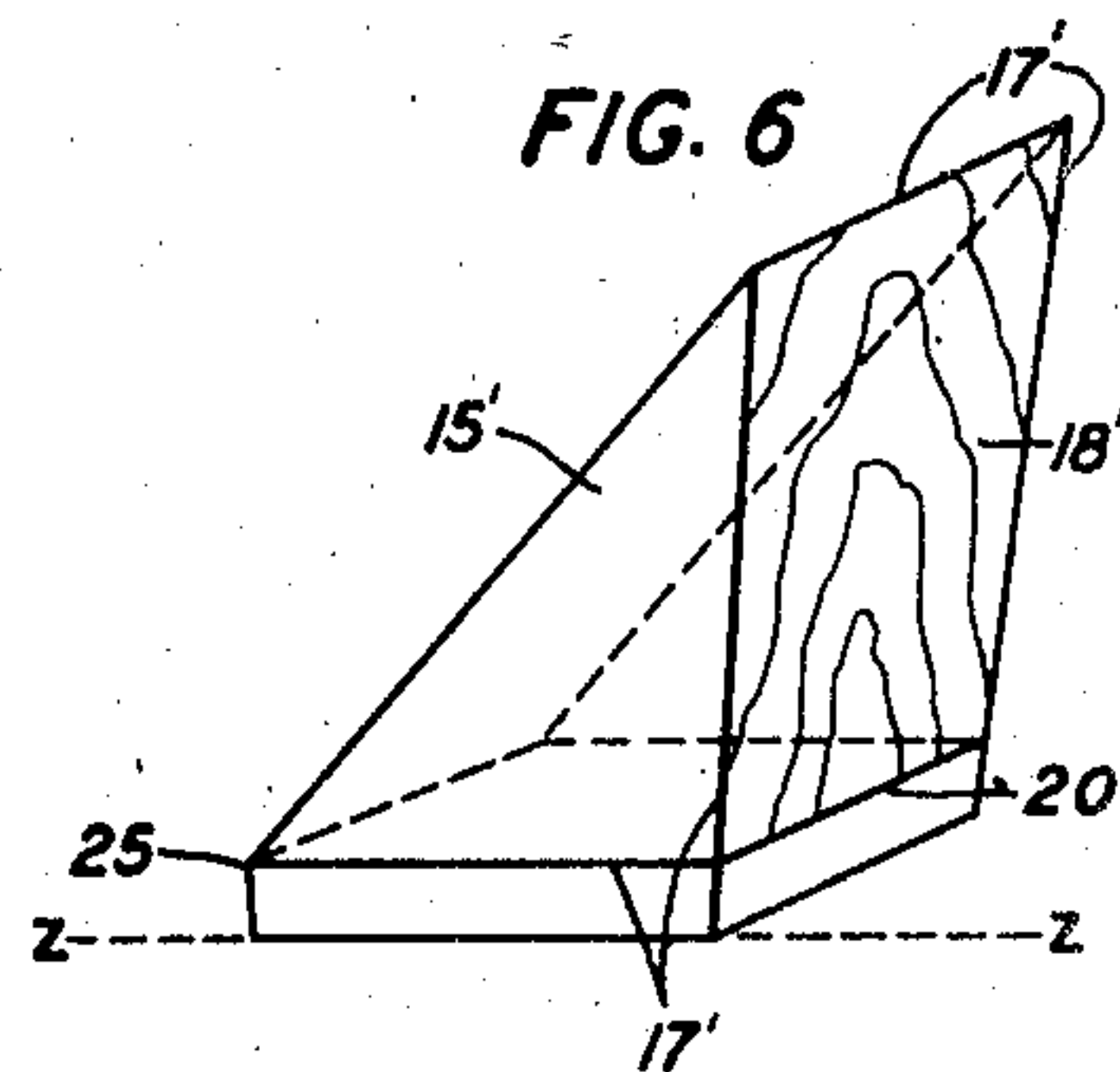
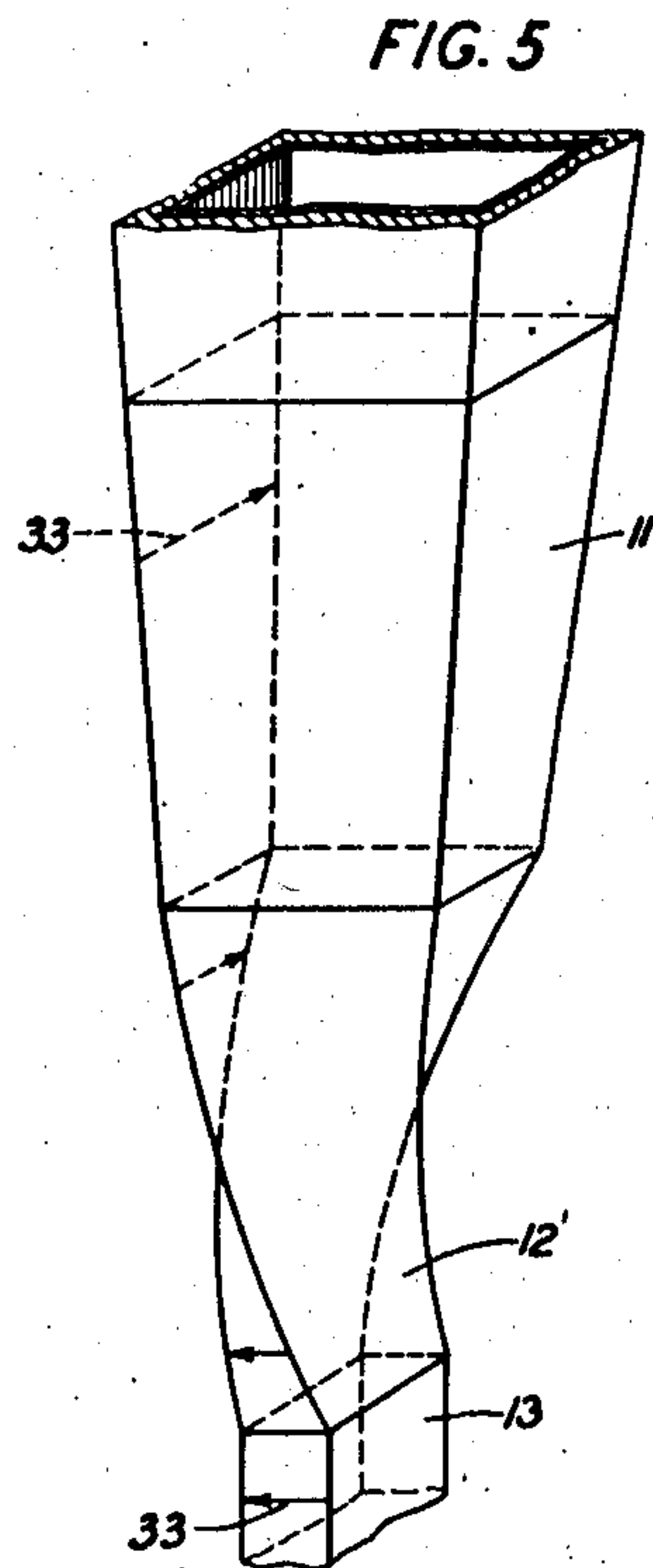
