

Oct. 16, 1956

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2,767,396

DIRECTIVE ANTENNA SYSTEMS

Filed April 30, 1946

2 Sheets-Sheet 1

FIG. 1

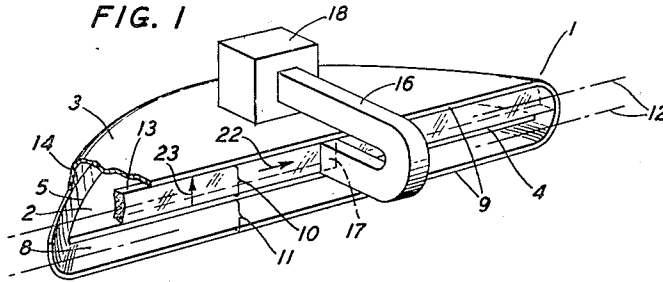


FIG. 2

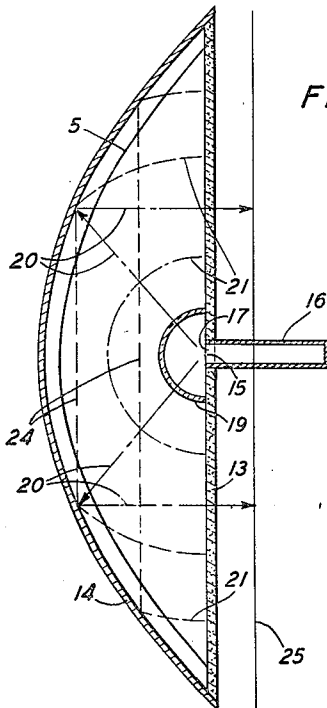


FIG. 4

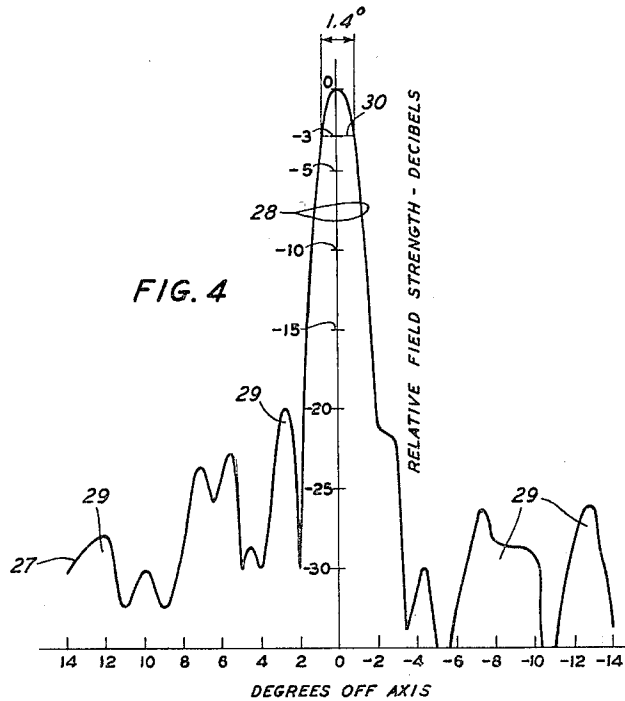
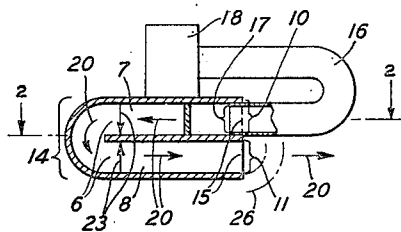


FIG. 3



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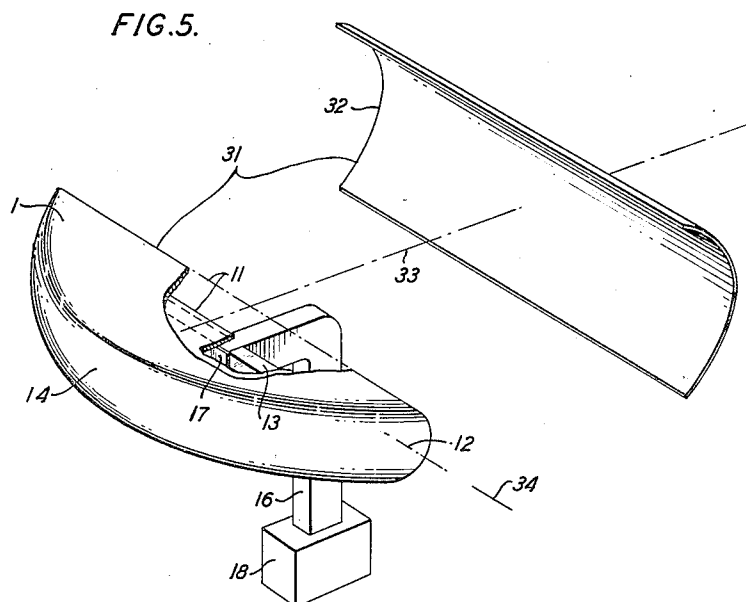
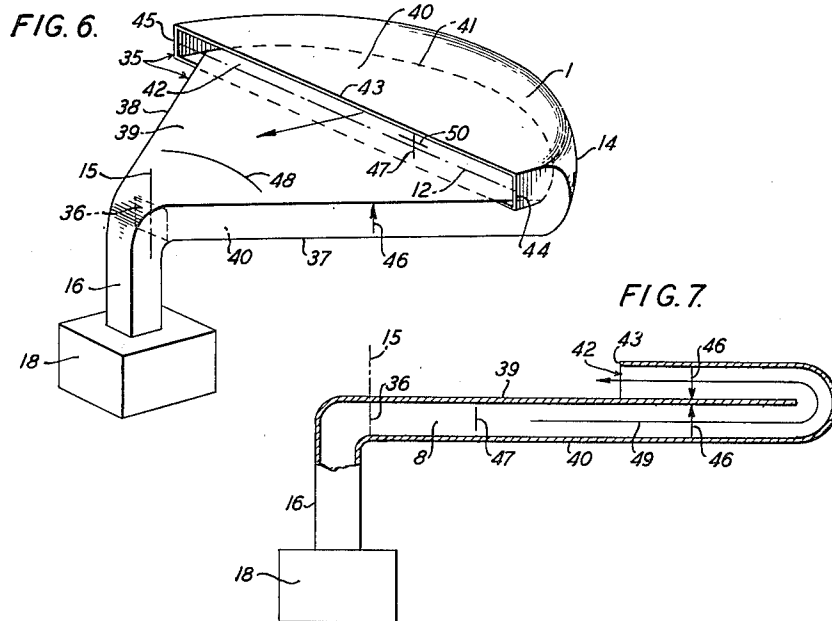
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2 Sheets-Sheet 2



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DIRECTIVE ANTENNA SYSTEMS

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Application April 30, 1946, Serial No. 665,955

11 Claims. (Cl. 343—780)

This invention relates to directive antenna systems and particularly to so-called line type primary antennas employed with secondary antenna members.

As is known, so-called pill-box or parallel-plate antennas of the type disclosed in the copending application of W. D. Lewis, Serial No. 574,334, filed January 24, 1945, now Patent No. 2,705,754, issued Apr. 5, 1945, and conventional open-ended sectoral horn antennas have been suggested for energizing cylindrical parabolic reflectors having a relatively long focal line. The pill-box comprises a cylindrical parabolic reflector having a short focal line and included between a pair of closely spaced parallel plates. A small horn, such as the open end of a dielectric guide, is positioned in front of the short pill-box reflector. The sectoral horn has an elongated rectangular mouth aperture, similar to that in the pill-box, and is flared in one place or dimension.

As used herein the terms "primary antenna" or "active antenna" and "secondary antenna" or "passive antenna" have their conventional meanings. The term "primary" or "active" as used with the term "antenna," signifies that the antenna member is directly or conductively connected to a source of energy such as a transmitter, or to a utilization device such as a receiver; and the term "secondary" or "passive," as used with the term "antenna," denotes an antenna member which is positioned adjacent to and spaced from the primary antenna, is not directly connected to the transmitter or receiver and receives energy from, or delivers energy to, the primary antenna member.

