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STEPPED DIELECTRIC CONSTANT END FIRE ANTENNA

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FIG. 1

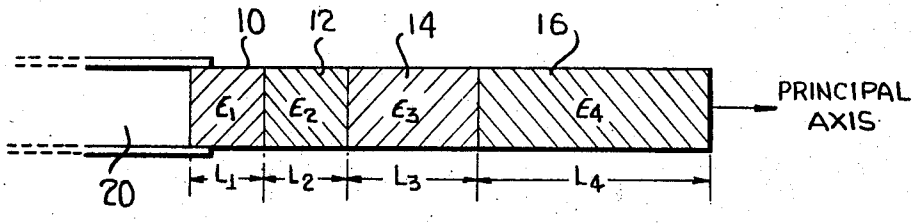
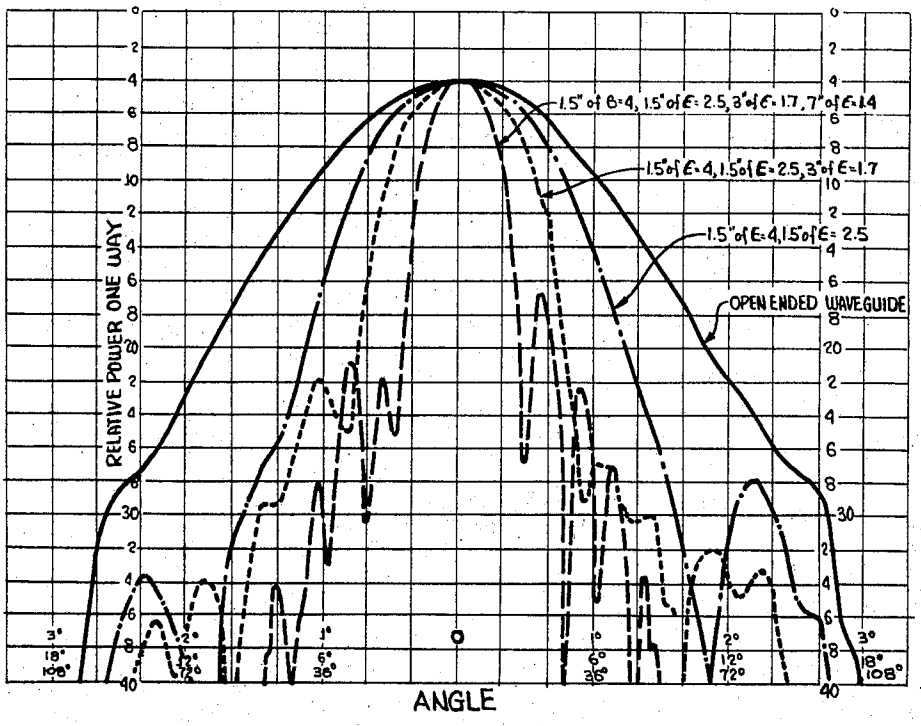


FIG. 2



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STEPPED DIELECTRIC CONSTANT END FIRE ANTENNA

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ABSTRACT OF THE DISCLOSURE

An end fire antenna includes an electromagnetic wave launcher including an open ended wave guide for feeding a series of colinear dielectric members, the dielectric members cascaded in axial alignment relative to the principal axis of radiation of the wave guide and having distinct and different dielectric constants greater than one (i.e., 1) and distinct and different lengths, the dielectric constants progressively decreasing with successive positions of the dielectric members in the direction of radiation of waves along the principal axis of the launcher and the lengths of the dielectric members progressively increasing with successive positions of the dielectric members in the aforementioned direction. The dielectric constant of each member is selected to provide a critical angle for total internal reflection of components of the waves incident on the longitudinal boundaries of the respective member at least approximately equal to the angle between the peak and the half power points of the radiation pattern produced by the launcher and by the preceding dielectric members relative to the aforementioned direction of radiation and the dielectric member under consideration. The length of each dielectric member is selected to be of such magnitude that a null is created at the half power point of the radiation pattern produced by the preceding section, including the wave launcher and the preceding dielectric members.

