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J. W. CLARK ET AL

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DIELECTRICALLY WEDGED BICONICAL ANTENNA

Filed March 12, 1948

2 SHEETS—SHEET 1

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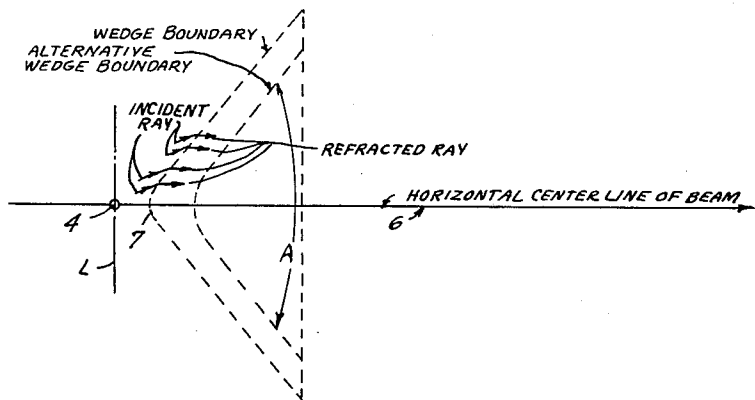


Fig. 5.

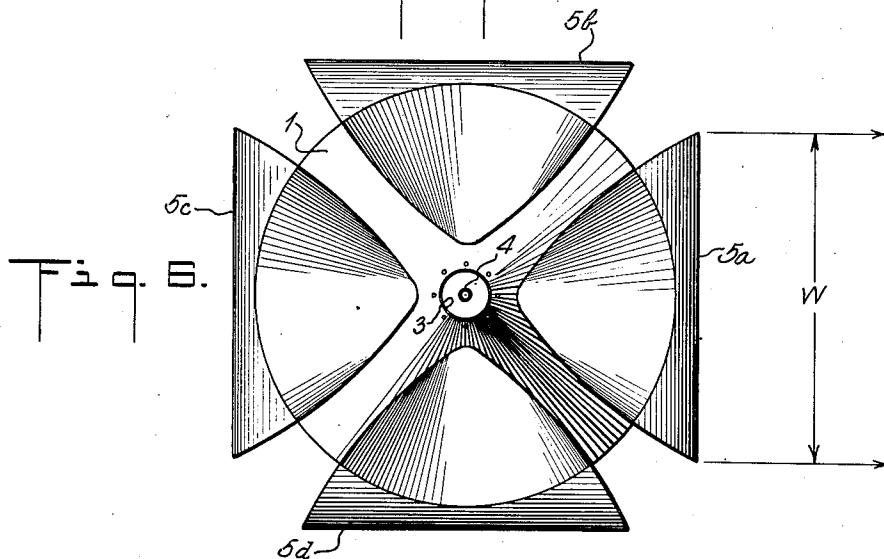


Fig. 6.

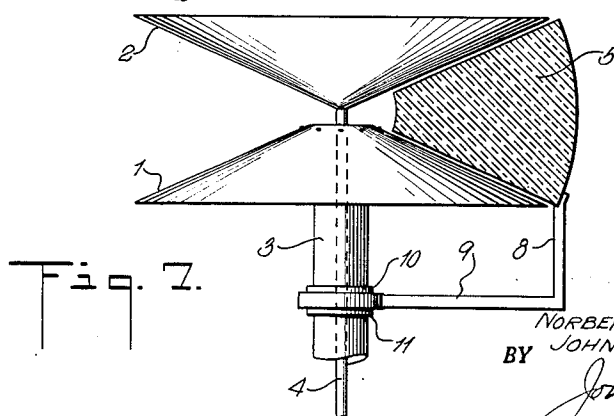


Fig. 7.

INVENTOR.
NORBERT J. GAMARA
BY JOHN W. CLARK
John J. Hogan
ATTORNEY

June 10, 1952

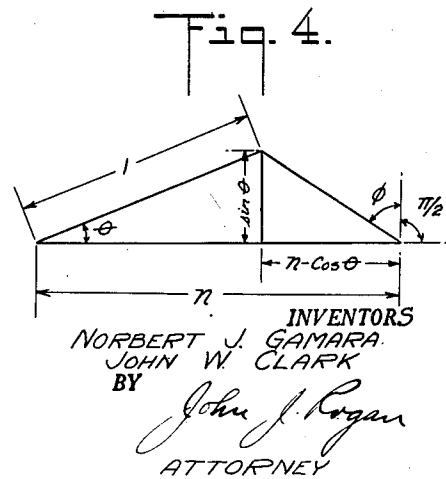
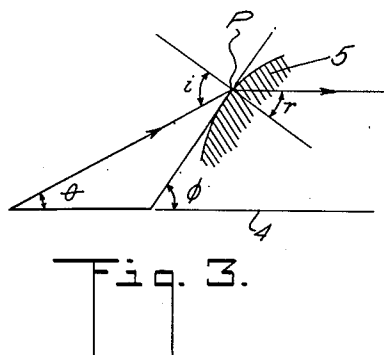
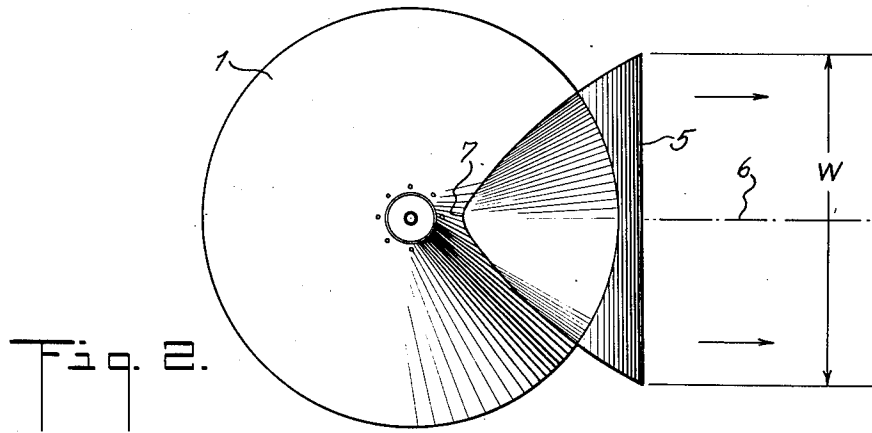
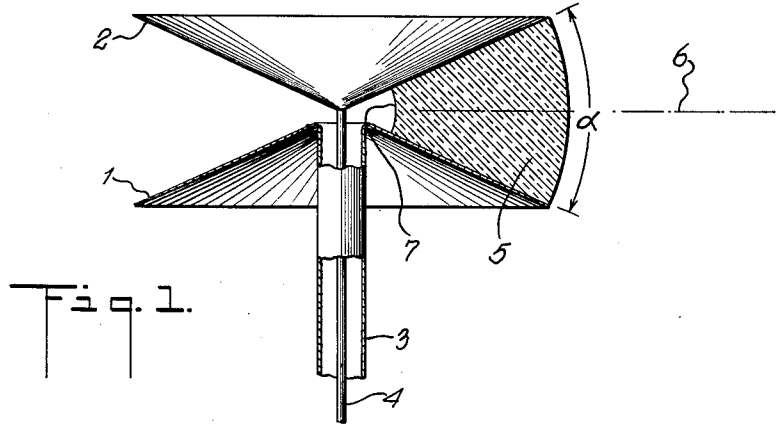
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2 SHEETS—SHEET 2



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DIELECTRICALLY WEDGED BICONICAL ANTENNA

John W. Clark, Cedar Rapids, Iowa, and Norbert J. Gamara, Minneapolis, Minn., assignors to Collins Radio Company, Cedar Rapids, Iowa, a corporation of Iowa

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9 Claims. (Cl. 250—33.63)

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This invention relates to antenna structures, and more particularly to directionalized antennas capable of radiating wide frequency bands.

A principal object of the invention is to provide an improved antenna of the generic biconical radiator type.

Another object is to provide a biconical antenna having means to direct the emergent radiation into a well-defined beam or beams.

A further object is to provide a biconical antenna having a specially designed dielectric wedge for controlling the directivity of the radiation.

A further object is to provide a biconical antenna having a plural lobe radiation pattern controlled by a corresponding plurality of dielectric wedges located between the conical sections of the antenna.

A further object is to provide a biconical antenna with a rotatable dielectric wedge for producing a highly-directionalized and rotatable radiation beam.

A feature of the invention relates to the novel organization, arrangement and relative location and proportioning of parts which cooperate to provide an improved beamed antenna of the biconical type.

Other features and advantages not particularly enumerated, will be apparent after a consideration of the following detailed descriptions and the appended claims.

In the drawings,

Fig. 1 is a vertical elevation, partly sectional, of an antenna according to the invention.

Fig. 2 is a bottom view of Fig. 1.

Figs. 3 and 4 are graphical diagrams explanatory of the antenna of Figs. 1 and 2.

Fig. 5 is a graph showing two typical wedge contours according to the invention.

Fig. 6 is a bottom view of a modification of Figs. 1 and 2.

Fig. 7 is another modification of Figs. 1 and 2.

Referring to Figs. 1 and 2, there is shown a typical biconical antenna comprising the conically-shaped antenna members 1, 2, which are supported in coaxial but vertically-spaced relation by any suitable means. Preferably the lower member 1 is supported by attachment to the outer pipe 3 of a coaxial transmission line; and the upper member 2 is supported by attachment to the rigid central conductor 4 of the same line. In accordance with the well-known theory of such antennas, the two conical members are arranged with their apices facing each other but separated vertically from each other so as to define, in effect, what may be termed an annular

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conical horn. The neck of this horn is at the common center of the two members 1, 2, and the cylindrical mouth is defined by the peripheral extremities of the said two members. When two such conical members are mounted with their central axis vertical, and are excited by high frequency electro-magnetic waves of the appropriate mode, the radiation pattern is confined to a relatively small vertical angle determined by the combined pitch of the two conical members. If desired, a special wave mode filter can be provided between the coaxial line and the conical members to confine the excitation of the antenna to the $TE_{0,1}$ mode, as described in detail in application Serial No. 781,428, filed October 22, 1947, now abandoned.

In some applications of the biconical antenna, it is desirable to radiate the beam with a well-defined width in the horizontal plane, and also with a well-defined width in the vertical plane. We have found that these results can be obtained by using a specially-shaped dielectric wedge 5 between the members 1 and 2. This wedge may be of any suitable low-loss dielectric material customarily used in ultra-high-frequency radio apparatus, and of which Polystyrene is typical because of its desirable refractive index for ultra-high frequency waves. This wedge is so shaped that it contacts the two members 1 and 2 as shown in Figs. 1 and 2. The wedge is also shaped so that for any angle θ (Fig. 3) between the center line 6 and the direction of any ray incident upon the surface of wedge 5, the emergent rays represented by the arrows (Fig. 2) are parallel to the beam axis. The horizontal width W of this beam is determined by the distance from the tip of the wedge 5 to the central vertical axis and by the diameter of the cones 1 and 2.

Referring to Fig. 3, it can be shown that if the dielectric of the wedge 5 has a refractive index of "n", then,

$$\sin i = n \sin \gamma \quad (1)$$

where i is the angle of incidence and γ is the angle of refraction. From the geometry of Fig. 3, it appears that

$$\phi + \gamma = \pi/2 \quad (2)$$

$$\theta + \pi/2 - i = \phi \quad (3)$$

where ϕ is the slope of the dielectric surface at the point P of the ray under consideration. The combination of Equations 1, 2 and 3 provides the requisite differential equation for the surface of wedge 5.

$$n \sin (\pi/2 - \phi) = \sin (\theta + \pi/2 - \phi) \quad (4)$$

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This equation is derived by the following mathematical process:

Substitute γ for $(\pi/2 - \phi)$ to obtain:

$$n \sin \gamma = \sin (\theta + \gamma)$$

Expand the right side by the sum of two angles formula to obtain:

$$n \sin \gamma = \sin \theta \cos \gamma + \cos \theta \sin \gamma$$

Divide both sides of equation by $\cos \gamma$ to obtain:

$$n \tan \gamma = \sin \theta + \cos \theta \tan \gamma$$

Solve for $\tan \gamma$ to obtain:

$$\tan \gamma = \frac{\sin \theta}{n - \cos \theta}$$

and since

$$\gamma = \pi/2 - \phi$$

there is obtained:

$$\tan(\pi/2 - \phi) = \frac{\sin \theta}{n - \cos \theta} \quad (5)$$

This is the differential equation of the curve, as

$$\tan(\pi/2 - \phi) = \cot \phi = dx/dy$$

It is not necessary to solve this equation analytically, as a simple graphical method can be used. The graphical solution is shown in Fig. 4. Thus one can lay out segments of length "n" and unity respectively, as shown, with the angle θ between them. Inspection of the figure will show that the angle ϕ satisfies the above equation. The construction just described can readily be carried out on a drawing board, so the curve can be built up by successive approximations. It will be seen that when $\theta=0$, $\phi=\pi/2$ and the curve must cross the beam axis at right angles.

Fig. 5 shows two typical wedge boundary curves arrived at by the above method, assuming $n=1.58$ which is appropriate for such materials as polystyrene. An infinite family of such curves exists, depending upon the distance between the vertical center line 4 of the antenna and the apex or tip 7 of the wedge considered along the horizontal center line 6 of the beam, the exact shape depending upon the value of refractive index assumed. Thus considering the outline of the wedge shown in Fig. 5 as the boundary of a horizontal plan section of the wedge, the complete wedge is symmetrical on opposite sides of the horizontal center line 6 of the beam. The complete wedge is defined by rotating this section around the line L as an axis, this line being perpendicular to the vertical center line 4 of the antenna and to the horizontal center line 6 of the beam, and passing through the intersection of the said lines 4 and 6. Thus the external surface of the wedge is a section of a cylinder centered on the line L, and the internal surface is also a section of the cylinder centered on this same line. Its external surface is a section of a cylinder centered on the line which is normal to the beam axis.

