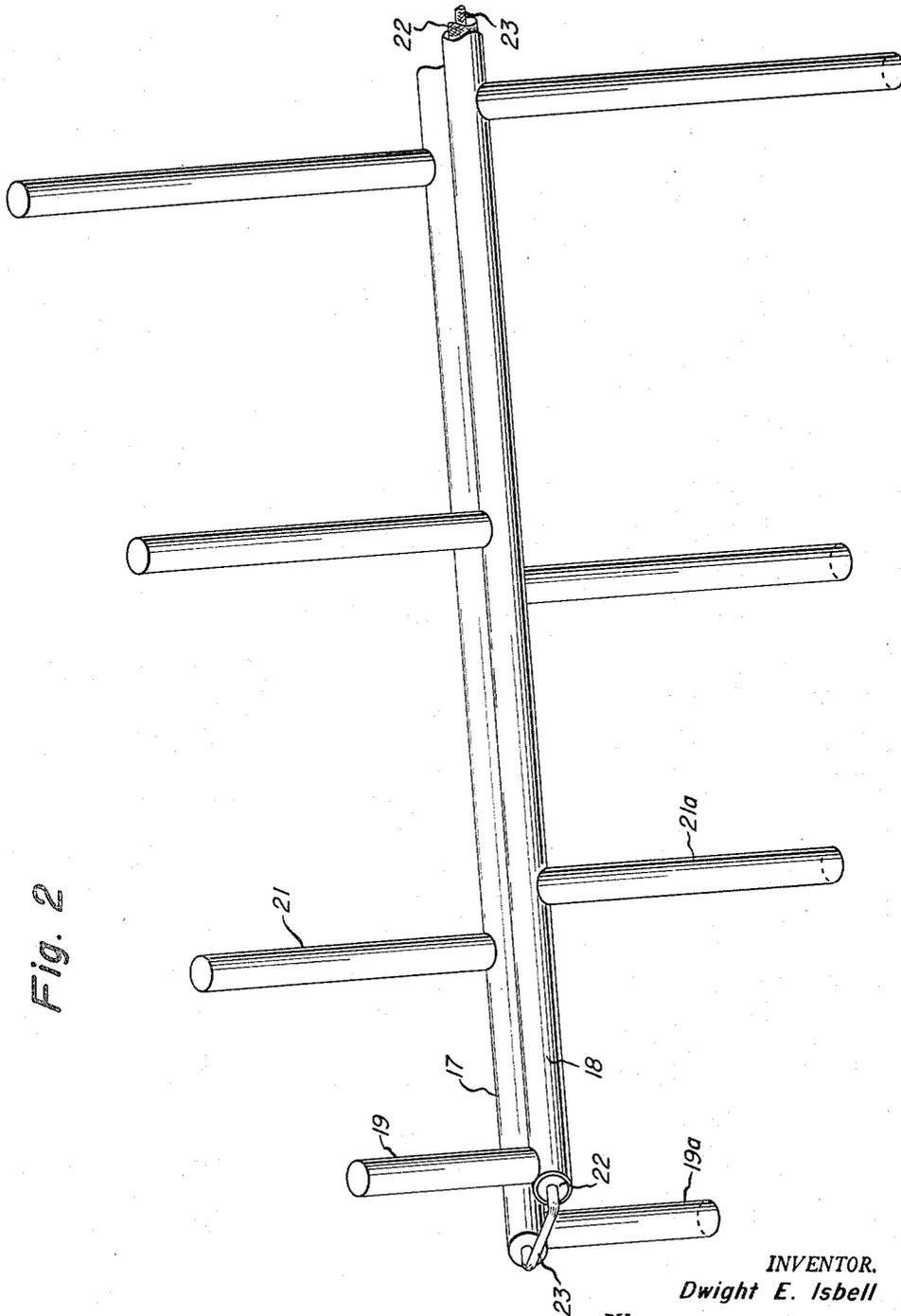


Fig. 2

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FREQUENCY INDEPENDENT UNIDIRECTIONAL ANTENNAS

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This invention relates to antennas, and more particularly, it relates to antennas having unidirectional radiation patterns that are essentially independent of frequency over wide bandwidths.

The antennas of the invention are coplanar dipole arrays consisting of a number of dipoles arranged in side-by-side relationship in a plane, the length and the spacing between successive dipoles varying according to a definite mathematical formula, each of the dipoles being fed by a common feeder which introduces a phase reversal of 180° between connections to successive dipoles. The antennas of the invention provide unidirectional radiation patterns of constant beamwidth and nearly constant input impedances over any desired bandwidth.