The present invention relates generally to antennas and more particularly to end fire antennas employing dielectric elements to improve antenna gain and to reduce side lobes.

Generally speaking, end fire antennas cover the broad class of antennas, arrays of antennas, and arrays of arrays having a principal axis and so designed and excited that the maximum intensity of radiation (i.e., the major lobe of the radiation pattern) is directed along the principal axis. Among the conventional antennas and antenna arrays included in this broad classification are the dielectric rod, disc on rod, Yagi, and ferrite rod antennas.

It is a principal object of the present invention to provide dielectric end fire antennas having higher gain, larger effective area and lower sidelobes than are obtainable using conventional end fire antennas in general, and using the latter-mentioned antennas included in the broad end-fire class in particular.

Briefly, in accordance with the present invention an open ended waveguide is employed to feed a series of colinear dielectric rods, each having a dielectric constant and a length different from that of the preceding rod and each acting as a launcher for the next successive rod in the series. In essence, then, the antenna constitutes a colinear stepped dielectric constant array. The dielectric constant and length of each rod of the array are so chosen that electromagnetic waves launched by the preceding sections or elements combine with the waves launched as a result of the combined effect of the preceding sections with the rod under consideration to produce cancellation of the radiation at the half power points of the beam

radiated by the the preceding sections. In other words, each succeeding rod is effective to produce a null at the 3 db points in the total radiation pattern of the preceding sections and, thus, to halve the beamwidth. Advantages of such an antenna include high launching efficiency and large effective area, with attendant high gain and low sidelobes.

I am aware that certain prior art antennas have utilized a plurality of layers or strata of differing dielectric constant in a dielectric medium associated with a waveguide, but the purpose of such structure has, in the past, been to provide a gradual match between the impedance of the waveguide and the radiation resistance of the free space into which the waves are launched. Hence, the use of stepped dielectric constant elements with a waveguide, per se, is old and well known in the art. To my knowledge, however, the principles involved in the selection of the dielectric constant and the dimensions of each element according to the present invention, and the function to be served thereby, have not heretofore been suggsted or utilized in the antenna art.

Accordingly, it is a further object of the present invention to provide a stepped dielectric constant end fire antenna wherein the dielectric constant and the dimensions of the dielectric elements are selected to produce a reduction in the beamwidth of the overall radiation pattern of the antenna, and thus to increase the dielectric gain of the antenna.

Another object of the present invention is to provide a stepped dielectric constant end fire antenna that can be arrayed with like units to provide high gain tracking arrays.

Still another object of the present invention is to provide a stepped dielectric constant end fire antenna requiring a much smaller launcher and cross-sectional area than would be necessary with a single dielectric rod antenna having the same gain.

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of a preferred embodiment thereof, especially when taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a side elevational view, in cross-section, of a preferred embodiment of the invention; and

FIGURE 2 is a chart showing a plurality of exemplary radiation patterns, each associated with respective successive sections of an antenna of the type shown in FIGURE 1.

Referring now to the drawings, and in particular to FIGURE 1, a preferred embodiment of the antenna comprises a plurality of dielectric rods **10, 12, 14, 16,** cascaded end-to-end in a co-linear array. Although four dielectric rods are shown in the figure, it will be understood that this is purely by way of example, and that a greater or fewer number of elements may be used, as may be desired for a particular application.

The co-linear array is fed by an open ended waveguide **20**, the array being mounted or otherwise suitably fastener or supported adjacent the aperture of the waveguide. The rods may be solid cylindrical elements or solid rectangular elements, preferably conforming in cross-sectional shape to that of waveguide **20** (i.e., according to whether the waveguide is circular or rectangular, respectively). The cross-section (d) of each rod normal to the principal axis is the same, but each is assigned a different dielectric constant (ϵ_1, ϵ_2, . . . ϵ_n, where the subscripts correspond to the number of the element in the array, ϵ_1 being the dielectric constant of the first rod adjacent the open end of the waveguide, and ϵ_n being the dielectric constant of the nth rod in

the array, i.e. that element most remote from the waveguide aperture), and a different length (L_1, L_2, . . . L_n).