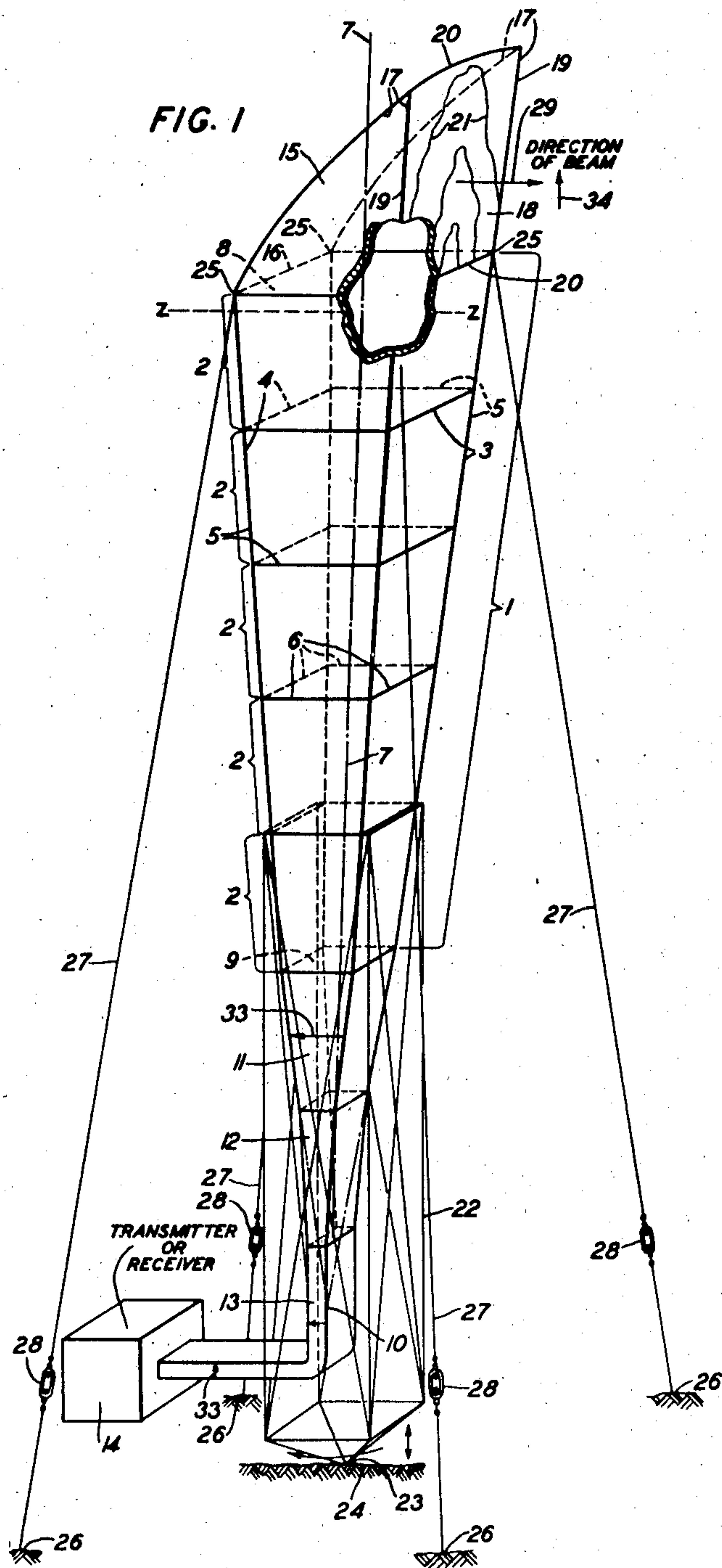


