

Sept. 9, 1958

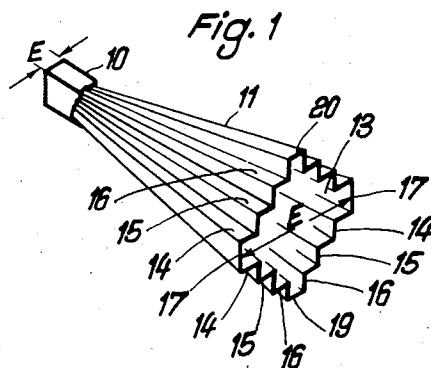
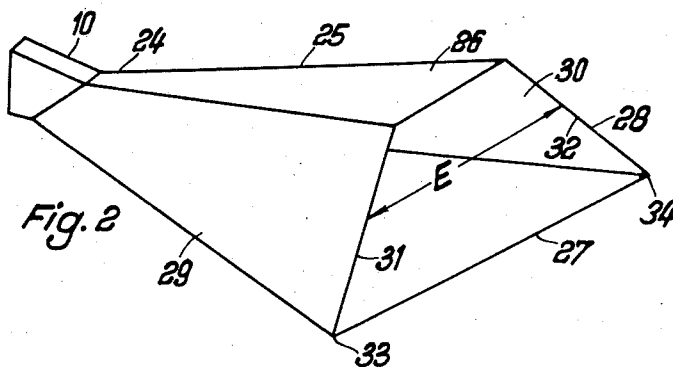
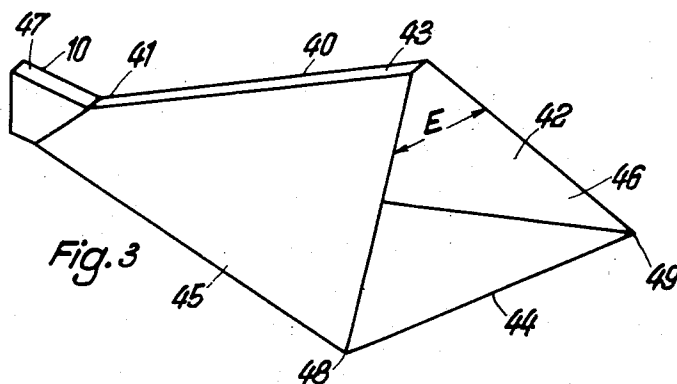
B. G. HAGAMAN

2,851,686

ELECTROMAGNETIC HORN ANTENNAS

Filed June 28, 1956

5 Sheets-Sheet 1



INVENTOR

Raynton G. Hagaman
BY *Moses, Nolte & Nolte*
ATTORNEYS

Sept. 9, 1958

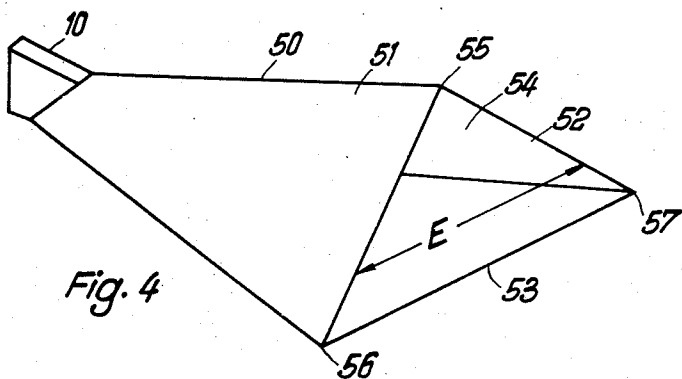
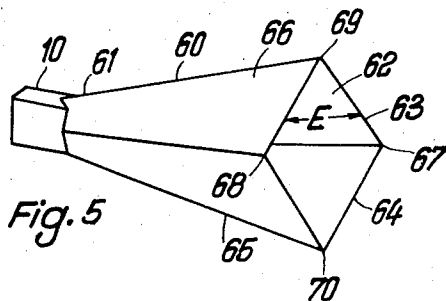
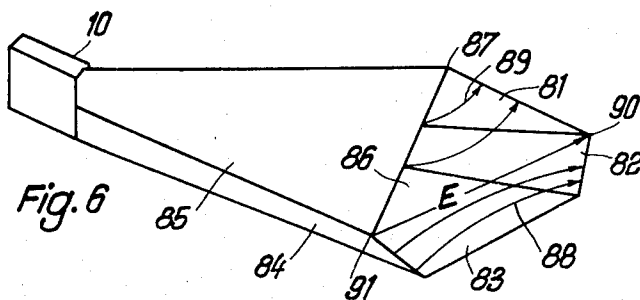
B. G. HAGAMAN