The principles involved in the determination of dielectric constant and length of each of the cascaded elements are as follows:

The dielectric constant of the first element (i.e., rod **10**) is selected so that the critical angle of total internal reflection is equal, or approximately so, to the angle between the peak and the half-power (3 db) points of the beam in the radiation pattern of the open ended waveguide **20**. The beam or major lobe is, of course, directed along the principal axis (i.e., the central axis) of the antenna. The critical angle is defined as the angle of incidence of electromagnetic wave components propagating through a dielectric medium with the boundary between that medium and a second dielectric medium, at which and above which the wave components are totally reflected from the boundary. In general, the critical angle is

$$\theta_{cr} = \sin^{-1}\frac{\sqrt{\epsilon_b}}{\sqrt{\epsilon_a}} \quad (1)$$

where ϵ_a is the dielectric constant of the medium in which the waves are propagating, and ϵ_b is the dielectric constant of the second medium, forming the boundary with medium *a*. The dielectric constant of air, surrounding the sides of each rod in the embodiment of FIGURE 1, is 1, so that expression (1) reduces to

$$\theta_{crk} = \sin^{-1}\frac{1}{\sqrt{\epsilon_k}} \quad (2)$$

where ϵ_k is the dielectric constant of the *k*th element of the *n*-element co-linear array, $k \leq n$. If the angle between the peak and the half-power points in the radiation pattern constituting the combination pattern of the waveguide and the elements of the array up to and including the $(k-1)$th element is designated ϕ_{k-1}, then the previously stated relationship between dielectric constant, critical angle, and half angle of beam width (i.e., angle between peak and 3 db point of the beam), may be mathematically expressed as

$$\phi_{k-1} \cong \theta_{crk} = \sin^{-1}\frac{1}{\sqrt{\epsilon_k}} \quad (3)$$

Hence, for the first dielectric rod (i.e., **10**) this relationship is

$$\phi_0 \cong \theta_{cr1} = \sin^{-1}\frac{1}{\sqrt{\epsilon_1}}$$

where ϕ_0 is the half angle of beam width in the radiation pattern of the open ended waveguide. If the length L_1 of rod **10** is now selected so that the radiation from the end of that rod cancels that at the 3 db angle ϕ_0 of the pattern produced by waveguide **20**, the beam width of the combination pattern of the waveguide and the first rod is half that of the waveguide alone, i.e. $\phi_1 = \phi_{0/2}$.

Similar considerations are employed in the determination of the dielectric constant and the length of each succeeding rod, with the launcher radiation pattern in each case being the combination pattern of the waveguide and those elements (rods) through the one immediately preceding the rod under consideration. In other words, each rod and those elements driving it act as the launcher for the next rod in the series to obtain high launching efficiency and large effective area with attendant high gain and low sidelobes.

The process for determining dielectric constant and length may continue as long as is desired, utilizing expression (3) and

$$\phi_k = \frac{\phi_{k-1}}{2} \quad (4)$$

where ϕ_k is the 3 db angle (half angle of beam width) of the radiation from the *k*th rod as a result of the combined radiation pattern of that rod and the preceding section (where the preceding section includes the waveguide and all rods between the waveguide and the *k*th rod). It will be apparent that each additional rod produces a null in the total radiation pattern at the 3 db points of the preceding section, thus halving the beam width.