March 4, 1947.

A. C. BECK ET AL
HORN ANTENNA SYSTEM
Filed Nov. 26, 1941

2,416,675

3 Sheets-Sheet 1



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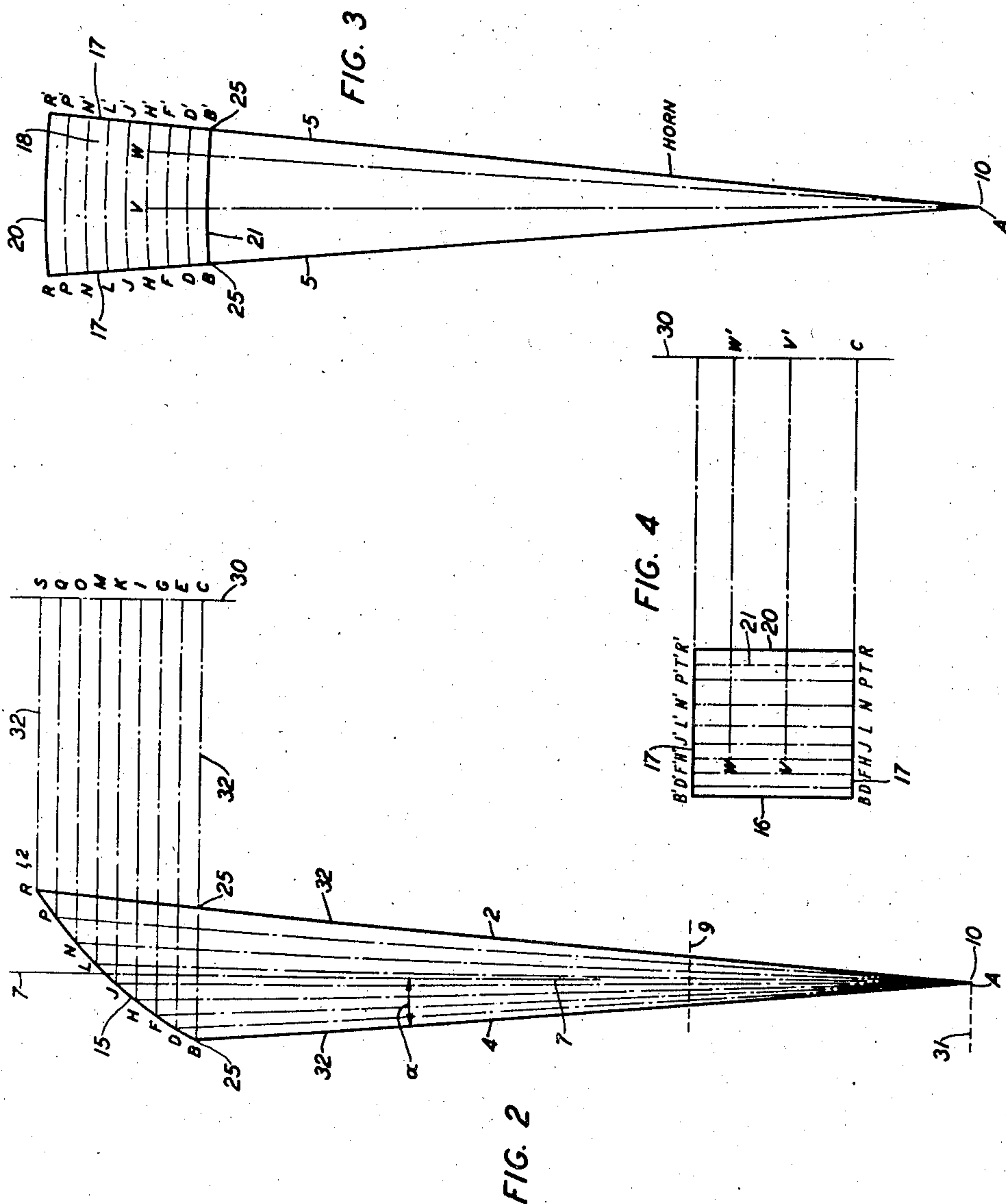
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FIG. 7