The invention will be better understood from the following detailed description thereof taken in conjunction with the accompanying drawing, in which:

FIGURE 1 is a schematic plan view of an antenna made in accordance with the principles of the invention;

FIGURE 2 is an isometric view of a practical antenna embodying the invention; and

FIGURES 3 and 4 are radiation patterns of a typical antenna, in the E plane and H plane, respectively.

Referring to FIGURE 1, it will be seen that the antenna of the invention was composed of a plurality of dipoles 10, 11, 12, etc., which are coplanar and in parallel, side-by-side relationship. It will be noted that the lengths of the successive dipoles and the spacing between these dipoles is such that the ends of the dipoles fall on a pair of straight lines which intersect and form an angle α . In the preferred embodiment the antenna is symmetrical about a line passing through the midpoints of the dipoles, as shown.

The antenna is fed at its narrow end from a conventional source of energy, depicted in FIGURE 1 by alternator 13, by means of a balanced feeder line consisting of conductors 14 and 16. It will be seen that the feeder lines 14 and 16 are alternated between connections to consecutive dipoles, thereby producing a phase reversal between such connections.

The lengths of the dipoles and the spacing between dipoles are related by a constant scale factor τ defined by the following equations:

$$\tau = \frac{L_{(n+1)}}{L_n} = \frac{\Delta S_{(n+1)}}{\Delta S_n}$$

where τ is a constant having a value less than 1, L_n is the length of any intermediate dipole in the array, $L_{(n+1)}$ is the length of the adjacent smaller dipole, ΔS_n is the spacing between the dipole having the length L_n and the adjacent larger dipole, and $\Delta S_{(n+1)}$ is the spacing between the dipole having the length L_n and the adjacent smaller dipole.

It will be seen from the geometry of the antennas, as given above, that the distance from the base line 0 at the vertex of the angle α to the dipoles forming the array are defined by the equation:

$$\tau = \frac{X_{(n+1)}}{X_n}$$

where X_n is the distance from the base line 0 to the dipole having the length L_n , $X_{(n+1)}$ is the corresponding distance

from the base line to the adjacent smaller dipole, and τ has the significance previously given.

The radiation pattern of the antennas of the invention, having the geometrical relationship among the several parts as defined above, is unidirectional in the negative X direction, i.e., extending to the left from the narrow end of the antenna of FIGURE 1.

The construction of an actual antenna made in accordance with the invention is shown in FIGURE 2. In this antenna the balanced line consists of two closely-spaced and parallel electrically conducting small diameter tubes 17 and 18 to which are attached the dipoles, each of which consists of two individual dipole elements, e.g., 19 and 19a, 21 and 21a, etc. It will be noted that each of the two elements making up one dipole is connected to a different one of said conductors 17 and 18, in a direction perpendicular to the plane determined by said conductors 17 and 18. Moreover, considering either one of the conductors 17 and 18, consecutive dipole elements along the length thereof extend in opposite directions. It will be seen that this construction has the effect of alternating the phase of the connection between successive dipoles, as depicted schematically in FIGURE 1. Although the dipoles of FIGURE 2 are not precisely coplanar, differing therefrom by the distance between the parallel conductors, in practice this distance is very small so that the dipole elements are substantially coplanar and the advantages of the invention are maintained. The antenna of FIGURE 2 may be conveniently fed by means of a coaxial cable 22 positioned within conductor 18, the central conductor 23 thereof extending to and making electrical connection with conductor 17 as shown.

As an example of the invention, an antenna of the type shown in FIGURE 2 was constructed using 0.125 inch diameter tubing for the balanced line and 0.050 inch diameter wire for the elements. The elements were attached to the feeder line with soft solder, and the array was fed with miniature coaxial cable inserted through one of the balanced line conductors. The antenna was defined by the parameters $\tau=0.95$ and $\alpha=20^\circ$. The antenna had a total of 15 dipoles, with the longest dipole element being $2\frac{1}{2}$ " long, while the shortest element was one-half of this length, or $1\frac{1}{4}$ ". The array was $7\frac{1}{2}$ " long.

Typical radiation patterns for the above-described antenna in the E plane and the H plane are shown in FIGURES 3 and 4, respectively. These patterns were found to remain essentially constant over the band of about 1100 to 1800 mc./sec. The minimum front-to-back ratio over this band was 17 db and the directivity over the range from about 1130 to 1750 mc./sec. was better than 9 db over isotropic.