2,851,686

ELECTROMAGNETIC HORN ANTENNAS

Filed June 28, 1956

5 Sheets-Sheet 2



INVENTOR
Bogdan G. Hagaman
BY *Thos. Holte & Holte*
ATTORNEYS

Sept. 9, 1958

B. G. HAGAMAN

2,851,686

ELECTROMAGNETIC HORN ANTENNAS

Filed June 28, 1956

5 Sheets-Sheet 3

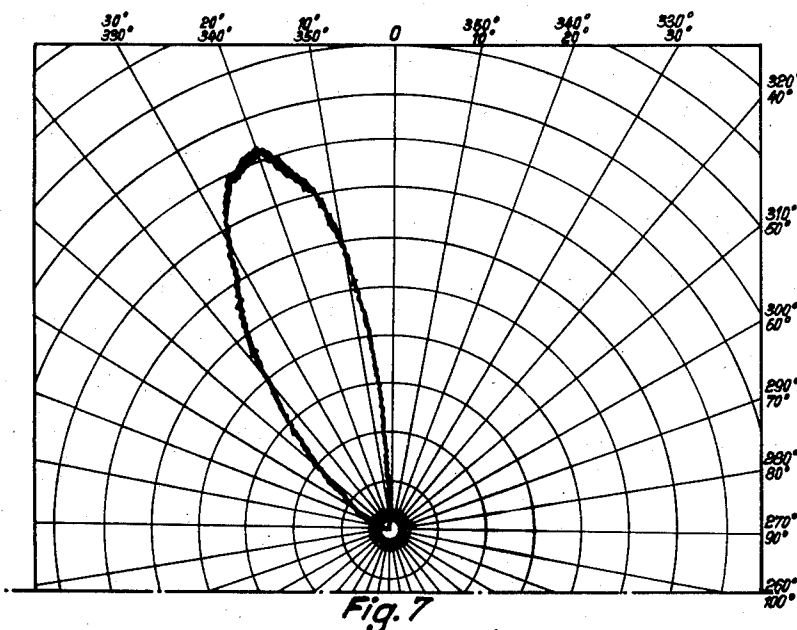


Fig. 7

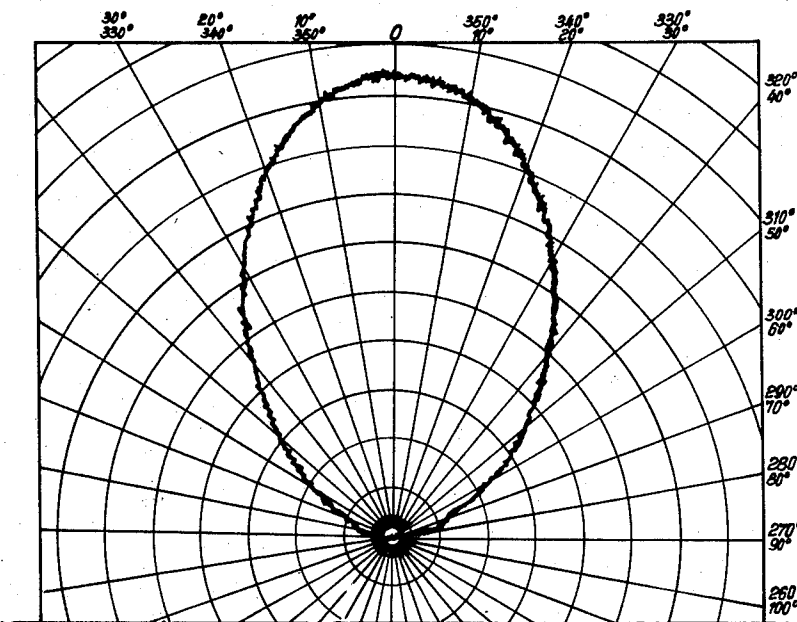


Fig. 8

INVENTOR

Boydton G. Hagaman

BY

Moses, Nolte & Nolte

ATTORNEYS

Sept. 9, 1958

B. G. HAGAMAN

2,851,686

ELECTROMAGNETIC HORN ANTENNAS

Filed June 28, 1956

5 Sheets-Sheet 4

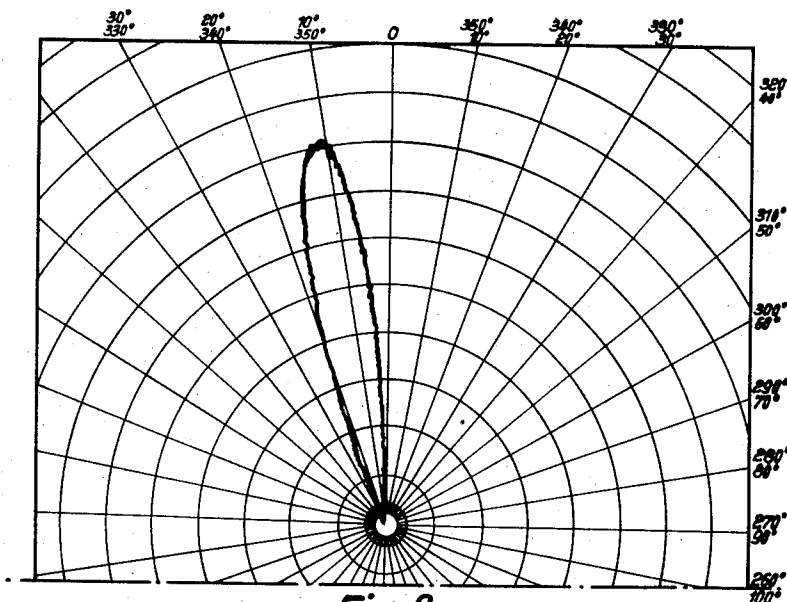


Fig. 9

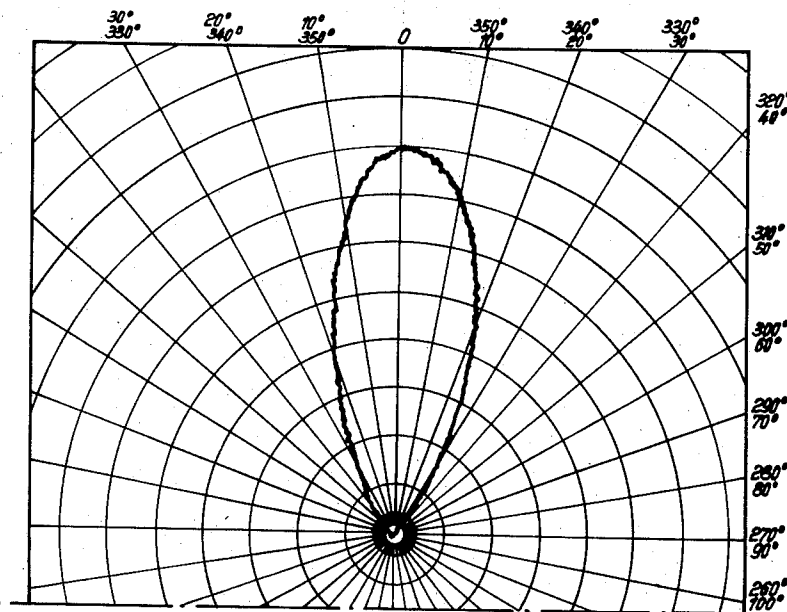


Fig. 10

INVENTOR
By *Raymond G. Hagaman*
Moses, Nolte & Nolte
ATTORNEYS

Sept. 9, 1958

B. G. HAGAMAN

2,851,686

ELECTROMAGNETIC HORN ANTENNAS

Filed June 28, 1956

5 Sheets-Sheet 5

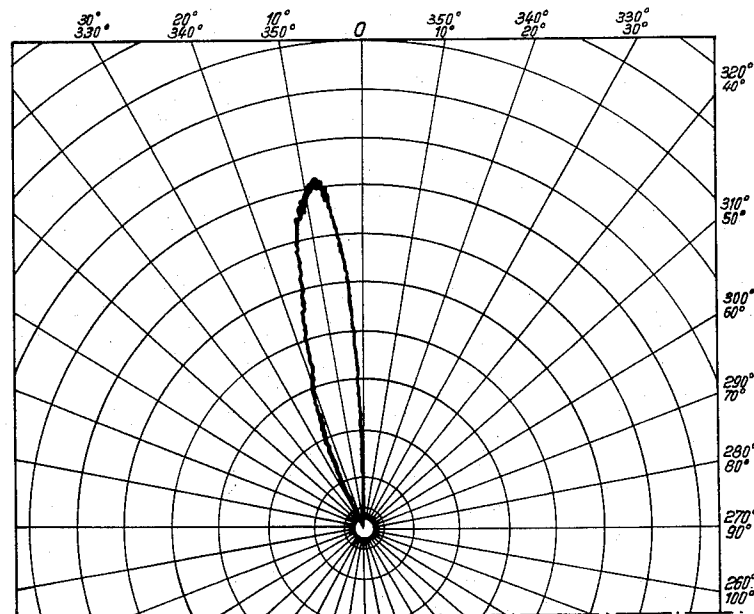


Fig. 11

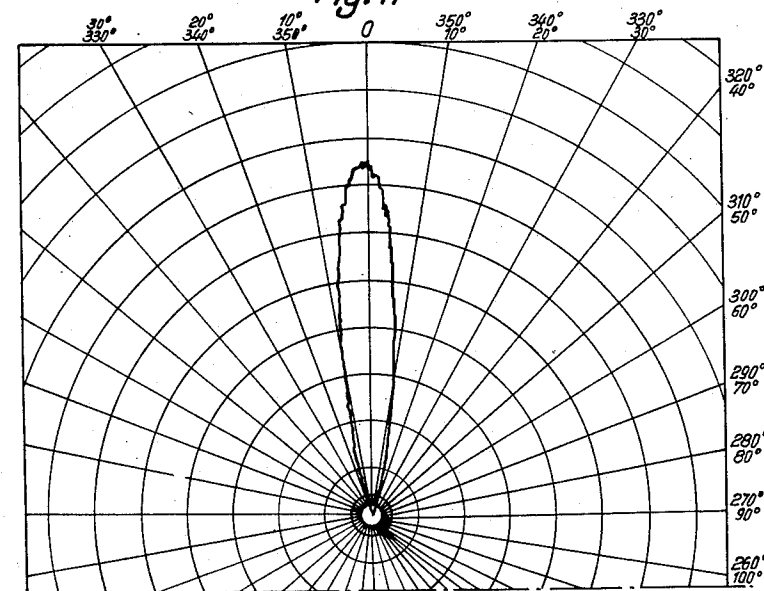


Fig. 12

INVENTOR

Bogdan G. Hagaman

BY

Moses, Nolte & Nolte

ATTORNEYS

1