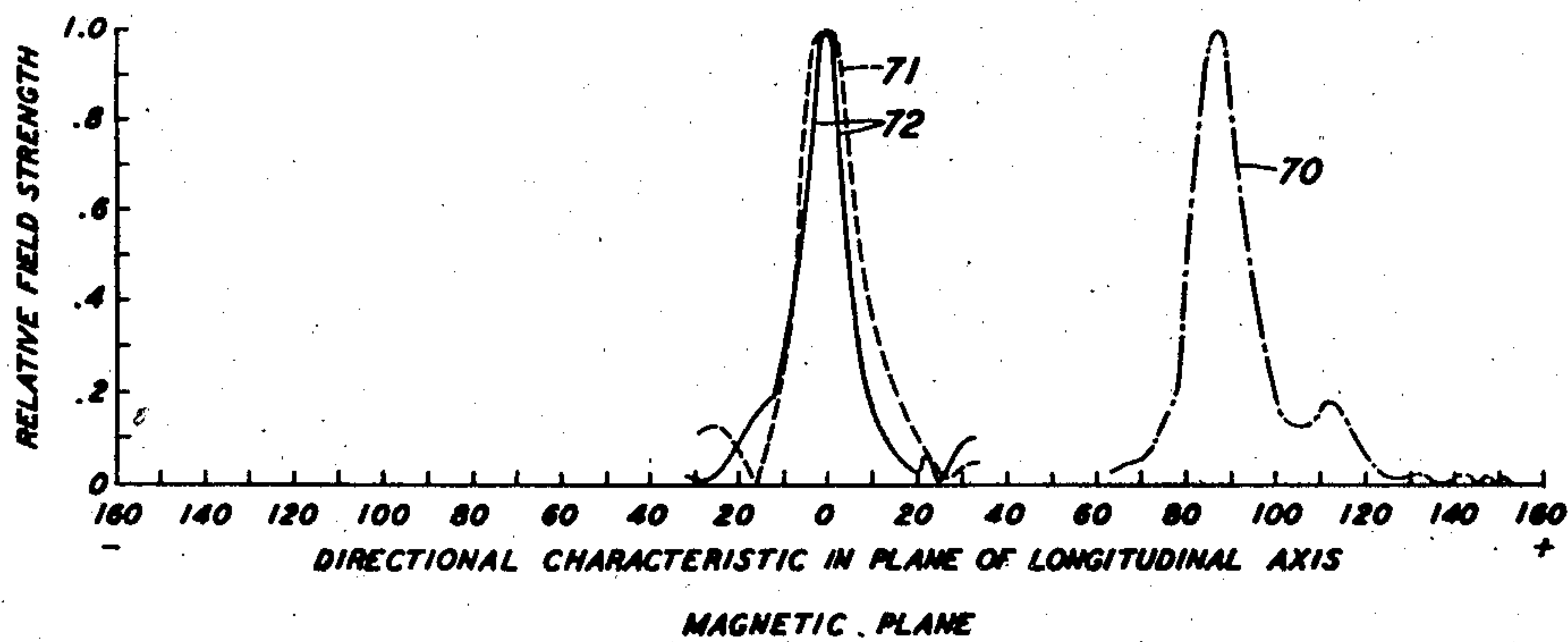
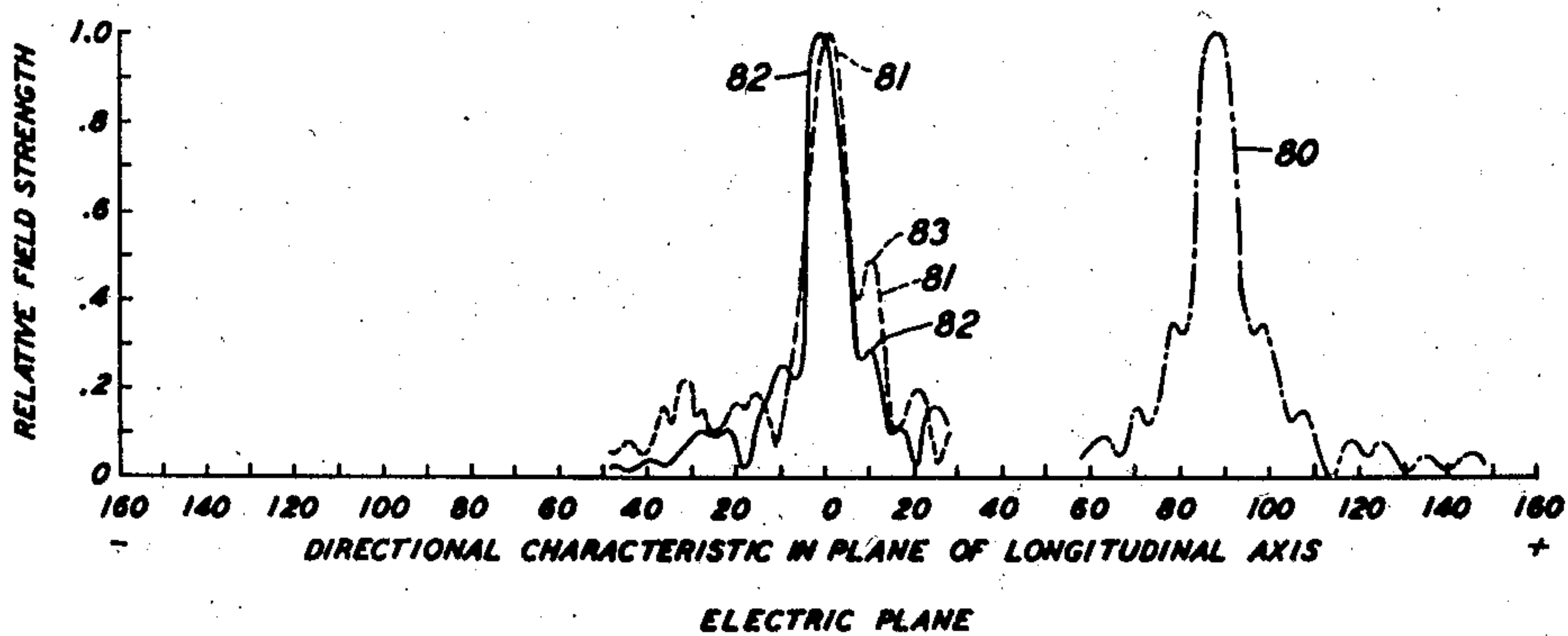