Referring now to FIGURE 2, there is shown a typical set of radiation patterns for the antenna of FIGURE 1, which was constructed in accordance with the preceding principles, with $\epsilon_1=4$, $L_1=1.5$ inches; $\epsilon_2=2.5$, $L_2=1.5$ inches; $\epsilon_3=1.7$, $L_3=3$ inches; and $\epsilon_4=1.4$, $L_4=7$ inches. Again, the number of dielectric elements or their parameters in this physical embodiment are not to be construed as placing any limitations upon the scope of the invention. In another physical embodiment, for example, the dielectric constants and lengths of the rods were $\epsilon_1=4$, $L_1=1.2$ inches; $\epsilon_2=2.5$, $L_2=1.4$ inches; $\epsilon_3=1.7$, $L_3=2.4$ inches; $\epsilon_4=1.4$, $L_4=8.8$ inches; $\epsilon_5=1.2$, $L_5=18$ inches; the launcher was an H band rectangular waveguide 1.125 inches by 0.5 inch (internal dimensions) and the operating frequency was 8.1 gigacycles (kilomegacycles).

In FIGURE 2, all patterns were taken in the H-plane, at an operating frequency of 10 gc. Pattern **40** is that of the waveguide, pattern **42** that emanating from the waveguide and the first two rods (combined), pattern **44** the combined pattern for the waveguide and the first three rods, and pattern **46** for the full four-stepped dielectric constant antenna.

While I have disclosed a specific embodiment of my invention it will be apparent that variations in the particular details of construction which have been shown and described may be resorted to without departing from the true spirit and scope of the invention, as defined in the appended claims.

I claim:

1. An end fire antenna comprising feed means having an aperture for radiating electromagnetic waves; and a plurality of dielectric rods cascaded in end to end abutment and wave translating relationship with respect to said feed means along the principal axis of radiation thereof, for successively reducing the angle of beam width in the total radiation pattern of the preceding section of the antenna; said preceding section including said feed means and each of the dielectric rods producing the combined radiation pattern whose beam width is to be reduced, said dielectric rods having distinct and progressively different dielectric constants and lengths along said axis respectively preselected to produce a null at a predetermined point in the total radiation pattern of the preceding section.

2. The antenna according to claim **1** wherein each of said dielectric rods has a dielectric constant selected to provide a critical angle, for total internal reflection of electromagnetic waves propagating therethrough, approximately equal to the angle between the peak power point and said preselected power point less than the peak at which said null is to be produced in the radiation pattern of said preceding section; each of said dielectric rods having a length, along said principal axis, selected to produce a cancellation of the radiation from the preceding section at said preselected power point by the radiation from the wave-launching end of that rod.

3. The combination according to claim **2** wherein said aperture means comprises an open-ended waveguide, said dielectric rods being mounted in a co-linear array extending along the axis of said waveguide from the open end thereof.

4. The combination according to claim **2** wherein said aperture means comprises a waveguide for launching electromagnetic waves through the cascaded dielectric rods, so that each rod and the preceding elements driving it act as the wave launcher for the next rod in the cascade.

5. An end fire antenna comprising an electromagnetic wave launcher including feed means from which electromagnetic waves may be radiated, said launcher having a

principal axis of radiation; and a plurality of dielectric members cascaded in axial alignment relative to the axis of said launcher and positioned to receive and to translate waves radiating from said feed means, said members having distinct and different dielectric constants greater than one and distinct and different lengths, said dielectric constants progressively decreasing with successive positions of said members in the direction of radiation of said waves along said principal axis, and said lengths progressively increasing with successive positions of said members in said direction, each of said members having a dielectric constant to provide a critical angle for total internal reflection of components of said waves incident on the longitudinal boundaries thereof at least approximately equal to the angle between the peak power point and a power point of lesser magnitude than the peak, at which last-named power point a null is to be produced in the radiation pattern of said launcher and the preceding dielectric members relative to said direction, and each of said members having a length of dielectric material of such magnitude as to create a null at said lesser magnitude power point of said radiation pattern by cancellation of radiation at that point from said launcher and said preceding members by radiation produced upon translation via the member under consideration.

6. The invention according to claim 5 wherein said electromagnetic wave launcher comprises an open-ended wave guide and wherein said dielectric members have ends successively abutting one another to form a stepped dielectric rod of substantially uniform cross section.

7. The invention according to claim 6 wherein said dielectric constants and lengths of said dielectric members are preselected such that said lesser magnitude power point is the half power point of said radiation pattern.

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U.S. Cl. X.R.

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