2,851,686

ELECTROMAGNETIC HORN ANTENNAS

Boynton G. Hagaman, Alexandria, Va., assignor to Development Engineering Corporation, Washington, D. C., a corporation of Delaware

Application June 28, 1956, Serial No. 594,446

19 Claims. (Cl. 343-786)

The present invention relates to electromagnetic horn antennas.

Flared electromagnetic horns of various cross-sectional shapes have been used for radiating directional beams of very short waves. The horns may be rectangular in cross-section and flared in one direction, in which case they are called sectoral horns, or they may be flared in both directions, in which case they are referred to as pyramidal horns. The horn antenna is generally fed by a wave guide connected to the small end thereof, and the large end of the horn is open and forms the radiating aperture. The plane at right angles to the electric vector will hereinafter be designated the "H-plane" and the plane parallel to the electric vector will be designated the "E-plane." Horn antennas have generally desirable characteristics, but they also have some defects. One defect of the usual horn antenna is that in addition to the main radiated beam, there are also side or secondary lobes. Another undesirable characteristic of the usual horn antenna is that the radiation pattern may vary appreciably with frequency. Another difficulty with conventional horn antennas is that in order to obtain a sharp beam, the horn must have a rather small flare and a great length and mouth size. As a result of the last mentioned characteristic, horn antennas have been practical only for very short waves. For longer waves, the size and construction problems involved have hitherto prohibited horn antennas from being utilized.

It is an object of my invention to provide a horn antenna which reduces or virtually eliminates the side lobes of the radiation patterns.

Another object of my invention is to provide horn antennas which are practical over an extended frequency range.