FIG. 8



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UNITED STATES PATENT OFFICE

2,416,675

HORN ANTENNA SYSTEM

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Application November 26, 1941, Serial No. 420,454

14 Claims. (Cl. 250—11)

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This invention relates to antenna systems and more particularly to ultra-short wave and microwave horn antenna systems.

As is known, horn antennas for projecting or collecting radio energy in a fixed unidirection coinciding with the longitudinal horn axis, and horn antennas associated with deflectors for securing omnidirectional or non-directional radio action in a plane perpendicular to the longitudinal axis, have been suggested for use in the ultra-short wave (below 10 meter wave-length) and the microwave (below 1 meter) fields. For example, United States Patents 2,206,923 and 2,369,808, both granted to G. C. Southworth, and British Patents 534,066 and 534,067, W. L. Barrow, both complete accepted February 26, 1941, disclose horn antennas and horn antennas associated with deflectors. In most of the horn antenna systems heretofore proposed for propagating energy unidirectionally, the wave front is not flat since the diverging wave paths extending from the horn throat aperture to the horn mouth aperture, are unequal in length whereby the wave components in the plane of the mouth aperture are to some extent in phase disagreement. It now appears desirable to secure phase agreement among the wave components propagated in the same direction and to improve greatly the operation of unidirectional horn antennas. Moreover, it is now desirable to project or collect radiant energy, unidirectionally in a plane perpendicular to the longitudinal horn axis, and to control accurately the unidirectional action of horn antennas especially horn antennas having relatively large dimensions.

It is one object of this invention to project and collect, in a horn antenna system, only in-phase wave components in a given single direction.

It is another object of this invention to steer or control the direction of maximum radiant action of a large antenna in a simple manner utilizing a minimum of equipment.

It is still another object of this invention to deflect or direct all the wave energy emitted by a horn antenna along a single path, substantially, included in a plane perpendicularly related to the longitudinal horn axis.

It is a further object of this invention to project or collect radio waves unidirectionally in a horizontal plane utilizing a vertical horn antenna and relatively simple supporting structure.

It is still another object of this invention to project or collect, in a single point direction included in a horizontal plane, either horizontally

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or vertically polarized waves utilizing the same vertical horn antenna.

According to one embodiment of the invention a plane or paraboloidal unipoint directional deflector is attached to one mouth aperture edge of a large vertical horn antenna having a square transverse cross section, for projecting or collecting energy in a single direction in a horizontal plane. The paraboloidal deflector has a circular contour in the wave front plane and a parabolic contour in the wave propagation plane, the wave front plane being perpendicular to the wave direction and the propagation plane being perpendicular to the wave front plane and including the wave direction. The horn sides or walls adjacent the deflector are in effect continued to the deflector and the extended side portions function as shields to confine the radiation or collection to the given horizontal unipoint direction, the deflector aperture facing, of course, the desired horizontal direction of action. The horn may be self-supporting or it may be mounted in a crib or cradle having a pivot or point support, the horn being held in a vertical position by means of four guy cables attached to the corners of the mouth aperture. Preferably turnbuckles are provided in the guy cables for the purpose of permitting tilting of the horn in the vertical plane and slight twisting or rotation about the vertical or longitudinal horn axis. The horn is connected to a horizontal wave guide line through a straight throat section or 90° twisted throat section, dependent upon the plane of wave polarization desired and the direction of extension of the line relative to the front side of the horn.

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

Fig. 1 illustrates a horn-deflector antenna system constructed in accordance with the invention; Figs. 2, 3 and 4 are respectively side, front and top cross sectional diagrammatic views used in explaining the operation of the system of Fig. 1; Figs. 5 and 6 illustrate, respectively, a twisted horn throat section and a plane reflector which may be substituted in the system of Fig. 1 for the straight throat section and paraboloidal reflector, and Figs. 7 and 8 are directive diagrams for the system of Fig. 1 modified to include the plane reflector of Fig. 6.

Referring to Fig. 1, reference numeral 1 designates a vertical horn antenna comprising five horn sections 2 and having a front wall 3, back

wall 4, side walls 5, a transverse graduated cross sectional area 6, a longitudinal axis 7, a mouth aperture 8, a throat aperture 9 and an optimum ratio of horn length to horn mouth aperture area, the length being measured along the axis 7 between the mouth aperture 8 and the throat aperture 9. The horn proper is an inverted square pyramidal structure having a virtual apex 10. The throat aperture 9 is connected through coupling sections 11 and 12 to a wave guide 13 and a translation device 14 which may be a transmitter or receiver. As is shown on the drawing, the cross sectional area of the section 12 is rectangular whereas the cross sectional area of section 11 changes uniformly from rectangular to square. As used herein, the term "rectangular" denotes a rectangular configuration other than square, and the generic term "quadrangular" signifies rectangular or square.

Reference numeral 15 designates a paraboloidal deflector attached to the back edge 16 of the horn mouth aperture 8 and to the extended wall portions or shields 17, the deflector being positioned, as is explained in more detail below, so as to face both the throat aperture 9 and the wall opening 18 formed in the plane of the front wall 3 by the front edges 19 of the shields 17, the front edge 20 of the deflector 15, and the top edge 20 of the front wall 3. The horn 1 and deflector 15 are preferably of light weight construction as, for example, wood, the inside surfaces being lined with copper-coated paper or galvanized zinc. The opening 18 may, if desired, be equipped with a plywood cover 21 for weather protection. The horn sections 2 and throat sections 11 and 12, are preferably detachable so that they may be nested for the purpose of facilitating transportation.

The lower portion of horn 1 is symmetrically included within the metallic or wooden cradle structure 22 which is mounted on the pivot or point support 23 and ground plate 24. The corners 25 of the mouth aperture 8 are each connected to the ground 26 by a separate guy cable 27. Each guy cable includes a turnbuckle 28 which permits a certain amount of movement or twisting of the horn 1 about its longitudinal axis 7 and substantial rotation or tilting about the pivot support 23 in the plane of the wave direction 29 and the axis 7, whereby the effective direction of radio action of the system may be steered or aligned with a desired path of propagation.

Referring to Figs. 1, 2, 3 and 4, the deflector 15 has, in the moving vertical plane 30 of the wave front, a circular contour represented by the curved lines or arcs BB', CC', DD' . . . RR', Fig. 3, with centres on a line 31', Fig. 2, passing through point A. Point A is located at the virtual apex 10 of the horn. In the vertical plane 32 of wave propagation, the deflector has a parabolic contour BJR, Fig. 2, the focus of the parabolic curve being also at A. In Fig. 2, the plane 30 is perpendicular to the paper and includes points S and C and the plane 32 includes the paper and points A, B, R, S, and C. In other words, the deflector 15 is a paraboloid of revolution and resembles a portion of an automobile headlight reflector. As shown by Fig. 3, a longitudinal cross section of the horn and attached deflector, taken in the plane 30 of the wave front, is sectorial. The parabolic curve or contour is expressed by the following equation for polar coordinates

$$r = l \frac{1 + \sin \alpha}{1 - \sin (\beta - \alpha)}$$

where

l = the length of the wall edge AB,

r = the distance measured from A to any point Z on the inside surface of the deflector 15,

α = the angle between the front wall 2, or the back wall 4, and the longitudinal axis 7 in the plane 32, and

β = the angle in the plane 32 between AB and the line AZ as measured clockwise from the edge AB.

As illustrated by Fig. 2, the diverse bent paths ABC, ABE, AFG . . . ARS included in the plane of propagation 32 and extending from the virtual apex 10 via the deflector 15 to the plane 30 of the desired wave front, have by virtue of the position and shape of the deflector 15, equal lengths. In any of the planes ABB', ADD', etc., Figs. 3 and 4, which planes are in quadrature to plane 32, the diverse paths as, for example, AV and AW, are equal and the right-angle extensions VV' and WW' of these paths to the desired wave front 30 are also equal.

In operation, Fig. 1, assuming the system is used for transmission, energy from the transmitter 14 is supplied by the rectangular wave guide 13 to the horn 1 and the wave components are propagated along the diverging paths within the horn 1. After passing through the mouth aperture 8 the waves impinge upon deflector 15 and thence are directed or deflected through the wall opening 18 in a substantially horizontal direction 29. Since the lengths of the diverse paths in the plane 32 extending from the throat aperture 9 to the desired wave front 30 are substantially equal, the wave components or wavelets in the vertical wave front plane 30 are in phase and combine to produce a maximum effect in the given direction 29. The wavelets are propagated through the aperture 18 in contiguous, substantially parallel, horizontal directions or lines having the mean direction 29 and the beam is directed upon the distant station. The shield members 17 prevent side radiation and also provide weather protection for the horn interior. The shield member 17 and the non-conductive cover 21 may be omitted, if desired, for economical reasons at some sacrifice in operating effectiveness. The predominating wave propagated inside the wave guide 13 and supplied to the horn 1 is, as is well-known, polarized in a direction coinciding with the short transverse dimension as shown by arrows 33, Fig. 1. Hence, with the wave guide connected so as to extend in a front-to-back line direction relative to the horn, as shown in Fig. 1, the wave impinging upon deflector 15 is, immediately before intercepting the deflector, polarized horizontally in the vertical plane of propagation 32 and after reflection is vertically polarized in said plane as shown by arrow 34 in Fig. 1.

Referring to Fig. 5, numeral 12' designates a twisted throat section which may be used in place of the straight throat section 12 included in the system of Fig. 1 for rendering the polarization of the emitted wave horizontal. To make the conversion, section 11 shown in Fig. 1 is rotated 90°, as shown in Fig. 5, and the twisted throat section 12' is then fitted between horn section 11 and the wave guide 13. In operation, the twisted throat functions to rotate the polarization plane of the wavelets propagated within the horn 90°, the wave after passing through the twisted throat section being horizontally polarized in a vertical plane perpendicularly related

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to the vertical propagation plane 32. As a result, the polarization of the wave is reversed or changed 180° by deflector 15 but, as emitted through the aperture 18 in wave propagation direction 29, the wave is horizontally polarized. Thus, the same horn antenna system may be employed for emitting or receiving either vertically polarized or horizontally polarized waves in a given propagation direction. As an alternative, the line 13 may extend in a side-to-side line direction, that is, in a direction making a right angle to the direction shown in Fig. 1, the section 11 being oriented as shown in Fig. 5. With this modification the straight section 12 is employed to produce horizontally polarized waves and the twisted section 12' to produce vertically polarized waves.

Referring to Fig. 6, reference numeral 15' designates a plane reflector and numerals 17' denote triangular side shields which may be utilized, if desired, in the system of Fig. 1 in place of the curved reflector 15 and the curved shields 17. For horizontal propagation the plane deflector 15' is preferably positioned at an angle of 45° with respect to the plane of the mouth aperture 8 so that the energy is projected predominantly in the direction 29. The plane reflector assembly is less expensive in first cost than the paraboloidal assembly. In operation, however, the beam obtained with the plane deflector is more divergent than that emitted by the paraboloidal deflector assembly. As in the system of Fig. 1, the shield members 17' function to enhance the radio action in a desired direction and may be omitted for economical reasons with some sacrifice in operating effectiveness.

Referring to Figs. 7 and 8, curves 70, 71 and 72 (Fig. 7) and curves 80, 81 and 82 (Fig. 8) represent, respectively, the directive characteristics of a vertical horn not equipped with a deflector assembly, a horn antenna having a plane reflector 15' but not shield members 17', and a horn antenna equipped with a plane deflector and shield members, as illustrated by Fig. 6. Fig. 7 represents the magnetic plane directive characteristic and Fig. 8 represents the electric plane characteristic. As may be seen by comparing curves 70 and 71, and 80 and 81, the open deflector 15' functions to change the direction of maximum radio action 90°. Also as may be seen by comparing curves 71 and 72, and curves 81 and 82, the shield members 17' increase the sharpness of the directional effect and prevent or eliminate the minor lobes as, for example, lobe 83.

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 apparatus illustrated, inasmuch as other equipment and apparatus may be satisfactorily employed in practicing the invention.

What is claimed is:

1. A quadrangular horn antenna having metallic walls each of varying width and an aperture in one wall at its wide end, said horn antenna having a sectorial cross section in the plane of said aperture.

2. A dielectric channel for conveying electromagnetic waves, said channel having metallic walls and an aperture facing in a direction perpendicular to its longitudinal axis, substantially, said channel having in a plane perpendicular to said direction and including its longitudinal axis a cross-sectional area bounded by two angu-

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larly related lines and a curvate line connecting said lines at their widest separation.

3. In combination, a metallic horn antenna having a longitudinal axis and a quadrangular mouth aperture for propagating in a direction aligned with said axis waves having a concavo-convex or curved wave front, said horn comprising four angularly related walls each having a metallic inner surface, a concave metallic deflector attached to one edge of said horn aperture and a separate plane metallic shield attached to each aperture edge adjacent said first-mentioned edge, whereby the waves are propagated in a single direction substantially perpendicular to said axis and the curved wave front is changed to a plane wave front.

4. A quadrangular metallic horn antenna having a throat aperture and a side aperture in its front wall, a metallic paraboloidal deflector facing said apertures and having a finite focus located on the longitudinal axis of said horn, whereby the lengths of the wave paths extending from the horn throat aperture to said side aperture via said deflector are substantially equal.

5. In combination, a vertical horn-shaped dielectric channel for conveying transverse electric microwaves, a metallic paraboloidal reflector attached thereto and facing the mouth aperture of said horn, the focal axis of said reflector being in a horizontal plane, the horn being included between the reflector surface and the reflector focus, said horn having its longitudinal axis superimposed on a linear path extending between said focus and said surface, the length of the horn along said longitudinal axis being shorter than said path, whereby unidirectional action in the horizontal plane is secured.

6. A horn antenna system lined with conductive material and having a rectangular cross section, one side of said horn being extended beyond and at an angle to the plane of the horn mouth aperture and the two sides adjacent said first mentioned side being extended so as to touch the extended first side, whereby an aperture is formed in the plane of the remaining side.

7. In combination, a metallic horn antenna having its longitudinal axis aligned with a given direction, said horn having a throat aperture and a rectangular mouth aperture, a metallic deflector attached to said horn along one edge of the mouth aperture for confining the travel of waves projected or collected by said horn to a single direction, substantially, said deflector being included in a plane perpendicularly related to said given direction, and a device for generating or receiving radio waves connected to the throat aperture.

8. In combination with an antenna system comprising a horn and a deflector for projecting or collecting a maximum amount of radio energy in substantially one point direction, perpendicular to the longitudinal axis of said horn, means comprising a point supporting structure for mechanically steering the direction of maximum action of said system in a plane containing said horn axis and in a plane perpendicular to said axis.

9. A vertical horn antenna system having an aperture facing in a point direction included in a horizontal plane and means for adjusting or steering the directive characteristic of said horn comprising a point supporting structure for said horn antenna and adjustable guy wires extend-

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ing from different upper portions of said horn to the earth.

10. In combination, a metallic horn antenna having a square mouth aperture and its longitudinal axis perpendicularly aligned with the desired direction of radio action, a metallic deflector facing the mouth aperture of said horn, said deflector having a circular contour in the plane of said axis and a parabolic contour in the plane of said direction and having its focus on said longitudinal axis.

11. An antenna system for projecting or collecting wave components in a given direction, the system comprising a rectangular horn having a side aperture in its front wall and a throat aperture, a paraboloidal reflector facing said side aperture and said throat aperture, the reflector focus being located on the longitudinal horn axis and the distance between the focus and the reflector being greater than the length of the horn as measured along said longitudinal axis, the focal axis of said reflector being perpendicular to said longitudinal axis and aligned with said direction, whereby all of the wave paths extending from the throat aperture via said reflector to a plane perpendicular to said direction have equal lengths and the in-phase wave components emitted or collected by said system are included in a plane.

12. In combination, a vertical horn antenna having a square mouth, a unidirectional deflector attached to one edge of said mouth for confining the wave propagation to a single direction, substantially, in a horizontal plane, a transmitter connected to a rectangular wave

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guide, a wave guide member having at one end a square cross section and at the other end a rectangular cross section and connecting said wave guide to the horn throat.

13. A combination in accordance with claim 12, the wave guide member being linear along its longitudinal axis.

14. A combination in accordance with claim 12, the wave guide member being twisted 90 degrees about its longitudinal axis.

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