The performance of the above-described antenna clearly indicates that the antennas of the invention provide excellent rotatable beams for use particularly in the HF to UHF spectrum. In comparison to the well-known parasitic types of antennas which bear some resemblance to those of the invention, such as the Yagi array, the antennas of the invention provide a much wider bandwidth with essentially comparable directivity. Advantageously, however, the antennas of the invention need no adjusting for their performance over a wide bandwidth, compared to the parasitic types which must be adjusted by cut-and-try procedures for each frequency. Further experimental work with other antennas similar to that described above has indicated that the preferred values for the parameters which define the antennas of the invention include a range of values for angle α between about 20° and 100° , with τ having a value between about 0.8 and about 0.95. When these parameters have values within the preferred ranges the antennas were

found to have essentially frequency independent performance over any desired bandwidth. The upper and lower limits of the bandwidths may be adjusted as desired by fixing the lengths of the longest dipole and the shortest dipole, respectively. It has been determined experimentally that the longest dipole element should be approximately 0.47 wavelength long at the lower limit and the shortest element should be about 0.38 wavelength long at the upper limit. Moreover, in order to provide a suitable front-to-back ratio at the low frequency limit, there should be at least 3 dipoles in the array and preferably about 10 to 30 dipoles.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed is:

1. A broadband unidirectional antenna comprising an array of substantially coplanar and parallel dipoles of progressively increasing length and spacing in side-by-side relationship, the ratio of the lengths of any two adjacent dipoles being given by the formula

$$\frac{L_{(n+1)}}{L_n} = \tau$$

where L_n is the length of any intermediate dipole in the array, $L_{(n+1)}$ is the length of the adjacent smaller dipole and τ is a constant having a value less than 1, the spacing between said dipoles being given by the formula

$$\frac{\Delta S_{(n+1)}}{\Delta S_n} = \tau$$

where ΔS_n is the spacing between the dipole having the length L_n and the adjacent larger dipole, $\Delta S_{(n+1)}$ is the spacing between the dipole having the length L_n and the adjacent smaller dipole, and τ has the significance previously assigned, said dipoles being fed in series by a common feeder which alternates in phase between successive dipoles.

2. The array of claim 1 which is symmetrical about a line passing through the midpoint of each dipole in the array.

3. A broadband unidirectional antenna comprising an array of a plurality of substantially coplanar and parallel dipoles of progressively increasing length in side-by-side relationship, the ends of said dipoles falling on a V-shaped line forming an angle α at its vertex, the ratio of the lengths of any pair of adjacent dipoles being given by the formula

$$\frac{L_{(n+1)}}{L_n} = \tau$$

where L_n is the length of the longer dipole of the pair, $L_{(n+1)}$ is the length of the shorter dipole, and τ is a constant having a value less than 1, the dipoles in said array being fed in series by a common feeder which alternates 180° in phase between successive dipoles.

4. The antenna of claim 3 in which the angle α has a value between about 20° and 100° and the constant τ has a value between about 0.8 and 0.95.

5. The antenna of claim 3 in which said feeder is a balanced line which twists 180° between the connections to successive dipoles.

6. A broadband unidirectional antenna comprising a balanced feeder line consisting of two closely spaced, straight and parallel conductors, a plurality of dipoles each consisting of two dipole elements, one of which elements is connected to one of said conductors, the other element being connected directly opposite the first to the other of said conductors, the elements of any dipole extending in opposite directions perpendicular to the plane determined by said conductors, consecutive dipole elements on each of said conductors extending in opposite directions, the ratio of the lengths of the ele-

ments in any two adjacent dipoles being given by the formula

$$\frac{l_{(n+1)}}{l_n} = \tau$$

where l_n is the length of an element of any dipole in the antenna, $l_{(n+1)}$ is the length of an element in the adjacent smaller dipole and τ is a constant having a value less than 1, the spacing between said dipoles being given by the formula

$$\frac{\Delta S_{(n+1)}}{\Delta S_n} = \tau$$

where ΔS_n is the spacing between the dipole having the element length l_n and the adjacent larger dipole, $\Delta S_{(n+1)}$ is the spacing between the dipole having the element length l_n and the adjacent smaller dipole, and τ has the significance previously assigned.

7. The antenna of claim 6 wherein τ has a value of about 0.8 to 0.95.

8. The antenna of claim 6 wherein said feeder line conductors are tubular.

9. An aerial system including at least one set of parallel dipoles spaced along and substantially perpendicular to the longitudinal axis of a two-conductor balanced feeder to which the halves of the dipoles are connected at their inner ends, said dipoles being of different electrical lengths increasing substantially logarithmically from the connected end of the feeder to the other end and the dipole feeder connections being crossed over one another between adjacent dipoles, the spacings between which also increase substantially logarithmically from said connected end to the other end.