A still further object of my invention is to reduce the length of a horn antenna.

A still further object of my invention is to increase the gain-to-aperture ratio of a horn antenna.

A still further object of my invention is to provide a horn antenna which is practicable in the high frequency range.

According to my invention, the above and other objects and advantages are obtained by mechanically shaping the radiating aperture to obtain the distribution necessary for the desired radiation pattern characteristics. The necessary aperture distribution for low side lobe level requires that the illumination taper gradually to a low value at the sides of the aperture.

My invention will be more fully understood from the following specification and the drawing, in which:

Fig. 1 shows one embodiment of my invention wherein the width of the horn in the direction of the electric vector varies in discrete steps;

Figs. 2 to 6 show additional embodiments of my invention;

Figs. 7 to 12 show radiation patterns of one embodiment of my invention.

2

Referring to Fig. 1, there is shown an antenna comprising an electromagnetic horn 11 connected at its small end to a rectangular wave guide 10. For the sake of simplicity of description, it will be assumed that the wave guide is operated in a primary mode such as the $TE_{0,1}$ mode and, thus supplies electromagnetic waves to the horn 11 which are polarized in the direction indicated by arrow E. It is well known, of course, that the electromagnetic waves may be supplied to horn 11 in other ways and that the wave guide 10 may be provided with a small radiator, or may extend to any suitable source of waves. The horn 11 has a stepped construction so that at the aperture 13, the height is not constant but decreases from a maximum value at 19-20 in discrete steps 16, 15, 14 to a minimum value at the end 17-17. The step construction of the wave guide may extend from aperture 13 all the way to the wave guide 10 or may extend only part of the distance back to the wave guide 10.

It is evident that the horn described above and shown in Fig. 1 will produce a greater intensity of radiation from the center portion, 19-20, and lesser intensity of radiation from the portion, 16-16, 15-15 and 14-14. The widths, depths and number of steps may be varied to obtain the effective aperture illumination desired and to thereby control the radiation pattern in the E-plane. Generally, it is preferred to dimension the steps so that the side lobes which usually occur in horn antenna radiation patterns are greatly reduced or virtually eliminated. It will be understood of course, that while only three steps, 14, 15 and 16 have been shown for the sake of convenience, that generally a greater number of steps may be provided, depending on the size of the aperture, the wavelengths and other parameters. It has been found that by suitably varying the shape of the aperture, the directivity of the horn can be increased, along with the virtual elimination of side lobes.

Fig. 2 shows rectangular wave guide 10 connected to the small end 24 of the horn 25. The horn has essentially four plane walls 26, 27, 28 and 29. At least the walls 26, 28 and 29 are flared outwardly from the end 24 to the aperture 30. The wave guide may be energized so that the waves are polarized in the direction E. The height of the aperture perpendicular to the E direction is tapered from a maximum value at the wall 26 to a minimum value at the corners 33-34. Thus, the radiation from the horn 25 will vary from a maximum at the center portion to a minimum at the ends of the aperture 33-34. By suitably adjusting the angles at which the sides 31 and 32 of aperture 30 are inclined toward each other, an optimum radiation pattern may be obtained having minimum side lobes.

Fig. 3 shows still another embodiment of my invention wherein a rectangular wave guide 10 is connected to the small end 41 of a horn antenna 40. The horn has an aperture 42 which is essentially triangular in shape. Here again, for the sake of simplicity, it is assumed that wave guide 10 is supplied with waves polarized only in the E direction. The horn 40 comprises two parallel walls 43 and 44 and two inclined walls 45 and 46. Wall 43 may have the same width throughout as does the narrow side 47 of wave guide 10. Here again it will be seen that the height of aperture 42 normal to the E vector varies from a maximum value near the wall 43 to a minimum value at the edges 48, 49 and the antenna is capable of giving a radiation pattern of high directivity with virtually no side lobes.

Fig. 4 shows still another embodiment of the invention in which the rectangular wave guide 10 is connected to a flared electromagnetic horn 50 in the shape of a triangular pyramid formed by walls 51, 52 and 53. Here

again it is assumed that the radiator is energized so that the electric vector extends in the E direction. It will be seen that the height of aperture 54 decreases from a maximum value at point 55 substantially to zero at the ends 56, 57 of the aperture. The radiation patterns of an antenna of the type shown in Fig. 4 will be described later.