While the above-mentioned primary antennas have been used with success, the results obtained have not always been satisfactory. Thus, in transmission, in the pill-box antenna, a portion of the energy emitted by the horn is undesirably reflected back into the horn whereby, as explained in the copending application of W. E. Kock, Serial No. 589,899, filed April 23, 1945, now Patent No. 2,607,010, issued Aug. 12, 1952, mismatch effects are obtained and the resulting band width is relatively narrow. Also, in the pill-box, the feed horn is in front, and at the focus, of the parabolic reflector and is therefore positioned on the path of maximum action. Since the horn is metallic it deflects or reflects waves impinging thereon and tends to cause splitting of the major lobe and establishment of pronounced minor lobes. Hence, while the horn is essential in the system, it nevertheless constitutes an obstacle to the incoming and outgoing waves and, in a sense, shadows the vertex portion of the reflector. Considered differently, by reason of the "shadow effect" of the horn, the cylindrical wave front established by the pill-box is distorted to some degree. Again, a portion of the energy or rays emitted by the pill-box horn may avoid the pill-box reflector, and this spill-over effect is highly undesirable because of the energy waste involved. Considering the sectoral horn, this type of antenna is inherently bifocal, as explained in my copending application, Serial No. 665,027, filed April 26, 1946, now Patent No. 2,548,655, issued Apr. 10, 1951, and

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therefore does not function to establish a cylindrical wave front, as is required for optimum energization of a passive antenna member having a line focus, such as a cylindrical parabolic reflector or cylindrically symmetrical lens. Accordingly, it now appears desirable to obtain a line-type primary antenna which is devoid of the defects mentioned above and, in addition, possesses distinct advantages not found in the line-type antennas of the prior art.

It is one object of this invention to secure, in radio transmission, an undistorted cylindrical wave front.

It is another object of this invention to secure, in a line-type antenna, a wide band width characteristic.

It is another object of this invention to avoid, in a line antenna of the parallel-plate type, mismatch, spill-over and shadow effects.

It is another object of this invention to obtain a sectoral horn antenna having a single focal plane.

It is still another object of this invention, in a line-type parallel-plate antenna having an elongated aperture and including an emitting element, to obtain in the aperture a flat wave front without refracting, and without reflecting toward the element, an appreciable portion of the propagated waves.

In accordance with one embodiment of the invention, one plate of a parallel-plate antenna has a linear edge and a parabolic edge. The other plate is circularly bent about the parabolic edge and forms with the linear edge two channel ends, one of which is open and constitutes a line-type antenna aperture and the other of which is closed by a conductive wall. The bent portion of the outer plate constitutes a circularly-concave parabolic deflector having a short focal line at the closed channel end. A small horn is positioned at the aforesaid focal line. The deflector functions to guide the waves from one side of the encircled inner plate to the other side, and to convert the cylindrical wave front established by the small horn to a flat wave front in the antenna aperture. Since the horn is not in the antenna aperture shadow effects are eliminated, and since little, if any, energy is reflected by the deflector into the horn, mismatch effects are minimized. Also, the end conductive wall prevents wasteful spill-over.

In another embodiment a sectoral horn or, more accurately, the dielectric path inside a sectoral horn, is bent or folded circularly and 180 degrees in the plane of the narrow unflared horn walls, and parabolically in the plane of the wide flared walls, whereby the horn is rendered unifocal and a flat wave is obtained in the horn mouth aperture.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawing on which like reference characters denote elements of similar function and on which:

Figs. 1, 2 and 3 are respectively perspective, sectional plan and sectional side views of one embodiment of the invention;

Fig. 4 is a measured directive pattern of the embodiment of Figs. 1, 2 and 3;

Fig. 5 is a perspective view of a system comprising the embodiment of Figs. 1, 2 and 3; and

Figs. 6 and 7 are, respectively, perspective and side sectional views of a sectoral horn constructed in accordance with the invention.

Referring to Figs 1, 2 and 3, reference numeral 1 denotes a line-type quasi-toroidal antenna comprising an inner metallic plate 2, an outer metallic plate 3 and the air dielectric medium or path included therebetween. The small plate 2 has a front linear edge 4 and a back parabolic edge 5; and the large outer plate 3, which is wider and longer than the inner plate 2, encircles the parabolic edge 5 of the inner plate 2, so as to form a

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parallel-plate dielectric channel 6, Fig. 3, having two contiguous superimposed sections or portions 7 and 8. The outer plate 3 has a single prolate circular edge 9 which encompasses the linear edge 4 of plate 2 and forms therewith two substantially rectangular channel ends 10, 11 having parallel coplanar longitudinal axes 12. The channel end 11 is open and constitutes a line antenna aperture and the channel end 10 is closed by means of a conductive wall 13 which is preferably, but not necessarily, formed of absorbing material. For example, wall 13 may be a metallic plate coated with dissipative material. The circularly-concave parabolic bend 14 in the outer plate 3 constitutes a deflector having a focal line 15 extending substantially in the plane of the channel ends 10, 11 and perpendicular to the inner plate 2. More particularly, the contour of the outer plate 3, and of the air dielectric path bounded thereby, is parabolic, as viewed in a plane parallel to inner plate 2, and circular in all planes extending perpendicular to inner plate 2 and containing the focal line 15. Numeral 16 denotes a metallic dielectric guide projecting through the end wall 13 and having a transmitting or receiving horn mouth aperture 17 aligned in dielectric channel section 7 with the focal line 15. The guide 16 is connected to a translation device 18 which may be a transmitter or receiver. Numeral 19 denotes a cylindrical pressurizing dielectric window positioned in front of, and protecting, the antenna element or aperture 17.

In operation, assuming device 18 is a transmitter, waves are supplied over guide 16, and a cylindrical wave front is emitted by the horn aperture 17 and propagated in the channel section 7. On the drawing the wave directions are denoted by the arrows 20. In channel section 7, the wave front is circular, as shown by lines 21, in a plane parallel to plate 2 and linear (not shown) in a plane perpendicular thereto. As illustrated by arrow 22 the electric polarization of the wave may be parallel to the plates 2, 3, in which case the plate spacing must be greater than a half wavelength, or, as illustrated by arrows 23, it may be perpendicular to the plates, in which case the plate spacing is preferably less than a wavelength. The cylindrical wave propagated in channel section 7 is guided or deflected by deflector 14 into channel section 8 and simultaneously the circular front 21 is converted into a linear front, represented by lines 24, whereby, in the line aperture 11, a flat wave front is established. After emerging from the line aperture 11 the front becomes cylindrical as shown by lines 25, 26 and is therefore suitable for energizing a large line-type parabolic reflector or lens.

Inasmuch as the horn aperture 17 and associated feed 16 are not in the line antenna aperture 11 or in the path of the emergent waves, the horn and guide do not distort the cylindrical front 25, 26; that is, no shadow effect is produced and, as discussed below, a highly satisfactory directive pattern in the plane of axis 12 of line aperture 11 is obtained. Also, since the deflector 14 reflects little, if any, energy back into the horn aperture 17, mismatch effects are minimized and the antenna 1 has a relatively wide band width. Any spurious reflection by deflector 14 toward the channel end 10 is absorbed by the member 13, and the member 13 prevents undesired spill-overs of energy emanating from the horn aperture 17. In addition, the parabolic deflector 14 does not ordinarily produce undesired modes or undesired cross-polarized waves.

Numeral 27, Fig. 4, denotes the directive pattern of antenna 1, Fig. 1 taken in the plane containing the circular front 21, Fig. 2, and measured at a design wavelength of 3.2 centimeters. The pattern 27 includes the major lobe 28 and the minor lobes 29. The half power width 30, taken at the -3 decibel point, is about 1.4 degrees and hence the circularly-concave parabolic deflector 14 functions to produce a high degree of direc-

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tivity or, in other words, a substantially linear front 25, 26 in line aperture 11. The minor lobes 29 are about 20 decibels down and therefore negligible. The gain of antenna 1 is considerably higher than comparable line feed antennas. The beam produced by antenna 1 is of the fan type, that is, it is fairly wide in the plane perpendicular to plate 2 and, as discussed above, narrow in a plane parallel to plate 2. In reception, the converse operation is obtained by virtue of the reciprocity theorem.

Fig. 5 illustrates an antenna system 31 comprising a cylindrical parabolic reflector 32 having an axis 33 and a relative long focal line 34, and numeral 1 denotes a parabolic-bend line-type primary antenna, such as that illustrated by Fig. 1. The focal line 34 of the main reflector 32 is aligned with the axis 12 of the line aperture antenna 11. In operation, the line antenna 1, or more accurately, the deflector 14, produces unidirectional action in the plane containing the axis 33 and focal line 34, whereas the main reflector 32 produces unidirectional action in a plane perpendicular to the aforesaid plane, whereby a point-type beam is secured. In other words, antenna 1 and main reflector 32 have perpendicularly related fan-beams and, in a sense, these two fan-beams combine to produce a point-beam. Considered differently, and assuming focal line 34 is horizontal, the horn aperture 17 produces a cylindrical wave front centered on a short vertical axis; antenna 1 converts this front to a cylindrical wave centered on a long horizontal axis, and the large reflector converts this last-mentioned cylindrical wave front to a flat wave front extending perpendicular to axis 33. As before, in reception, the converse operation is obtained.

Referring to Figs. 6 and 7, reference numeral 35 denotes a sectoral horn having a throat aperture 36 connected by guide 16 to a translation device 18 and comprising two narrow unflared metallic walls 37, 38 and two wide flared walls 39 and 40. The wide wall or plate 39 has a parabolic back edge 41 which is encircled by a 180-degree bend 14 in the longer wide wall 40, the curvature in wall 40 being parabolic, as viewed in a plane parallel to the wide wall 39, and circular as viewed in any plane perpendicular to wall 39 and containing the mid-point of the throat aperture 36. In other words, the longer wall 40, and the dielectric path 8 bounded thereby, each have a U shape. The circularly-concave parabolic bend 14 in wall 40 constitutes a deflector having a focal line 15. The focal line 15 extends in the plane, and passes through the mid-point, of the horn throat aperture 36. Numeral 42 denotes an elongated rectangular aperture having a longitudinal axis 12 and bounded by the long linear edge 43 of wall 40, the two short linear edges 44, 45 of narrow plates 37, 38 and the outer conductive surface of the wide wall 39.

In transmission, waves are supplied by device 18 through guide 16 to the throat aperture 36, a flat wave front being established in the throat aperture. As in the embodiment of Fig. 1, the electric polarization of the waves may be perpendicular to the wide walls, as shown by arrow 46, or parallel thereto. As the wave front propagates in the horn it becomes cylindrical since the horn is flared in one plane only. More specifically, the front is substantially linear in a plane perpendicular to the flared walls 39, 40, as shown by line 47, Fig. 7, and circular in a plane parallel to the aforesaid flared walls 39, 40, as shown by line 48, Fig. 6. As indicated by arrow 49, Fig. 7, the waves pass around the bend and deflector 14 converts the circular front 48 to a linear front, but does not affect the linearity of front 47. Hence, in the line aperture 42, the wave front is linear in each of the two above-mentioned planes, as shown by lines 47 and 50, that is, it is flat; and the wavelets in aperture 42 are cophasal. The flat front, 47 and 50, after emerging from aperture 42 becomes cylindrical, primarily by reason of the large dif-

ference in the transverse dimensions of aperture 42. In reception, the converse operation is obtained.

In the rectangular aperture 42, the front is linear in each plane, as discussed above, so that the phase center or focus for each propagation plane is in the plane of the aperture 42. In other words, the sectoral horn 35 has a single focal plane and therefore is, in a sense, unifocal; and this unifocal effect is obtained by virtue of the parabolic bend 14. By way of comparison, in the mouth aperture of the conventional open-ended sectoral horn comprising a pair of parallel flared sides and a pair of unflared angularly related sides, while the wave front is linear in a plane perpendicular to the parallel sides, it is circular in the plane parallel to the aforesaid parallel sides. Hence the phase centers or foci for the two propagation planes are spaced apart, one focus being in the plane of the mouth aperture and the other in the plane of the throat aperture; and the prior art horn is therefore bifocal. Consequently, the wave front on the mouth aperture is not, so to speak, properly conditioned to produce, at a distance from the mouth aperture, a wave front having the desired cylindricality.

Although the invention has been explained in connection with certain embodiments it is to be understood that it is not to be limited to the embodiments described inasmuch as other apparatus may be utilized in successfully practicing the invention. Thus, instead of an air dielectric medium, the dielectric path may be formed of solid dielectric material, and the solid dielectric path may or may not be enclosed by a metallic wall or walls.

What is claimed is:

1. A dielectric channel comprising a flat metallic wall, a second wall spaced therefrom and a dielectric path bounded by said walls, said second wall being curved about one edge of said flat wall, the curvature in said second wall being circular in a plane perpendicular, and parabolic in a plane parallel, to said flat wall.

2. A dielectric channel having different transverse dimensions, said channel having a semicircular contour in a plane containing the shorter transverse dimension and a parabolic contour in a plane containing the other transverse dimension.

3. A line-type antenna comprising a dielectric channel enclosing a dielectric path and having short and long transverse dimensions, said path having an elongated, closed end and an elongated open end, an antenna element at said closed end, said path having at an intermediate point a circular curvature in a plane containing said short transverse dimension and a parabolic curvature in a plane containing said long transverse dimension.

4. In combination, a metallic deflector having in a first plane a parabolic contour, a focal line perpendicular to said plane, and in each plane containing said line and intersecting said deflector a semicircular contour, and a flat metallic member positioned between the central portion of said deflector and the central portion of said focal line and extending perpendicular to said line.

5. In combination, a metallic deflector in accordance

with claim 4, said flat member having a parabolic edge uniformly spaced from said parabolic contour, and means for energizing said deflector or collecting energy therefrom, said means being aligned with said line and positioned only on one side of said shield member.

6. In combination, a guide comprising wide parallel metallic walls and a narrow metallic wall, said walls enclosing a dielectric path having a parabolic contour in a plane parallel to said wide walls and a semicircular contour in each plane perpendicular to said first-mentioned plane, means at the center of one end of said guide for emitting or receiving radio waves, means at said one end for absorbing radio waves and an antenna aperture at the other end of said guide.

7. A combination in accordance with claim 6, and an antenna member having a focal line aligned with the long dimension of said aperture.

8. A line-type primary antenna comprising a flat metallic plate having a linear edge and a parabolic edge, a U-shaped plate encircling said parabolic edge and forming therewith a dielectric channel, said U-shaped plate having a prolate circular edge encompassing said linear edge and forming therewith two superimposed substantially rectangular channel ends, one of said channel ends being open, a dissipative conductive member closing the other channel end, the bend in said U-shaped member constituting a deflector having a focal line extending parallel to the plane of said channel ends and perpendicular to said flat plate, and means for transmitting or receiving waves positioned in said dielectric channel adjacent said closed end and at said focal line.

9. In combination, a line-type primary antenna in accordance with claim 8 and a cylindrical parabolic reflector having a focal line aligned with the longitudinal axis of the open rectangular channel end.

10. A sectoral horn comprising a pair of unflared narrow walls having equal lengths and short linear edges, a pair of flared walls of different length, the shorter flared wall being flat and having a parabolic edge, the longer flared wall having a wide linear edge and including a deflecting bend encircling said parabolic edge, and said linear edges and a surface of the flared flat wall forming an elongated rectangular horn mouth aperture.

11. A sectoral horn in accordance with claim 10, said horn having a throat aperture, said deflecting bend having a focal line at said throat aperture, and a guide connecting said throat aperture to a translation device.

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