10. An antenna system for wide-band use comprising a plurality of substantially parallel conducting dipole elements arranged in substantially collinear pairs, the opposite dipole elements of each pair constituting dipole halves, a two-conductor balanced feeder having one conductor connected to each of said elements at substantially the inner end thereof, each of said dipole halves in a pair being connected to a different feeder conductor, adjacent dipole elements being reversely connected to different conductors of the feeder, said dipole elements being selectively spaced along and substantially perpendicular to said feeder, the elements of each pair being of substantially equal length, adjacent dipole elements of different pairs differing in length with respect to each other by a substantially constant scale factor, the selective spacings between adjacent dipoles generally decreasing from one end of the feeder to the other with the greatest spacing being between the longest dipoles, and means to connect the feeder to an external circuit at substantially the location of the smallest of the dipole elements.

11. An antenna system for wide-band use comprising a plurality of substantially parallel conducting dipole elements arranged in substantially collinear pairs, the opposite dipole elements of each pair constituting dipole halves, a two-conductor balanced feeder having one conductor connected to each of said elements at substantially the inner end thereof, each of said dipole halves in a pair being connected to a different feeder conductor, adjacent dipole elements being reversely connected to different conductors of the feeder, said dipole elements being selectively spaced along and substantially perpendicular to said feeder, the elements of each pair being of substantially equal length, adjacent dipole elements of different pairs differing in length with respect to each other by a substantially constant scale factor, the selective spacings between the dipoles along the feeder differing from each other also by a substantially constant scale factor, the greatest spacing being between the longest dipoles, and means to connect the feeder to an external circuit at substantially the location of the smallest of the dipoles.

12. The aerial system of claim 11 in which said scale

factors have values within the range from about 0.8 to about 0.95.

13. An antenna system for wide-band use comprising an array of at least three linear substantially parallel conducting dipoles, each dipole being composed of two opposite substantially collinear conducting elements, a two-conductor balanced feeder having one conductor connected to each of said elements at substantially the inner end thereof, adjacent parallel dipole elements being reversely connected to a different conductor of the feeder, the two elements of each dipole being of substantially equal length and successive elements being of lengths which differ from one dipole to the next by a substantially constant scale factor within the range from about 0.8 to about 0.95, the dipoles being spaced from each other in a generally decreasing manner in the direction of decreasing element length, and means to connect the feeder conductors to an external circuit at substantially the location of the smallest dipole elements.

14. An antenna system for wide-band use comprising a minimum of three pairs of linear substantially parallel conducting elements arranged substantially coplanarly, each pair being substantially collinear and comprising the halves of a dipole, a two-conductor feeder connected to the inner ends of said collinear pairs of elements, adjacent parallel elements being connected to different conductors of the feeder so that the halves of the dipoles connect to different conductors of the feeder and adjacent dipoles are reversely connected, the halves of each dipole being substantially the same length, adjacent dipole elements being selectively spaced from each other along the feeder, the length of the successive dipole elements along the feeder decreasing in accordance with a substantially constant scale factor, each dipole and the feeder between it and the adjacent dipole constituting a cell, the dimension of the several cells measured from the point of connection of one dipole and the feeder to the outer end of the next smaller adjacent dipole also decreasing from one cell to the next in the direction of decreasing dipole length according to a substantially constant scale factor so that the combination of cells provides a substantially uniform wide-band response, and means to

connect an external circuit to the feeder elements at substantially the location of the shortest of the dipoles.

15. An antenna system for wide-band use comprising a minimum of three pairs of substantially parallel and coplanar linear conducting elements arranged in substantially collinear pairs, each pair of elements comprising the halves of a dipole, a two-conductor feeder, one conductor of which is connected to each of said elements substantially at the inner end thereof, adjacent parallel elements being connected to different conductors of the feeder so that the halves of the dipoles connect to different conductors of the feeder and adjacent dipoles are reversely connected, the halves of each dipole being substantially the same length, adjacent dipole elements being selectively spaced from each other along the feeder, the lengths of the elements decreasing from one end of the feeder to the other substantially in accordance with a substantially constant scale factor within the range from about 0.8 to 0.95, each dipole and the feeder between it and the adjacent dipole constituting a cell, the cell dimension from the inner end of one dipole to the outer end of the next smaller adjacent dipole also generally decreasing from one cell to the next in the direction from the longer to the shorter dipoles so that the combination of cells provides a substantially uniform wide-band response, and means to connect an external circuit to the feeder elements at substantially the location of the shortest of the dipoles.

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