Assuming an infinite number of discrete steps are employed in the horn of Figure 1 a horn of the shape illustrated in Fig. 5 will be evolved. Here the horn 60 is in the form of a rectangular pyramid. At the small end 61 of the horn, it is connected to a rectangular wave guide 10. The horn comprises four essentially plane walls, 63, 64, 65 and 66. The aperture 62 has a maximum height at the axis of the horn, that is, between the edges 69 and 70 and tapers to zero at the two sides 67 and 68 of the aperture. Thus, the radiation is greatest at the middle portion of the aperture between the edges 69 and 70 and decreases towards the end 68 and 67. As a result of this construction, the sharpness of the radiated beam increases and the side lobes normally encountered are substantially reduced or virtually eliminated. It has been found also that for an aperture of a given area, an increase of the ratio of gain-to-aperture area is obtained.

Fig. 6 shows still another embodiment of the invention in which rectangular wave guide 10 is connected to a horn having five sides 81—85. The electric field vector is generally parallel to the narrow sides of wave guide 10. The maximum width of aperture 87 in the direction normal to the E vector is the distance between point 87 and wall 83. The width of the aperture tapers from the middle of the horn to the outer edges 90 and 91. The horn of Fig. 6 may be thought of as a triangular horn in which the two outer corners have been cut off by walls 82 and 84. By using the planes 82 and 84 a considerable saving of material is effected, particularly in instances when the antenna is to be used in the high frequency range, say from 2 to 30 megacycles, in which case the dimensions of height and length are several hundred feet, that is, for example, about two wave lengths high and about five wave lengths long. The antenna may be formed of No. 6 wires spaced about $\frac{1}{10}$ wave length. By varying the wire diameter and spacing a solid conductor may be simulated.

Another advantage of using a second pair of oblique walls such as walls 82 and 84 is that vertically polarized radiation is reduced. The electric field between walls 81 and 85 is slightly curved, as indicated by lines 89, and hence there is a vertically polarized electric field component. The field extending between walls 82 and 84 is curved, as indicated by lines 88, oppositely to the field 89. The vertically polarized components of the lines 88 and 89 therefore tend to cancel. By virtue of its shape, the illumination of aperture 87 is such that it produces a radiation pattern free of side lobes.

The improved radiation pattern characteristics and wide band frequency characteristics of antennas of the type above described are illustrated in Figs. 7 to 12. The radiation patterns shown in these figures were obtained from a horn having the shape shown in Fig. 4 and operated over a ground or reflecting plane parallel to the side 53 of horn 50. Fig. 7 shows the radiation pattern in the H-plane obtained at a frequency of 2300 megacycles. A noteworthy feature of the radiation pattern shown in this figure is the virtual absence of any side lobes.

Fig. 8 shows a radiation pattern in the E-plane taken with the same antenna at 2300 megacycles. It can be seen from this pattern that in the E-plane also, there are no significant lobes.

Fig. 9 shows a radiation pattern of the same antenna in the H-plane at 4160 megacycles, which is nearly twice the frequency at which the radiation patterns of Figs. 7, 8 were taken. It can be seen that even at this widely

different frequency, the antenna maintains a highly desirable radiation characteristic.

Fig. 10 shows a radiation pattern of the same antenna at 4160 megacycles taken in the E-plane. It can be seen that this radiation pattern is virtually free of side lobes.

Figs. 11 and 12 show the radiation patterns of the horn of Fig. 4 in the E and H planes at the still higher frequency of 4800 megacycles. These patterns indicate that the freedom from side lobes in both the E and H planes persists.

For the sake of simplicity, I have shown only a few simple embodiments of my invention. It will be quite evident to those skilled in the art that many variations and modifications of the embodiments shown herein can be made without departing from the principles of my invention. For example, the walls of the horn have been shown as being plane but it will be apparent to those skilled in the art that they may be flared outwardly and may be formed in such a way that the width of the aperture varies non-uniformly. Hence, the invention is not to be construed as limited except as defined in the following claims.

I claim:

1. A flared electromagnetic radiating horn having at least three walls and means connected to the small end of said horn for supplying electromagnetic waves to the horn, at least two of said walls being inclined toward each other so that at the aperture of the horn, the distance between said inclined walls in a direction parallel to the electric vector of said waves decreases to a minimum value at one edge of the aperture.