An antenna as described above, is a very broad band device as its action depends only upon the index of refraction of the dielectric material which is a very slowly varying function of frequency at any part of the spectrum where such a device might be used. The horizontal beam width of the device will depend only upon diffraction from the surface of the dielectric from which the radiation emerges, and this can in principle be made as large as necessary.

Since a dielectric wedge of the above-described

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type cannot be made much bigger than 90 degrees for the included angle, "A" (see Fig. 5) it is possible, by using two or more such wedges, to produce two or more beamed lobes of radiation.

Such an arrangement is illustrated in Fig. 6, wherein the corresponding parts of Figs. 1 and 2 are designated alike but with the lower antenna cone removed for clarity. In this embodiment, the biconical antenna is provided with a set of four dielectric wedges 5a, 5b, 5c, 5d, which are shaped in accordance with the above formulae so that each of the emergent beams has substantially the same width W in a horizontal plane, thus providing the antenna with four highly-directionalized radiation lobes.

Fig. 7 shows another modification of the invention, wherein the wedge 5 is rotatable around the vertical axis of the antenna, thus providing means for rotating the directionalized and width-controlled beam. For this purpose the wedge 5 can be attached to a suitable bracket 8 carried by an arm 9 which is rotatable around the coaxial line conductor 3. The arm 9 can be held in place on conductor 3 while permitting its rotation around the vertical axis of the antenna by suitable sleeves 10, 11, affixed to conductor 3.

In the foregoing embodiments, the vertical directivity depends only upon the angle α (Fig. 1) and the diameter of the cones, while the horizontal directivity depends upon the distance from the apex 7 of the wedge 5 to the center line of the cones 1, 2, and upon the diameter of the cones. It is thus possible to adjust independently the beam width considered in two mutually perpendicular directions.

While certain particular embodiments have been described herein, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An electric wave antenna of the type described, comprising a pair of similar conical shaped and coaxial spaced conductive members defining between their opposed faces an outwardly diverging annular horn opening extending around a central axis, and a dielectric wedge located between said opposed faces said wedge being tapered in cross-section both in a plane perpendicular to said axis and in a plane parallel to said axis and with the tip of the wedge facing said axis to refract the rays to produce a highly-directionalized substantially parallel ray beam.

2. An electric wave antenna of the type described, comprising a pair of similar conical shaped and coaxial spaced conductive members defining between their opposed faces an outwardly diverging annular horn opening extending around a central axis, and a dielectric located between said opposed faces said wedge being tapered in cross-section both in a plane perpendicular to said axis and in a plane parallel to said axis and with the tip of the wedge facing said axis to render the emergent rays parallel to the center line between said members.

3. An electric wave antenna of the type described, comprising a pair of conical radiator elements mounted in alignment around a common central axis and with the apices facing each other to define an outwardly diverging annular horn opening, and a dielectric wedge nested between said elements, said wedge being tapered in cross-section both in a plane perpendicular to said axis and in a plane parallel to said axis, the tip of the wedge facing said central axis and with the face

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of the wedge opposite to said tip being cylindrical-ly curved to render the emergent rays parallel to the center line between said radiators.

4. An antenna comprising a pair of conical radiator elements mounted in alignment around a common central axis and with their apices facing each other to define an outwardly diverging annular horn opening, and a doubly tapered dielectric wedge nested between said elements, said wedge having lateral walls tapered towards each other and towards said central axis, the outer wall of said wedge opposite to the tip of the wedge being curved along a line which is perpendicular to said central axis for causing rays having different angles of incidence on said side walls to emerge from said outer wall of the wedge in parallel rays.

5. An antenna comprising a pair of coaxially aligned superposed conical radiators forming an outwardly diverging annular horn around the central axis of the antenna, and a dielectric wedge fitted between said radiators having in a plane perpendicular to said central axis a cross-sectional shape which is tapered towards said central axis and also having in a plane parallel to said central axis a cross-sectional shape which is tapered towards said central axis, both said tapers being of predetermined dimensions for causing horizontal rays incident thereon to be refracted to a substantially parallel ray beam emerging from said wedge.

6. An antenna according to claim 1 having a plurality of discrete circumferentially spaced wedges as set forth in claim 1.

7. An antenna according to claim 1 in which the tip of said wedge is spaced from said central

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axis to control the width of the emergent beam in a plane perpendicular to said central axis while maintaining the emergent rays of the beam parallel.

8. An antenna according to claim 4 in which the said lateral walls of the wedge have a surface curvature defined by the formula

$$(\pi/2 - \phi) = \frac{\sin \theta}{n - \cos \theta}$$

wherein ϕ is the slope of the surface of the wedge at the point of incidence of any ray from said central radiator, θ is the angle of refraction of the ray through said wedge, and n is the refractive index of the dielectric of the wedge.

9. An antenna according to claim 1 in which said wedge is mounted for rotation around the central vertical axis of the antenna.

JOHN W. CLARK.

NORBERT J. GAMARA.

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