2. Apparatus according to claim 1, wherein the walls are arranged so that their intersections with a plane perpendicular to the axis of the horn is a trapezoid.

3. Apparatus according to claim 1, wherein said horn has only three walls arranged in the form of a triangular pyramid.

4. Apparatus according to claim 1, wherein said horn has four walls, each of which is inclined with respect to the direction of the electric vector.

5. Apparatus according to claim 1, wherein the walls are arranged so that the width of said aperture in the direction perpendicular to the electric vector is a maximum at the axis of the horn and decreases towards the outer ends of the aperture.

6. Apparatus according to claim 1, wherein the means for supplying electromagnetic waves to the horn is a rectangular wave guide.

7. Apparatus according to claim 6, wherein the walls are arranged so that their intersection with a plane perpendicular to the axis of the horn is a trapezoid, each wall of the horn intersecting only one wall of the rectangular wave guide and the walls forming the parallel sides of the trapezoid being formed so as to intersect only the narrow sides of the wave guide.

8. Apparatus according to claim 7, wherein one of the walls forming the parallel sides of the trapezoid has a constant width equal to the width of a narrow side of the wave guide.

9. An electromagnetic horn radiator having means at one end for supplying electromagnetic waves thereto, said horn having a plurality of walls flaring outwardly from said one end and providing a radiating aperture at the other end of the horn, said walls being arranged so that the width of the aperture in the direction perpendicular to the electric vector decreases from the center of the aperture to one edge thereof.

10. Apparatus according to claim 9, wherein the walls are arranged so that said width of the aperture is a maximum at the center and decreases from the center of the aperture to the ends of the aperture.

11. Apparatus according to claim 9, wherein the width of the aperture decreases in discrete steps from the middle of the aperture to one end thereof.

12. Apparatus according to claim 9, wherein the width

5

of the aperture decreases in discrete steps from the middle of the aperture to the opposite ends of the aperture.

13. Apparatus according to claim 9, wherein the means for supplying electromagnetic waves to the horn is a rectangular wave guide having its narrow dimension in the direction of the width of the aperture.

14. In combination, a rectangular wave guide and a pyramidal electromagnetic radiating horn having four plane walls flaring outwardly from and connected to said rectangular wave guide and providing a rectangular radiating aperture at the end of the horn remote from the wave guide, said walls being positioned so that the sides of the aperture extend in directions which are oblique to the sides of the rectangular wave guide.

15. An antenna comprising a flared electromagnetic radiating horn, means connected to said horn at the small end of the horn for supplying substantially linearly polarized electromagnetic waves to the horn, the large end of the horn being open to provide a radiating aperture, the horn being shaped so that the aperture is asymmetrical to any line parallel to the electric vector and the width of the aperture perpendicular to the direction of the electric vector is a maximum at the middle of the aperture and tapers toward the ends thereof at such a rate that substantially only a single lobe of radiation is produced.

16. An electromagnetic horn having a radiating aperture and a plurality of walls forming the boundaries of

6

the horn, said walls having such shapes that the width of the aperture perpendicular to the direction of the electric vector decreases at different rates from the middle of the aperture to both ends thereof.

17. A horn according to claim 16, wherein said width decreases uniformly at one rate throughout a middle portion of the aperture and at a greater rate near the ends of the aperture.

18. A horn according to claim 16, wherein the walls are shaped so as to form a pentagonal aperture.

19. An antenna comprising a flared electromagnetic radiating horn having a plurality of sides, means connected to said horn at the small end of the horn for supplying plane polarized electromagnetic waves to the horn, the large end of the horn being open to provide a radiating aperture, the horn being shaped so that the width of the aperture in the direction of the electric vector is a maximum at the middle of the aperture and tapers toward the ends thereof, and means for canceling the radiation of transversely polarized electric field components of said waves due to curvature of the electric field in the horn.

References Cited in the file of this patent

UNITED STATES PATENTS

2,316,151 Barrow ----- Apr. 13, 1943

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,851,686

September 9, 1958

Boynton G. Hagaman

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 2 and 12, and in the heading to the printed specification, lines 3 and 4, name of assignee, for "Development Engineering Corporation", each occurrence, read -- Developmental Engineering Corporation --.

Signed and sealed this 23rd day of December 1958.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents