

June 17, 1947.

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2,422,184

DIRECTIONAL MICROWAVE ANTENNA

Filed Jan. 15, 1944

6 Sheets-Sheet 1

FIG. 1
PRIOR ART

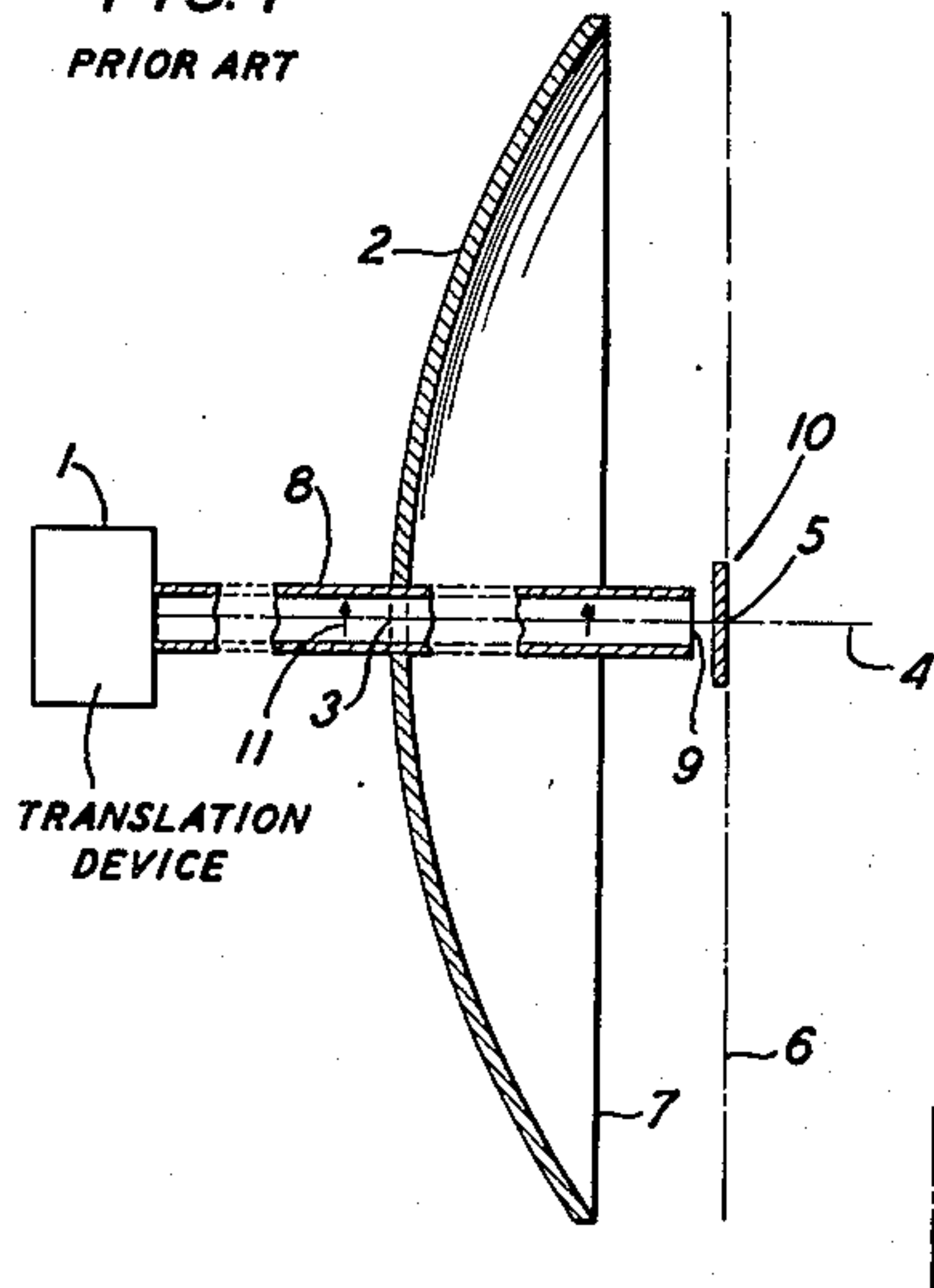


FIG. 2
PRIOR ART

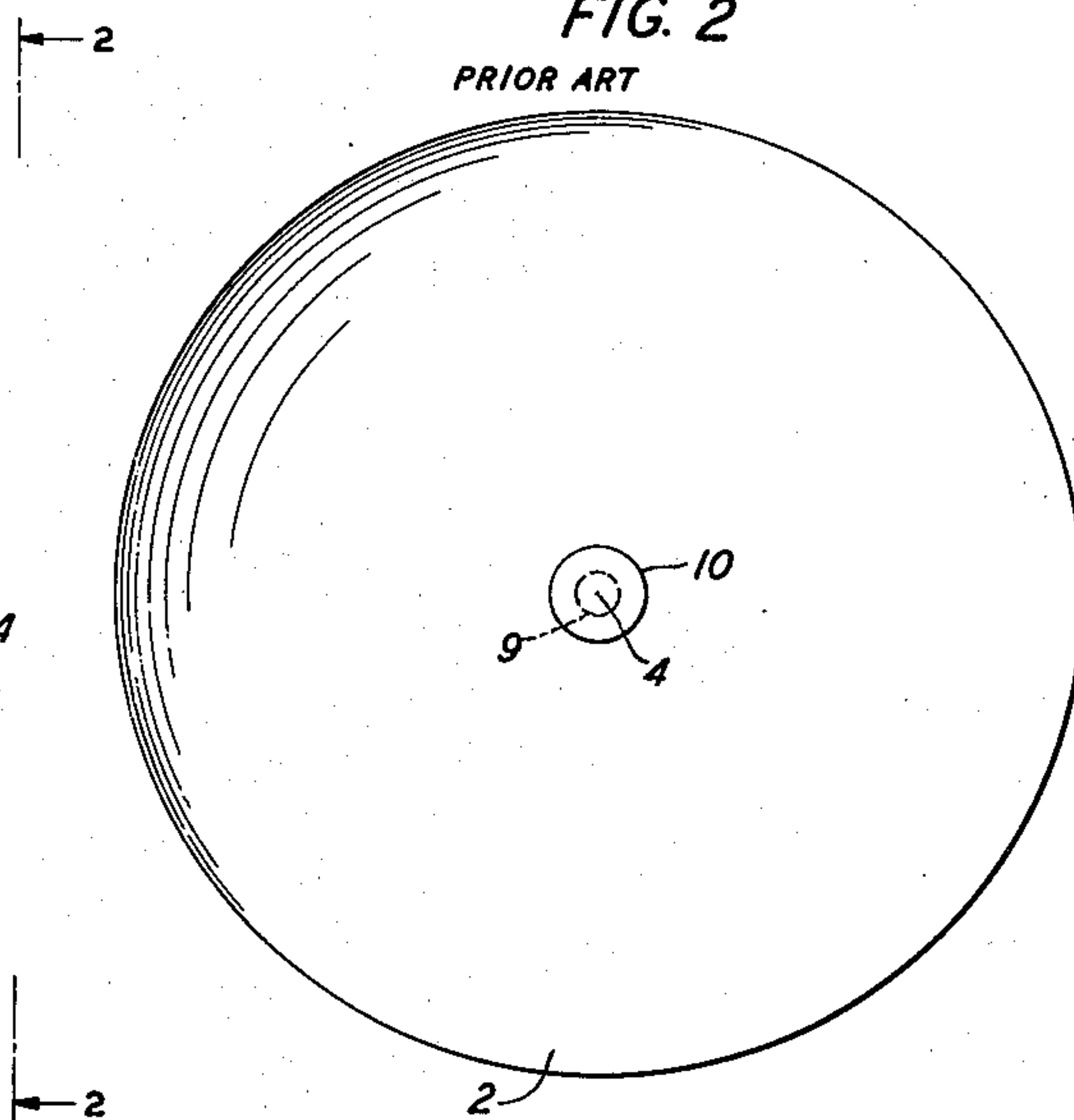


FIG. 3

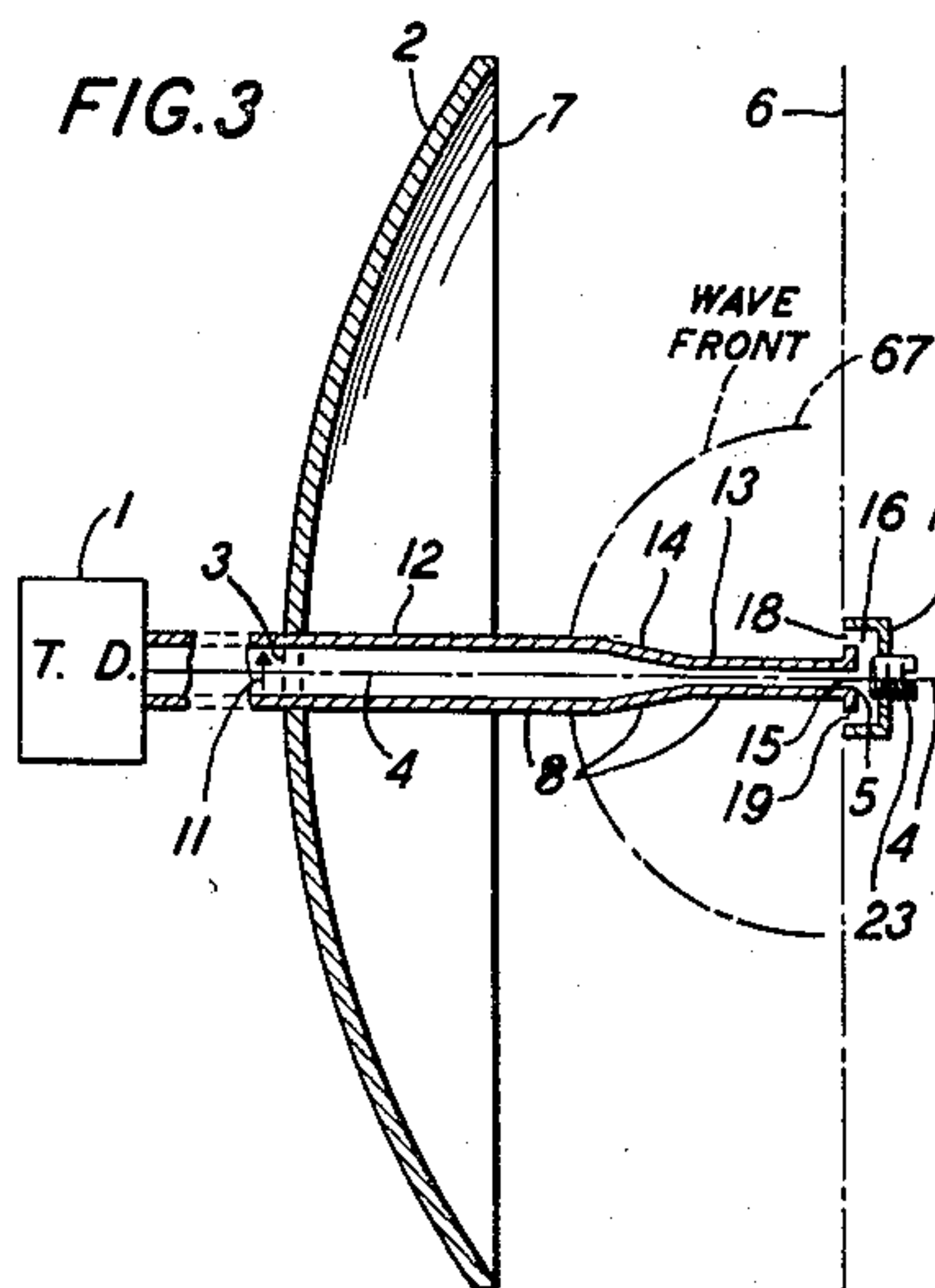


FIG. 4

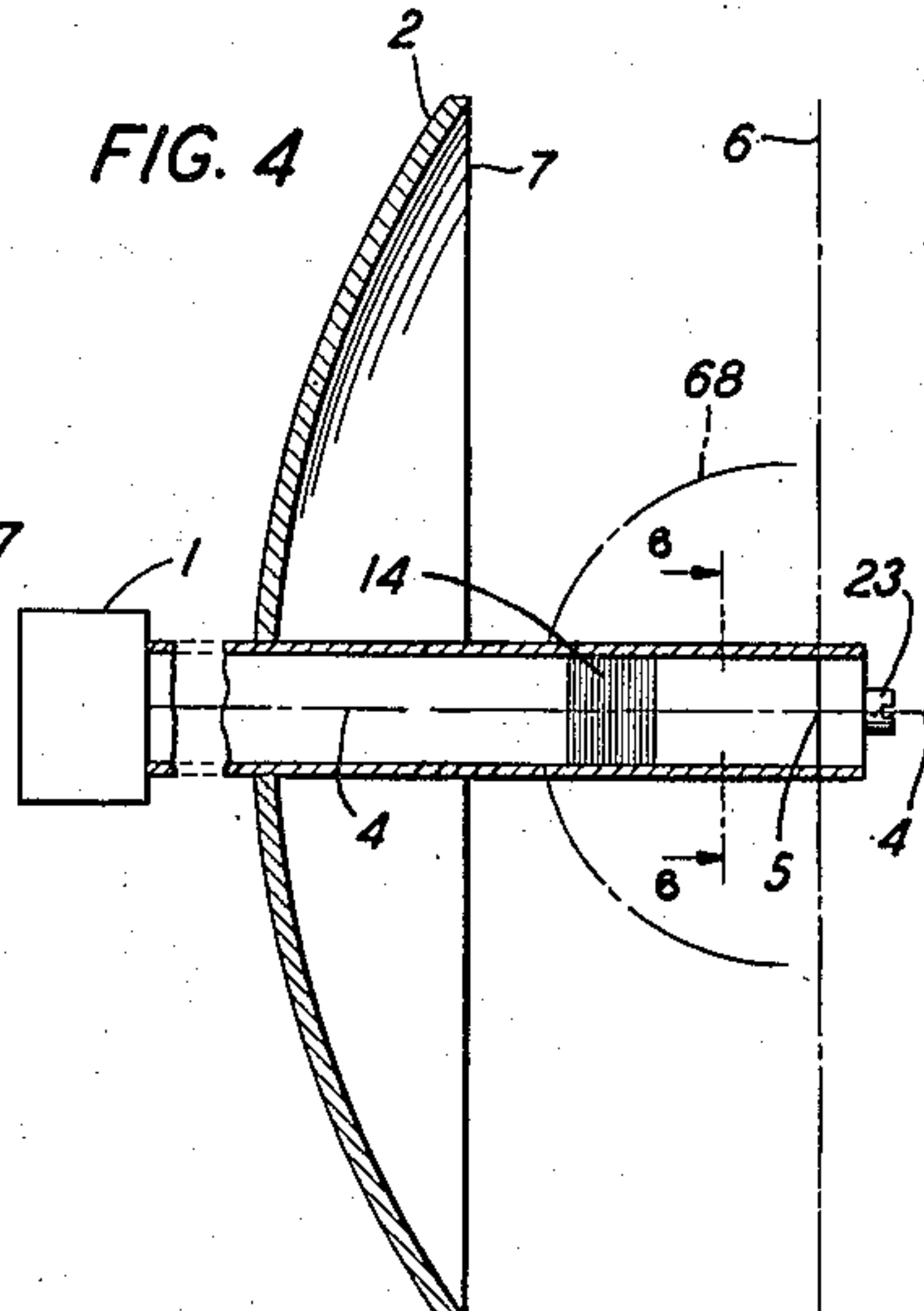


FIG. 5

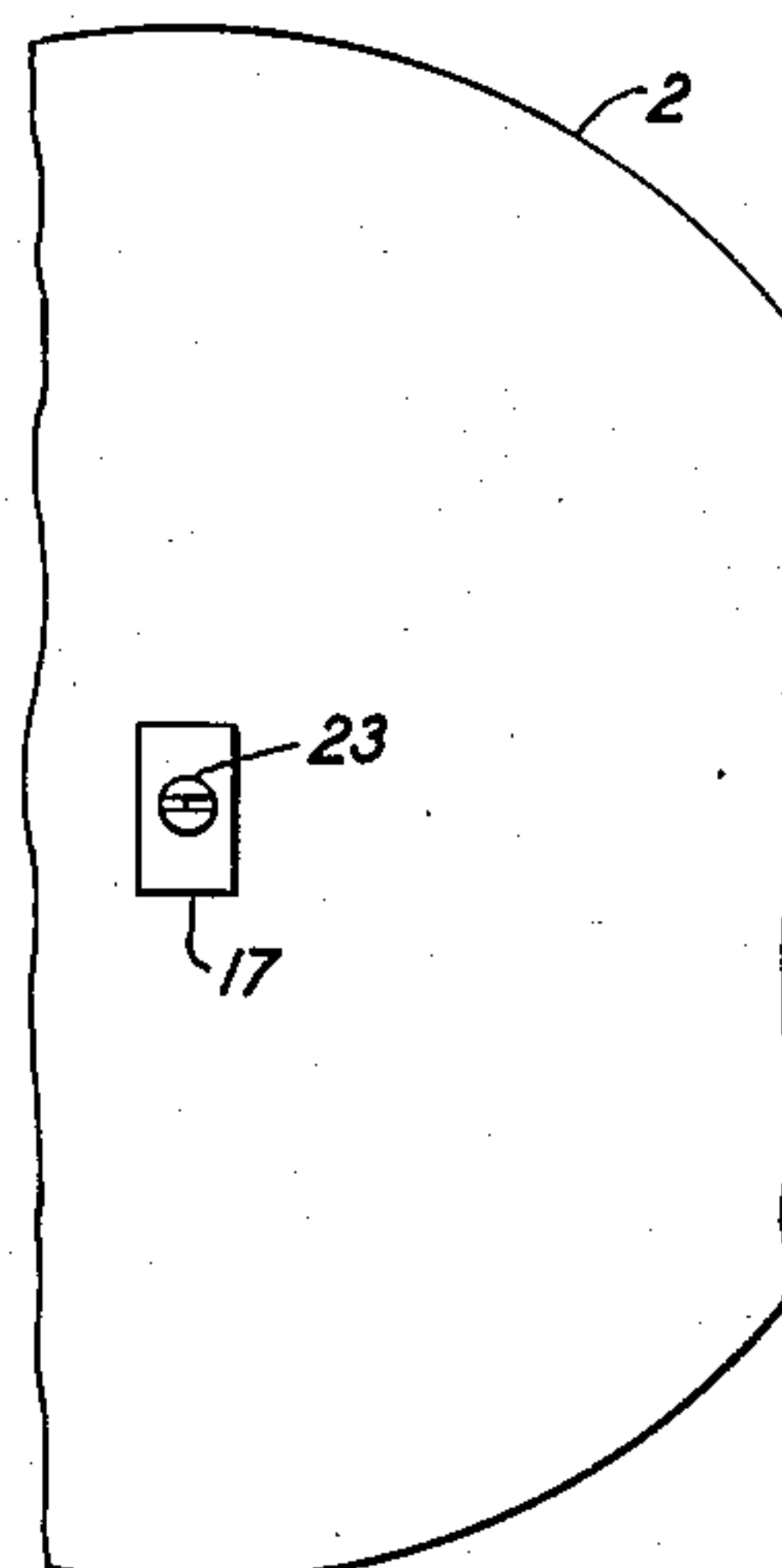
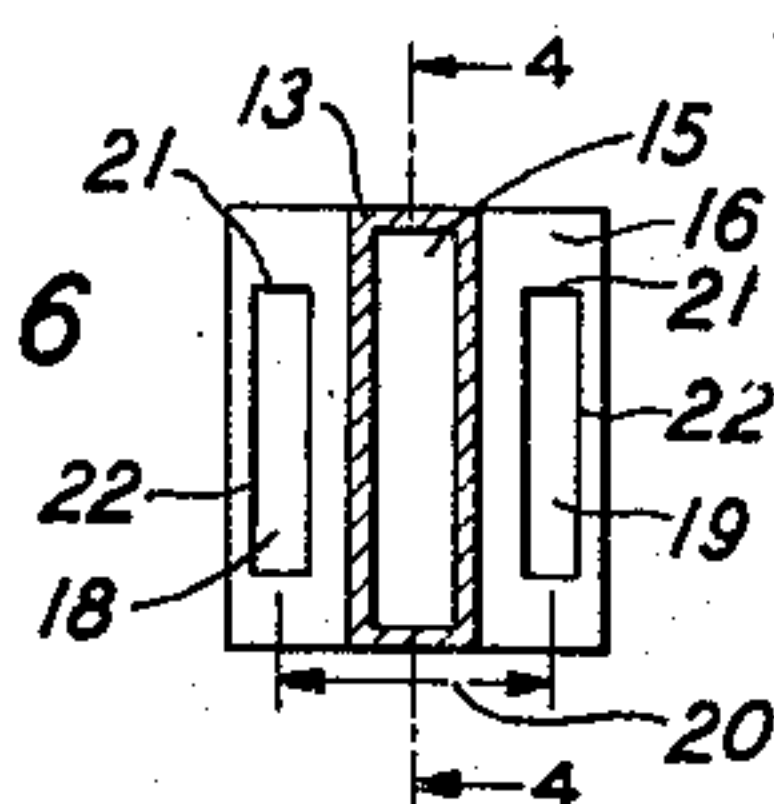


FIG. 6



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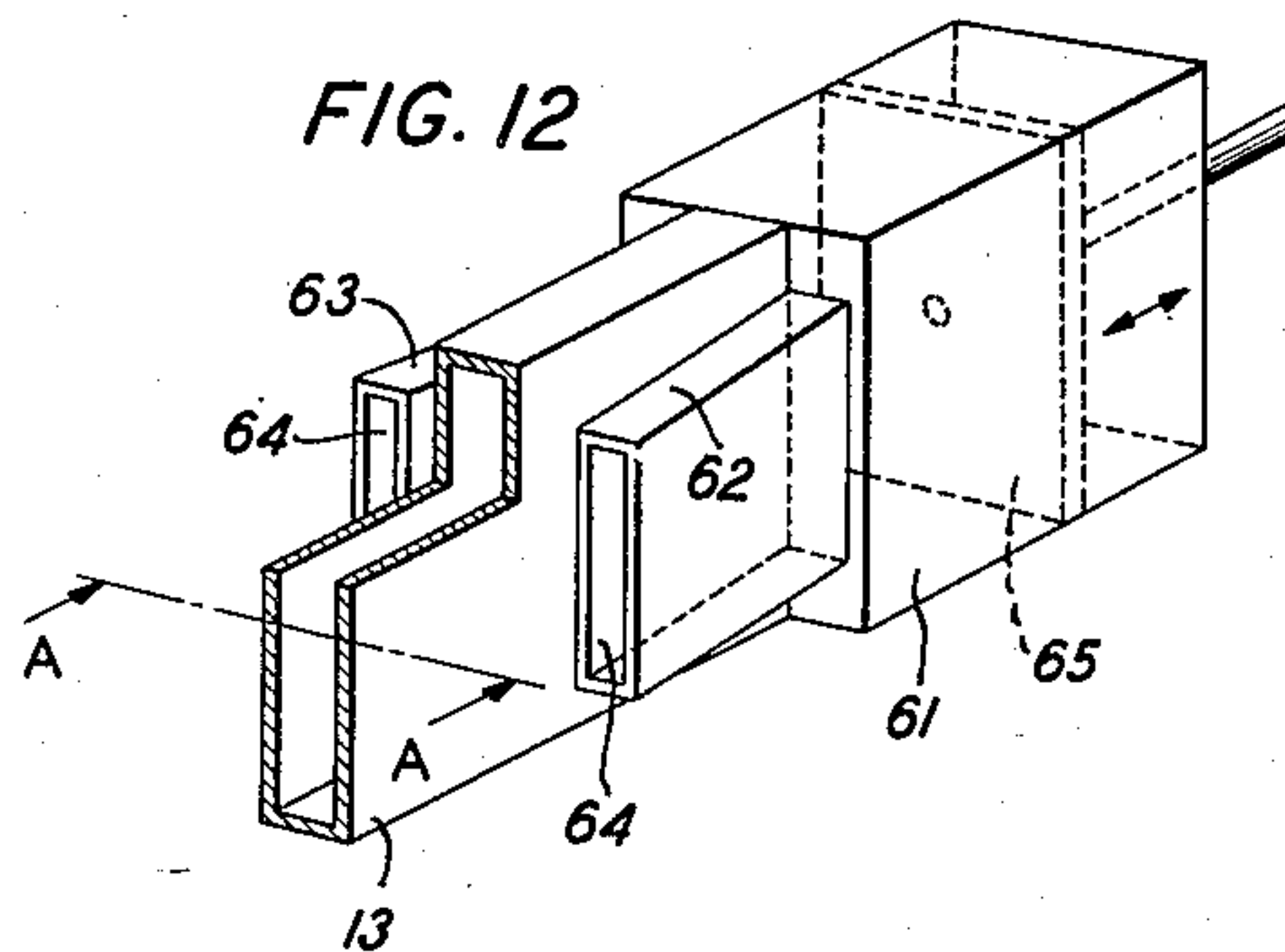
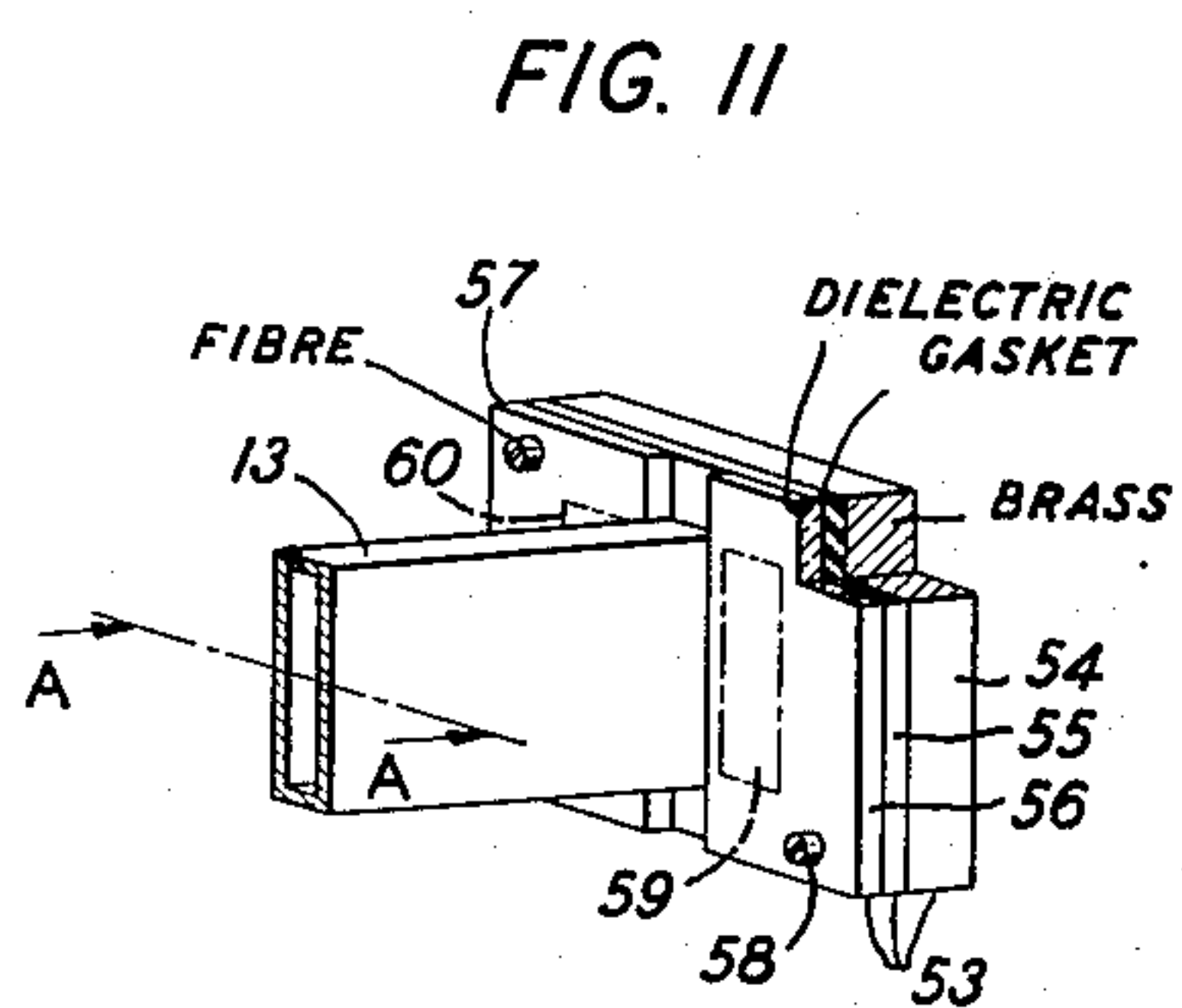
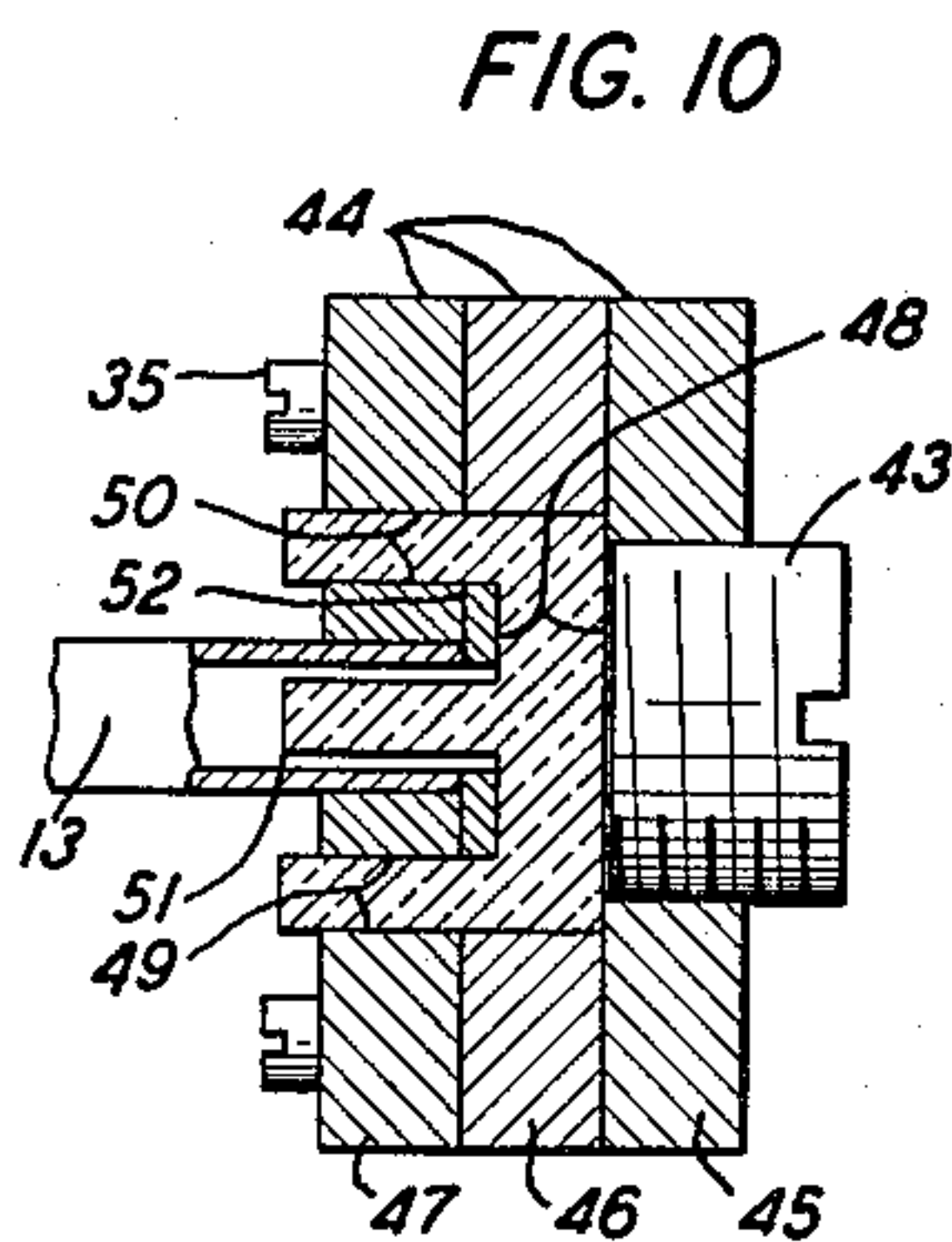
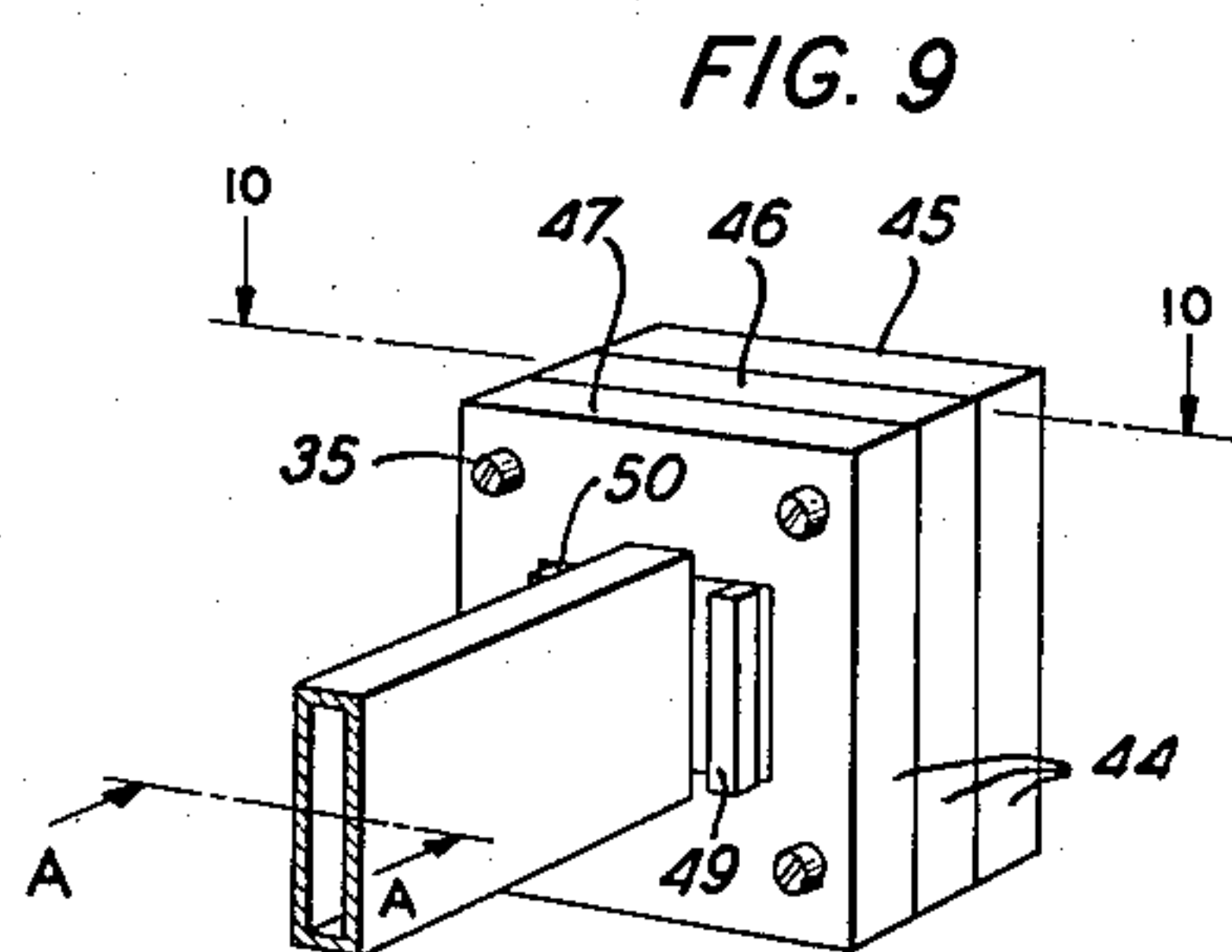
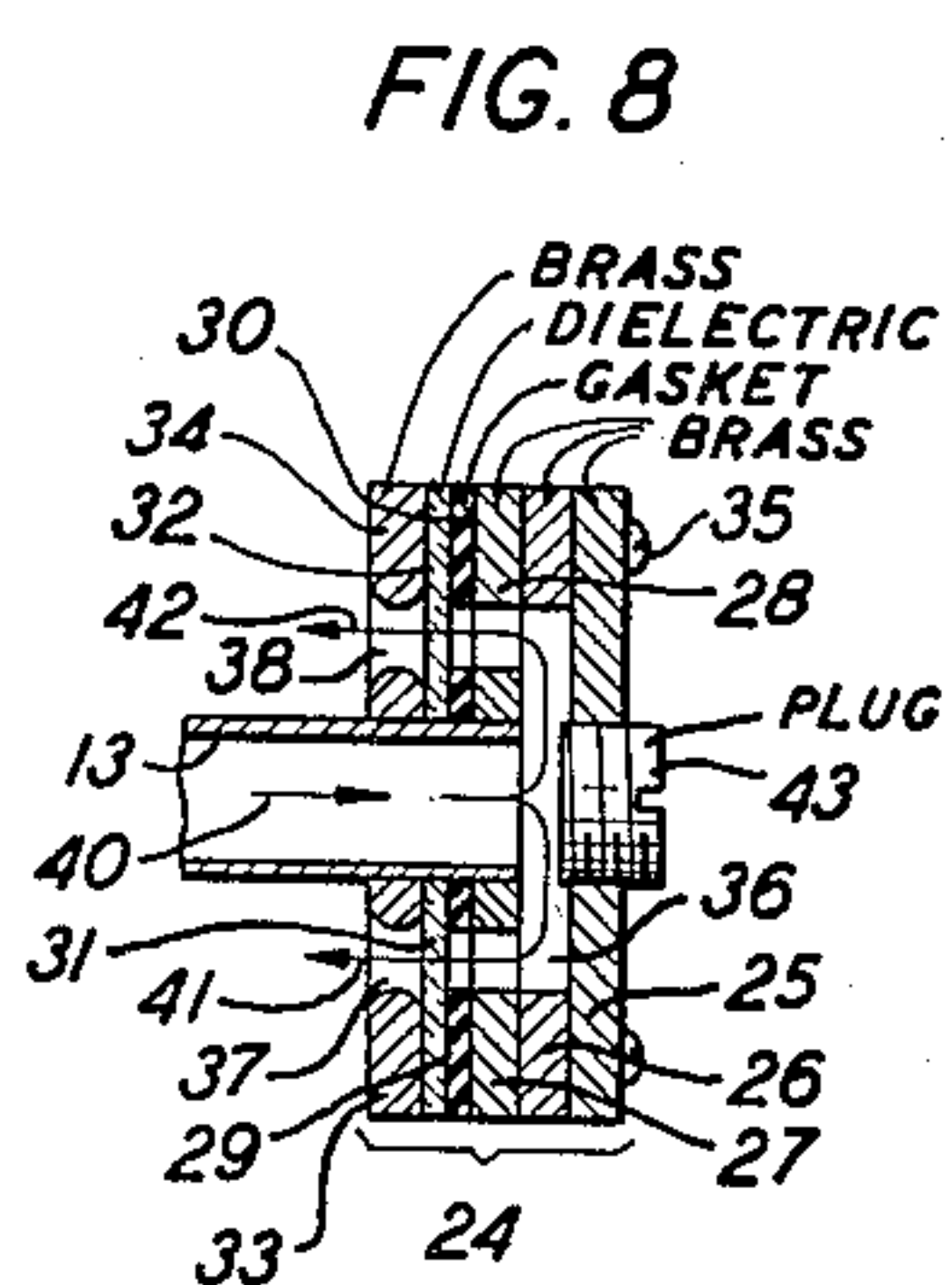
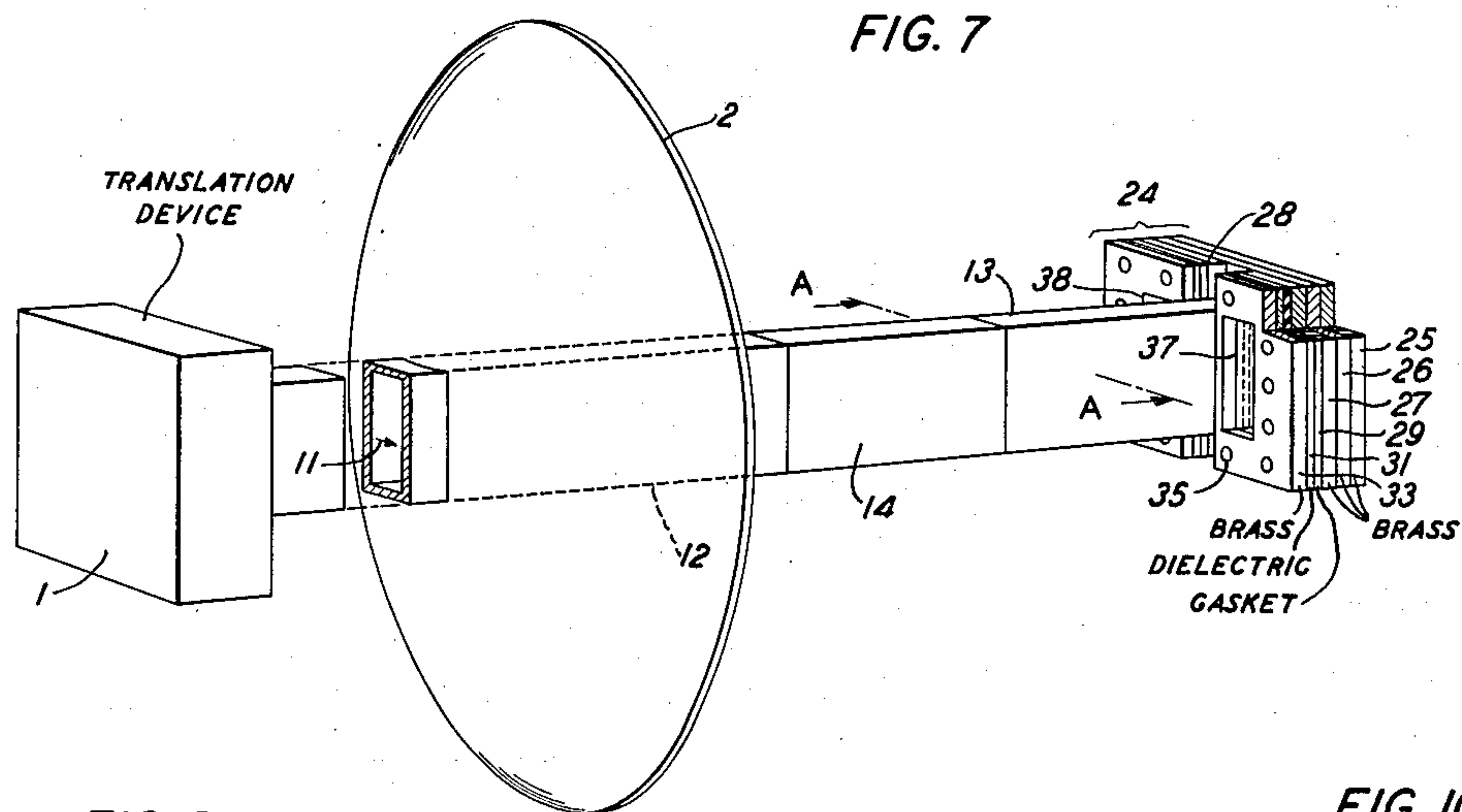
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DIRECTIONAL MICROWAVE ANTENNA

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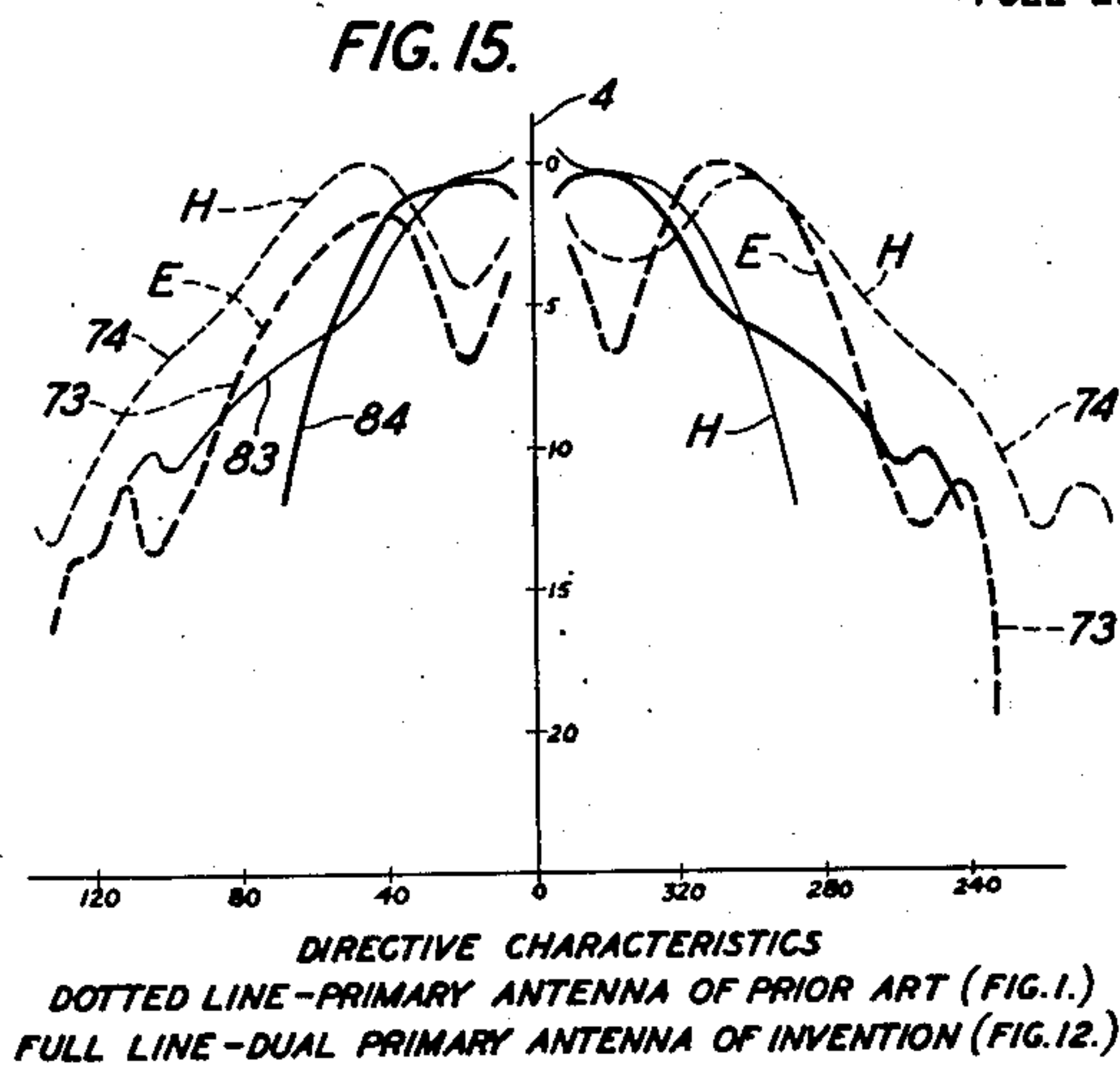
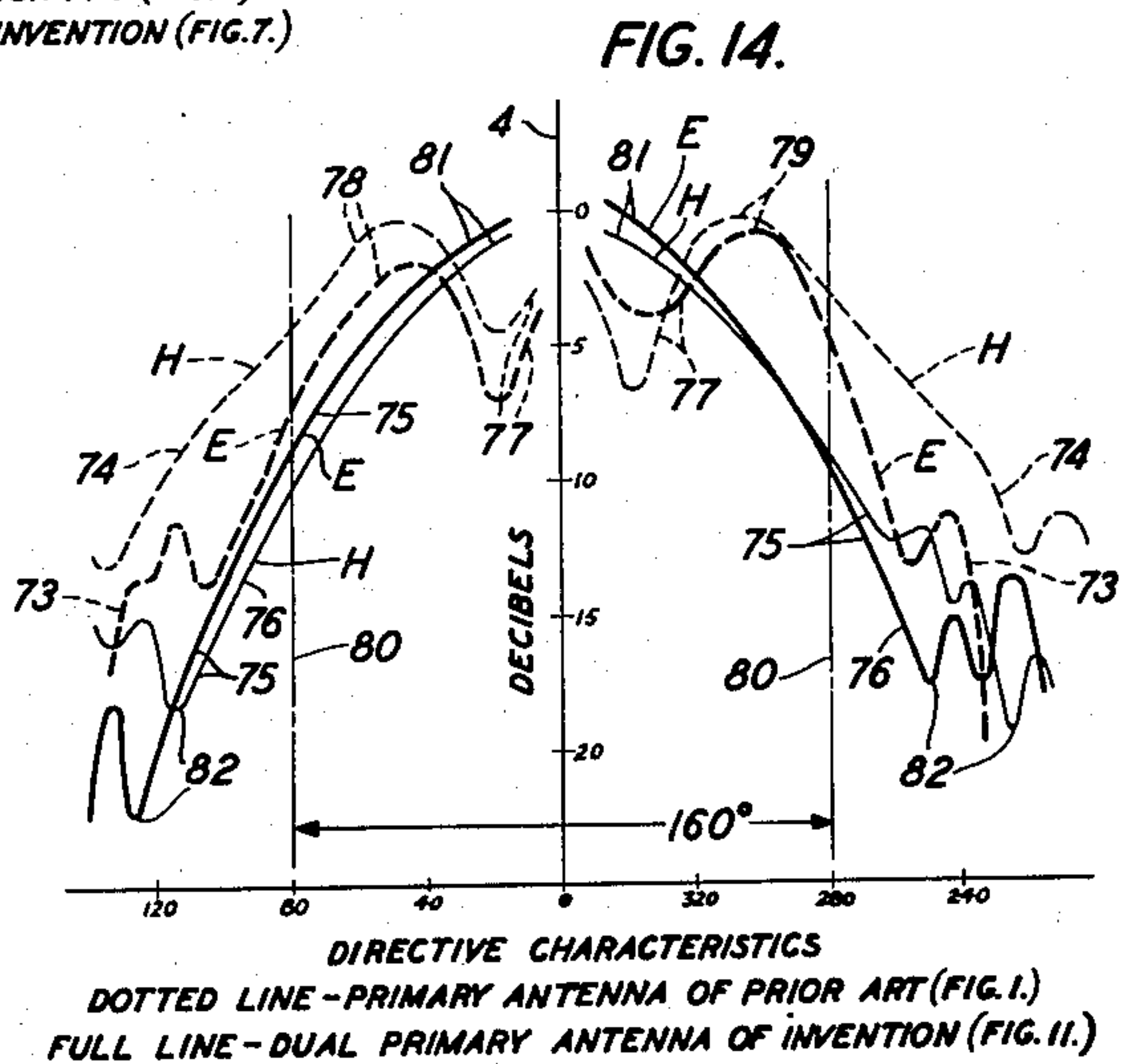
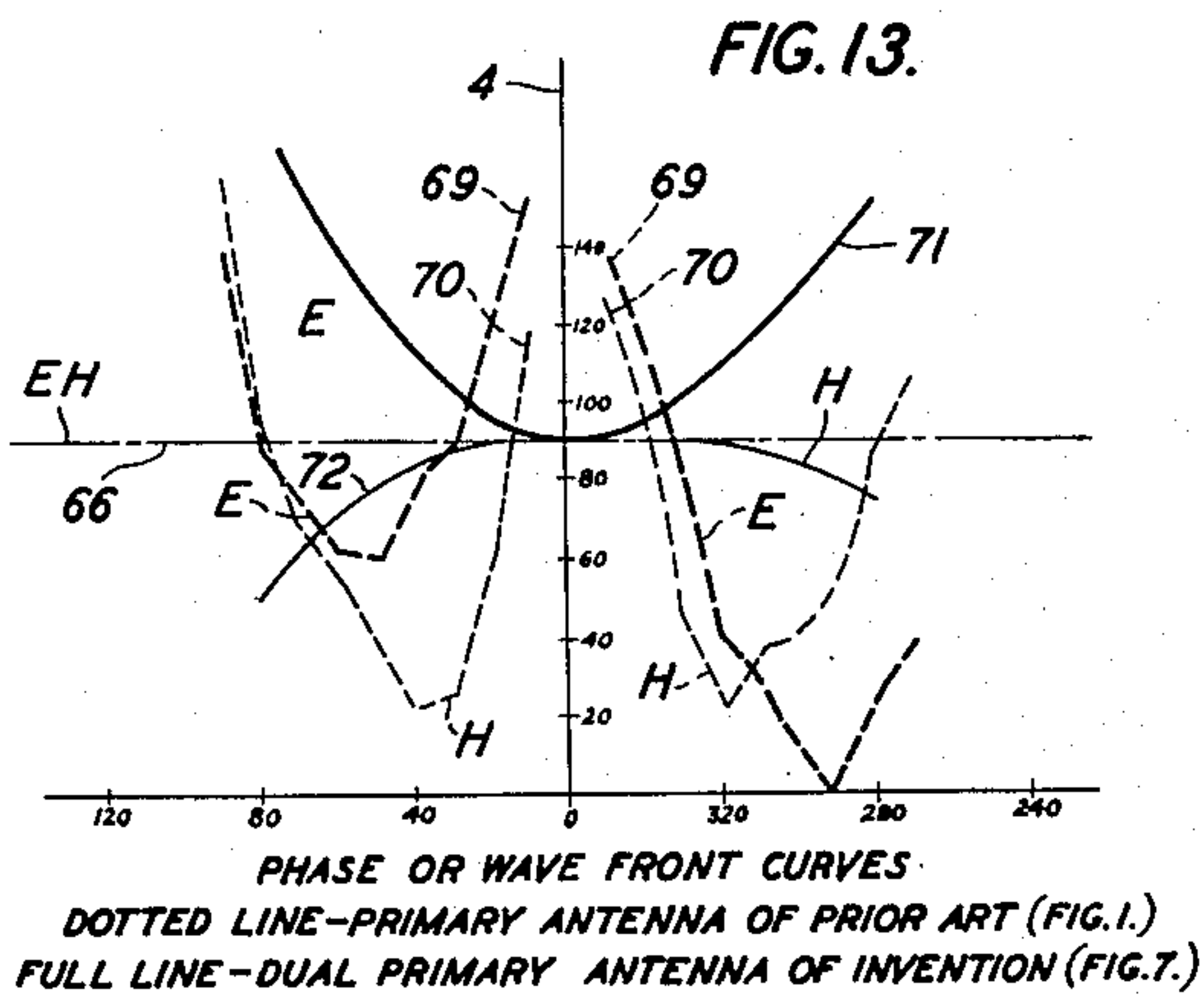
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DIRECTIONAL MICROWAVE ANTENNA

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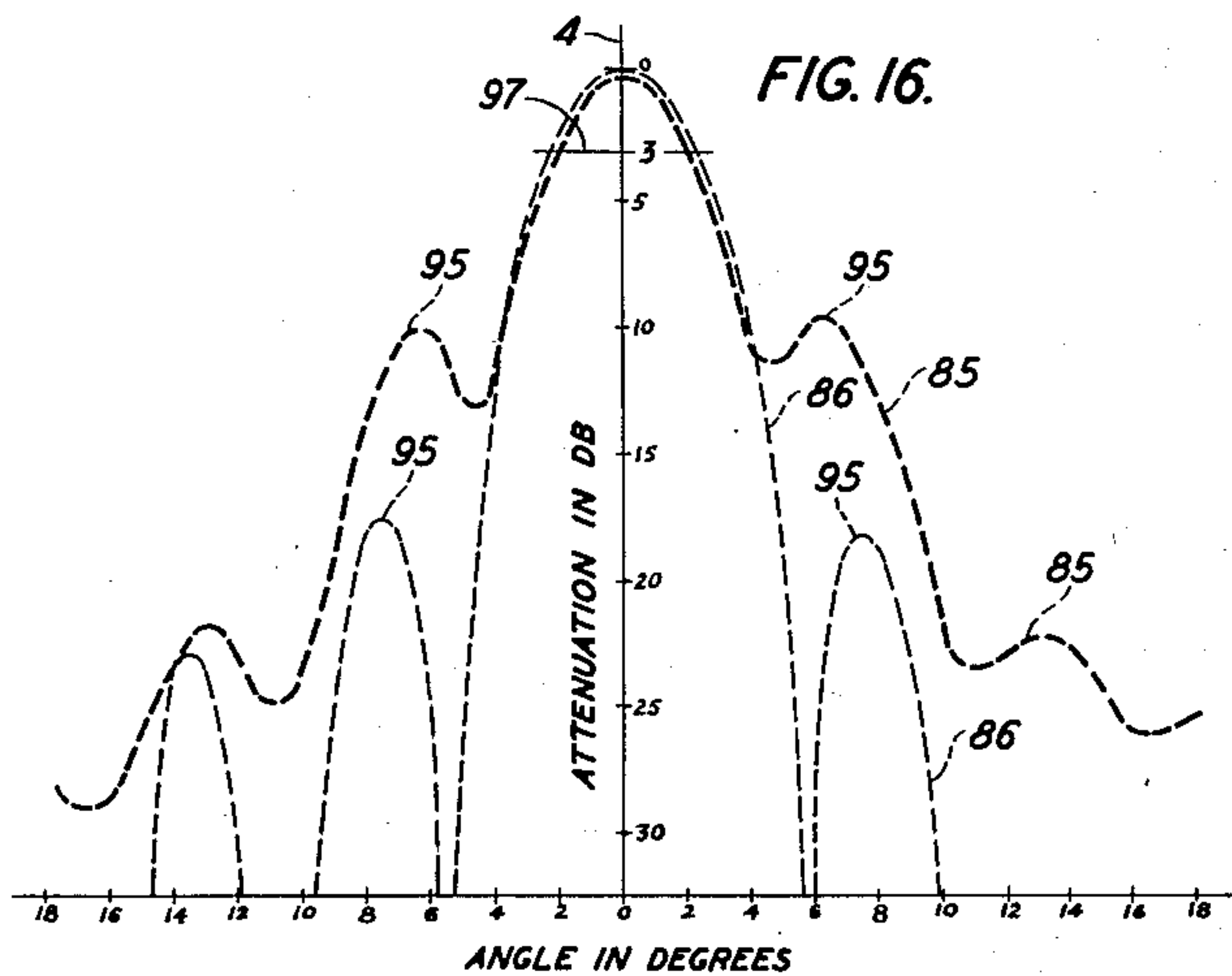
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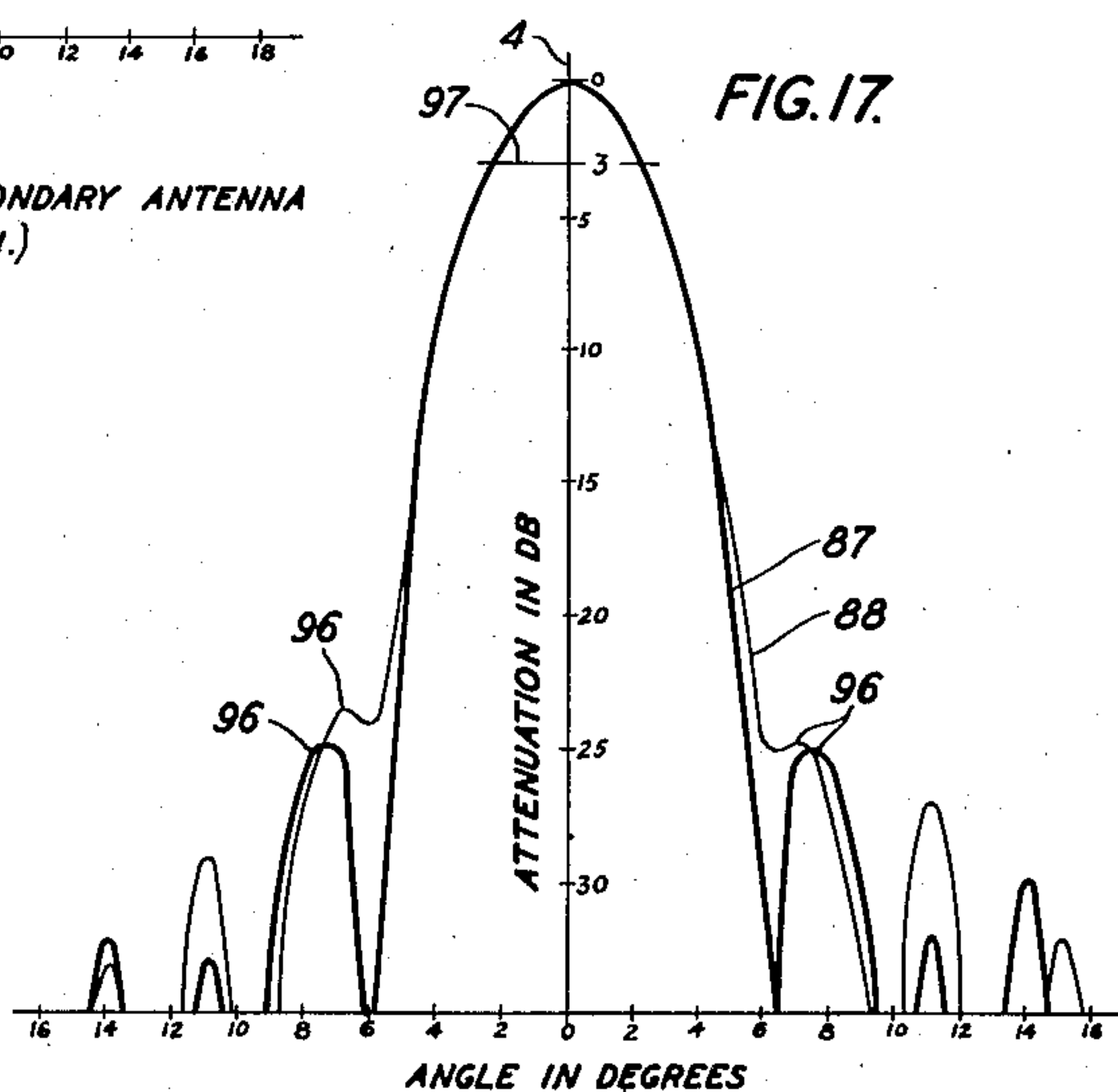
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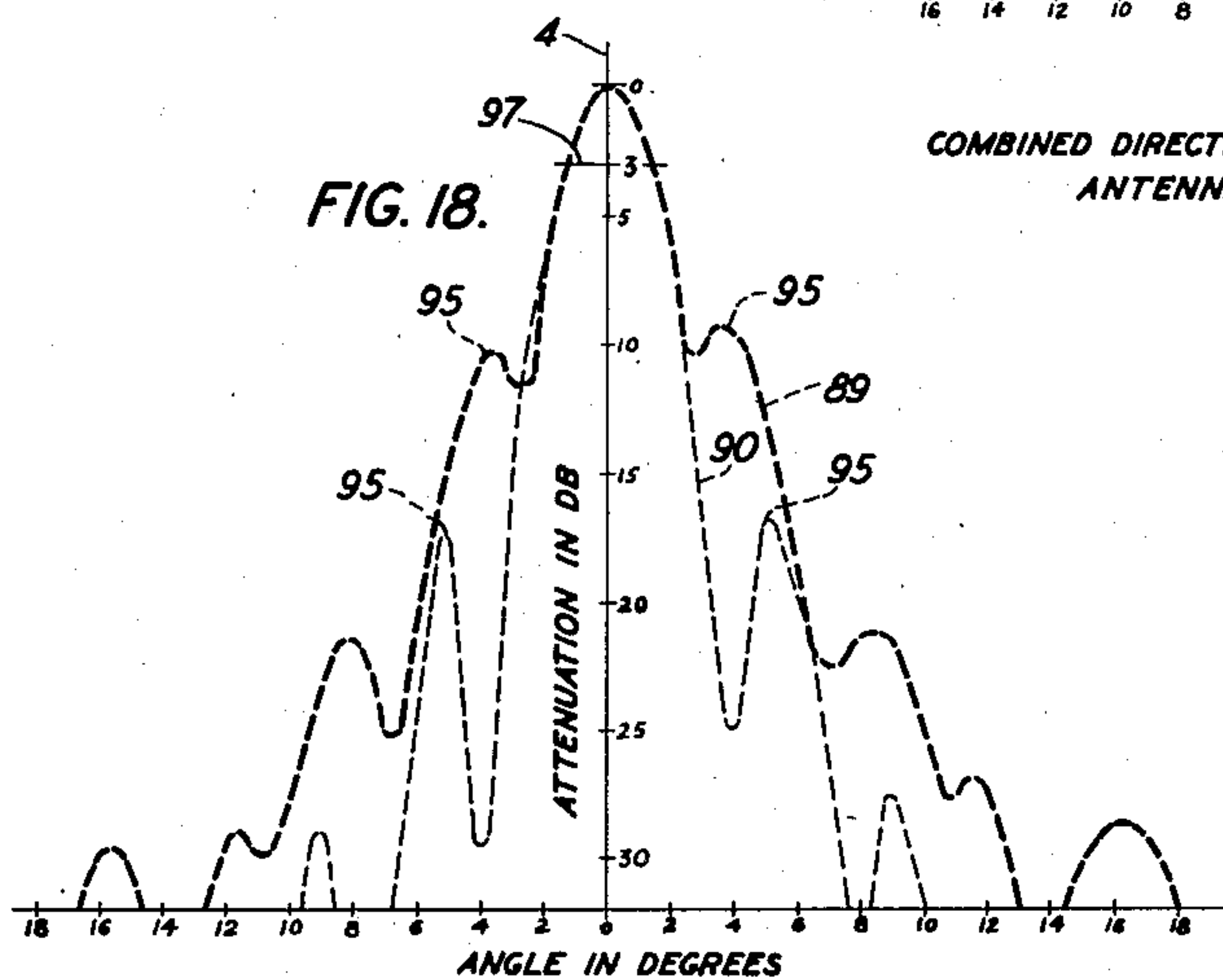
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COMBINED DIRECTIVE CHARACTERISTIC OF SMALL SECONDARY ANTENNA AND PRIOR ART PRIMARY ANTENNA (FIG. 1.)



COMBINED DIRECTIVE CHARACTERISTIC OF SMALL SECONDARY ANTENNA AND DUAL PRIMARY ANTENNA



COMBINED DIRECTIVE CHARACTERISTIC OF LARGE SECONDARY ANTENNA AND PRIOR ART PRIMARY ANTENNA (FIG. 1.)

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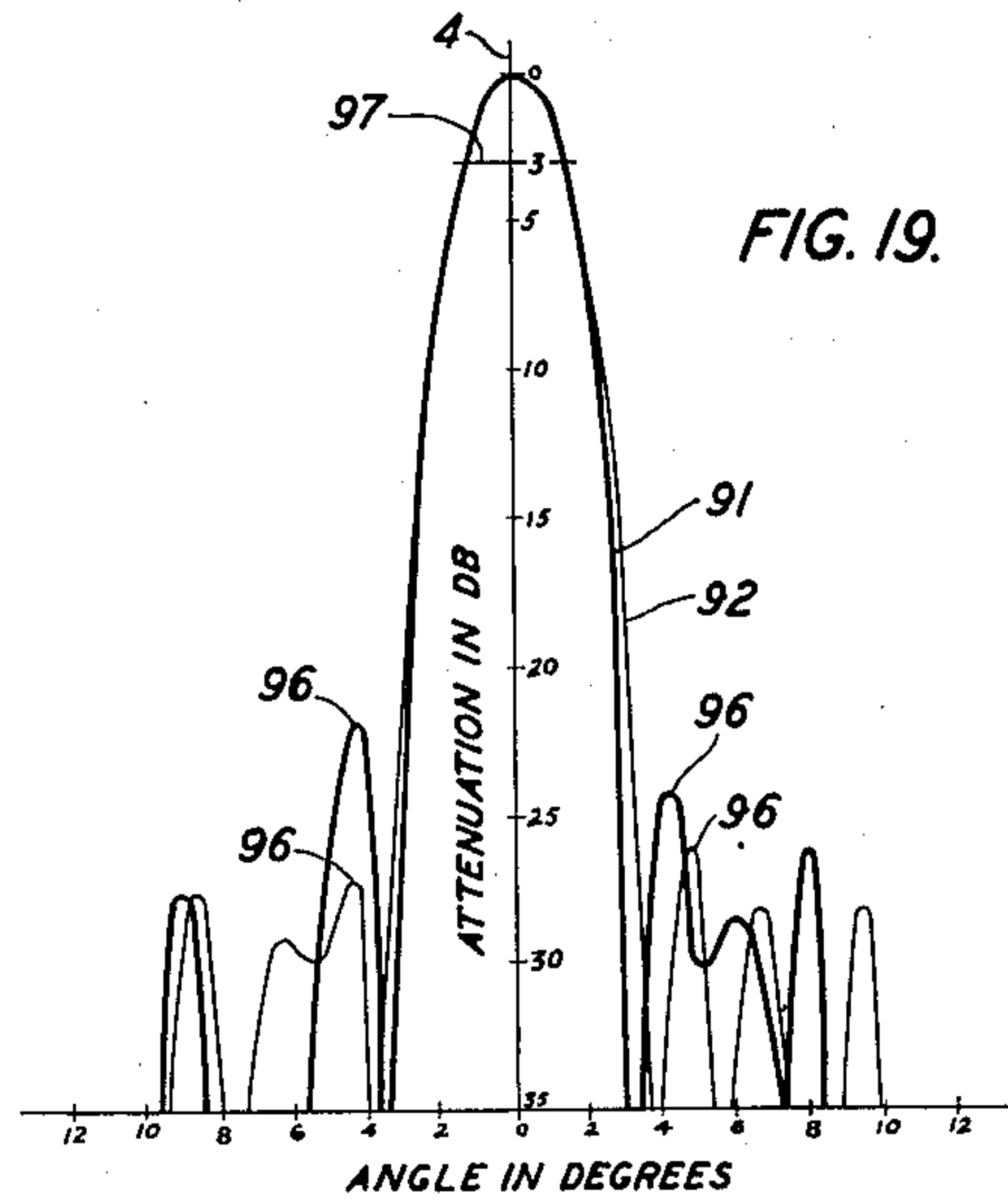
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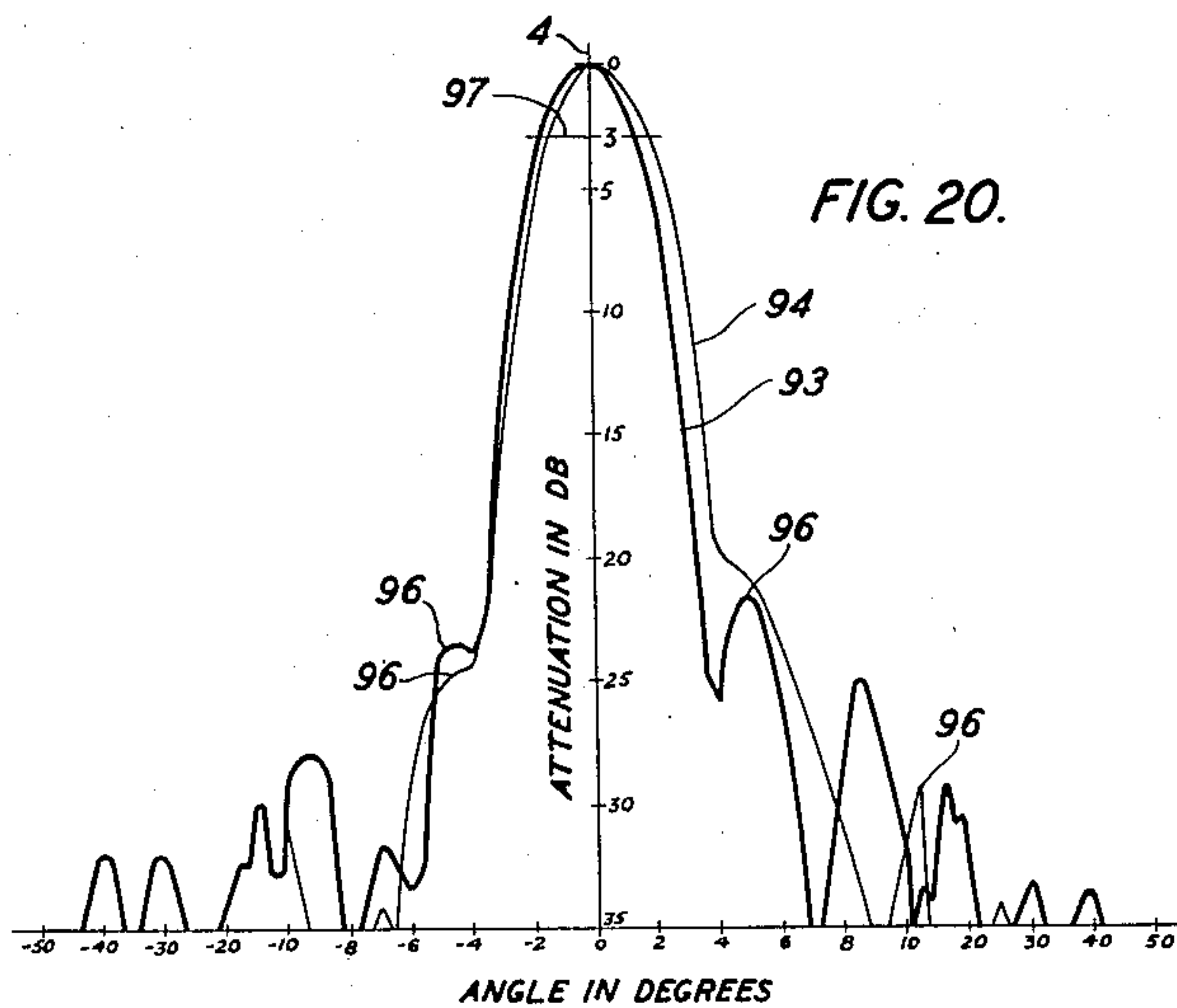
DIRECTIONAL MICROWAVE ANTENNA

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COMBINED DIRECTIVE CHARACTERISTIC OF LARGE
SECONDARY ANTENNA AND DUAL PRIMARY ANTENNA OF FIG. 7.



COMBINED DIRECTIVE CHARACTERISTIC OF LARGE
SECONDARY ANTENNA AND DUAL PRIMARY ANTENNA OF FIG. 11.

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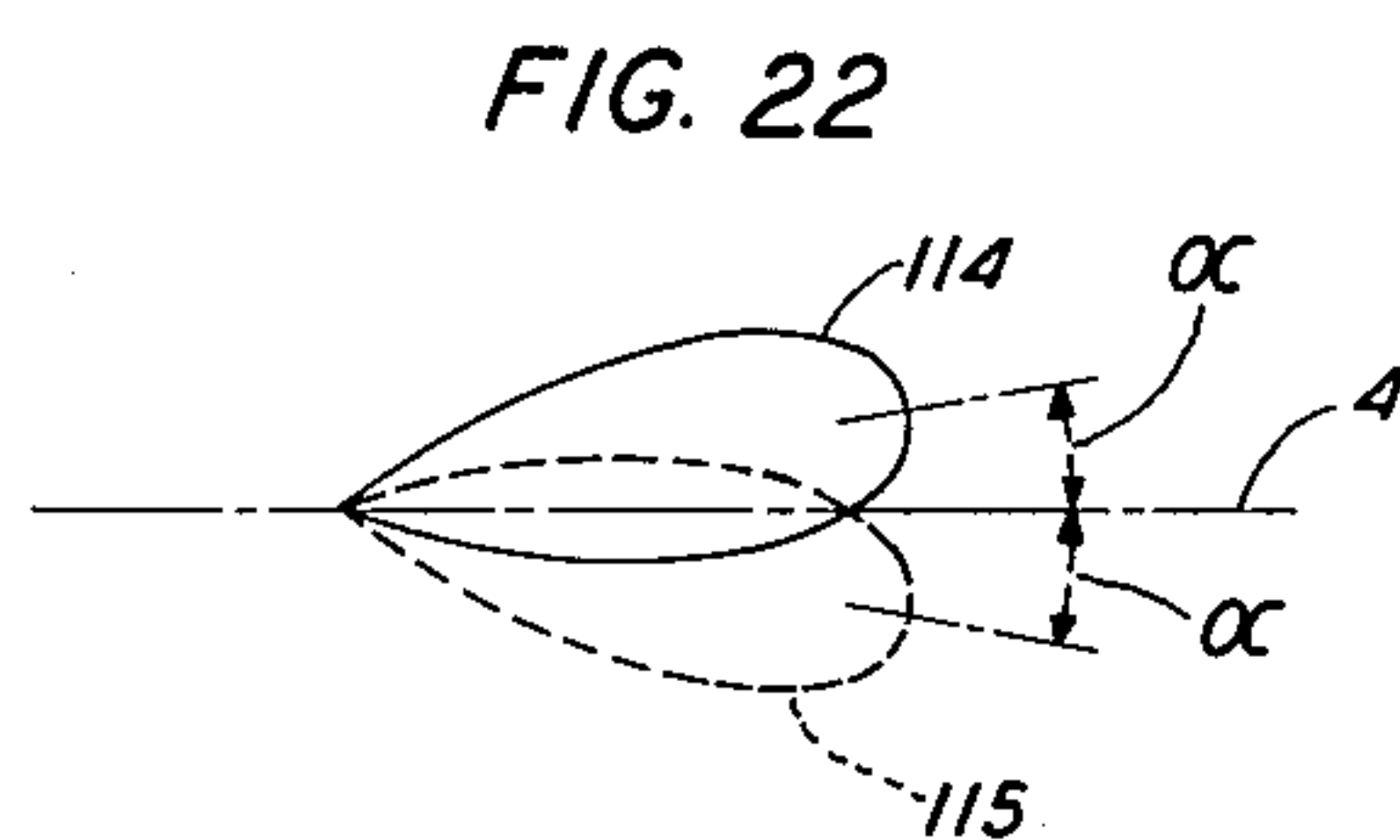
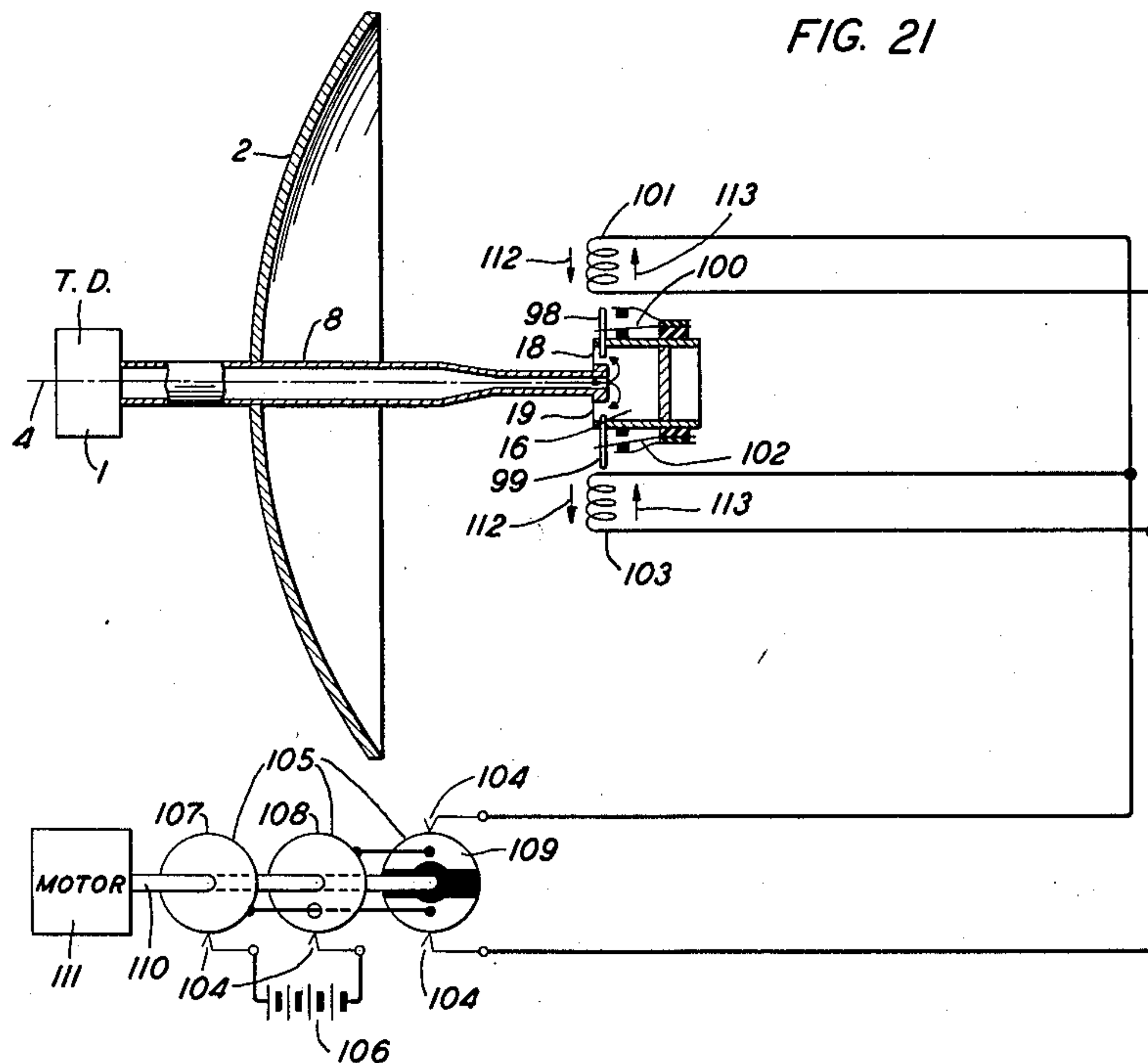
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DIRECTIONAL MICROWAVE ANTENNA

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6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

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DIRECTIONAL MICROWAVE ANTENNA

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20 Claims. (Cl. 250—11)

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This invention relates to directive antennas and particularly to highly directive microwave antenna systems.

As is known, lobe-sweeping, lobe-switching and lobe-rotating, or conical scanning antennas, are widely used for direction determination in radar systems. Also, directive antennas having a "fan" beam, that is, a wide vertical plane major lobe and a narrow horizontal plane lobe are commonly used in azimuthal lobe-sweeping radar systems; and directive antennas having a "point" beam, that is, a narrow vertical plane lobe and a narrow horizontal plane lobe are employed in lobe rotation systems and in dual plane (vertical and horizontal) lobe-sweeping systems. These directive antenna systems often include a cylindrical parabolic reflector or a paraboloidal reflector and, assuming horizontally polarized waves are used, the horizontal and vertical planes correspond, respectively, to the electric and the magnetic planes of the transceived wave. While fan beam antennas and point beam antennas are being used with success, the results secured with the prior art point beam antennas are not always entirely satisfactory because, among other reasons, the shapes of the electric plane major lobe and the magnetic plane major lobe are not the same and the minor lobes are large. In the case of antenna systems utilizing as a secondary antenna a paraboloidal reflector having a point focus, the difference in the shapes of the two lobes may be due to the fact that the primary antenna associated with the reflector does not transceive a spherically shaped wave front and in this respect does not approximate a point source or a point receiving antenna.

In view of the above, it appears desirable to obtain, for use in any of the radar systems mentioned above, and especially for use in a lobe-sweeping radar designed for dual plane scanning, a highly unidirectional antenna of the point beam type having electric plane and magnetic plane lobes of the same shape, substantially, and each lobe having at the half-power value a very small angular width. Moreover, it appears desirable to secure, in a system utilizing a paraboloidal reflector as a secondary antenna, a unidirectional primary antenna or feed which transceives a spherical wave front and therefore simulates a theoretical point-transceiving element positioned at the focus. At the same time it appears desirable to secure for use with a paraboloidal reflector a primary antenna which, in one sense, excels the theoretical non-directional point-type antenna element, inasmuch as substantially all energy emitted by the primary antenna is directed to-

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ward the secondary antenna, and the intensity of the energization, commonly called "illumination," of the paraboloidal reflector is tapered from a maximum value near the reflection vertex to a minimum value at the reflector periphery, whereby energy loss and pronounced minor lobes are reduced and optimum energization of the paraboloidal reflector is attained.

As used herein, the term "quadrangular" generically includes square and rectangular and the term "rectangular" excludes square. Also, as used herein, the term "paraboloidal reflector" denotes a metallic reflector having a shape corresponding to that obtained by revolving a parabola about its principal axis. In general a "rear" feed is an arrangement in which the line or guide connected to the primary antenna extends from a point at the back of the paraboloid through the reflector vertex; and a "front" feed is an arrangement in which the guide or line extends across the front or opening of the reflector, but does not pass through the reflector. A wave front is defined as a surface or a line which is the locus of wavelets or wave components having the same phase angle.

It is one object of this invention to obtain highly unidirectional radiant action.

It is another object of this invention to obtain a point beam which is symmetrical about the principal beam axis.

It is another object of this invention to obtain an antenna having sharp electric and magnetic plane major lobes of the same shape.

It is another object of this invention to obtain, in an antenna system, a directive characteristic having negligible minor lobes and a maximum lobe having at the half power point an angular width which, for a given wavelength and a given size of parabolic reflector, closely approaches the smallest or minimum width obtainable, according to optical theory.

It is another object of this invention to energize a paraboloidal reflector in an optimum manner and with minimum energy loss.

It is another object of this invention to secure, for use with a secondary paraboloidal reflective antenna member, a unidirectional primary antenna which emits or receives a spherical wave front.

It is another object of this invention to secure, for use with a paraboloidal reflector, a primary antenna having negligible minor lobes and a major lobe the shape of which conforms to the size of the reflector opening.

It is a further object of this invention to obtain for a paraboloidal reflector a feed or pri-

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mary antenna possessing highly desirable electrical characteristics, but devoid of the objectionable complicated mechanical features included in wave guide feeds of the "front" type and devoid of the likelihood of voltage breakdown inherent in coaxially-fed dipole primary antennas.

In accordance with one embodiment of the invention, the feed or primary antenna for a paraboloidal reflector comprises a metallic rectangular wave guide connected to a transceiver and extending from a point at the back of the reflector through the reflector vertex to a point at or near the reflector focus, the guide having at its end a rectangular transverse opening facing away from the reflector. An antenna "head" containing a tuned chamber and having a reflective wall facing the guide opening and a pair of rectangular antenna apertures of equal size facing the paraboloidal reflector, is provided for receiving the open ended guide. The guide is connected to the head at a point midway between the two antenna apertures. The long transverse dimension of the rectangular guide is preferably, but not necessarily, greater than the corresponding dimension of each antenna aperture. Also, the long transverse dimensions are substantially parallel to each other and to the magnetic plane of the TE₀₁ wave utilized, and the antenna apertures are spaced in the electric plane of the wave. The metallic guide section extending along the reflector axis has a threefold function, viz., (1) to convey energy between the transceiver and the dual antenna apertures, (2) to shield, at least to some extent, each antenna aperture from the other aperture and from approximately one-half the paraboloidal reflector, and (3) to guide the waves emitted by either aperture toward its associated half section of the paraboloidal reflector. Considered differently, the linear guide and the apertured head form a T-shaped wave guide, the two antenna apertures constituting a dual primary antenna and the linear wave guide section constituting a "rear" feed for the dual primary antenna. It should be noted particularly that the two antenna apertures face different halves of the paraboloidal reflector, and while in one sense the two antenna apertures constitute an array, since they are simultaneously energized by means of a common wave guide, strictly considered, they do not form an array because they are shielded from each other and their directive characteristics are not combined or multiplied to secure a resultant directive characteristic. In other words, the two antenna apertures do not have a space factor directive characteristic.

In operation, similarly polarized cophasal wave components are transceived by the two antenna apertures. The wave front transmitted or received by each aperture is substantially circularly shaped in the magnetic plane and circularly shaped in the electric plane, by reason of the spacing between the antenna apertures and the critical value of the long transverse aperture dimension. Hence a semispherical wave front is transceived by the entire structure comprising the two antenna apertures. Also, the intensity of the waves supplied to the rim or periphery of the paraboloidal reflector is approximately eight to ten decibels below that supplied to the apex region, whereby the minor lobes of the overall directive characteristic are relatively small and the energy loss caused by wave components emitted by the primary dual antenna and avoiding the paraboloidal reflector is negligible. The magnetic and electric plane directive characteristics

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for the primary antenna are substantially the same, and similarly, the combined magnetic and the combined electric plane directive characteristics for the entire structure or system are substantially the same. For a paraboloidal reflector having a given aperture, the angular beam widths, as measured at the half-power points of the magnetic and electric plane major lobe patterns, are only 7 per cent greater than the corresponding theoretical minimum widths obtainable with uniform illumination of a reflector having the same 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 and 2, are, respectively, a modified sectional plan view and an end view of a prior art system shown here for the purpose of explaining the invention;

Figs. 3, 4 and 5 are, respectively, a modified plan view in section, a side view in section and a front view of a simple embodiment of the invention, and Fig. 6 is a detail transverse cross-sectional view of this embodiment;

Figs. 7 and 8 are, respectively, a perspective view and a partial elevational cross-sectional view of the preferred embodiment of the invention;

Figs. 9 and 10 are, respectively, a perspective view and an elevational view of a dual primary antenna which may be substituted for the dual primary antenna shown in Figs. 7 and 8;

Figs. 11 and 12 are perspective views of different primary dual antennas either of which may be used in place of the primary dual antenna of Figs. 7 and 8;

Fig. 13 illustrates the phase or wave front characteristics, and Figs. 14 and 15 each illustrate the directive characteristics, of both the prior art primary antenna of Figs. 1 and 2 and a dual primary antenna constructed in accordance with the invention;

Figs. 16 and 17 are, respectively, sets of directive curves for a system comprising a given size paraboloidal reflector associated with the prior art primary antenna and a system comprising a paraboloidal reflector of the same size associated with a dual primary antenna of the invention;

Fig. 18 is a set of directive curves for a system comprising a larger paraboloidal reflector associated with a prior art primary antenna, and Figs. 19 and 20 are sets of directive curves for systems each comprising the large reflector associated with a dual primary antenna of the invention;

Fig. 21 illustrates the embodiment of Fig. 3 arranged for lobe-switching, and Fig. 22 is a lobe-switching diagram used in explaining the operation of the system of Fig. 21.

Referring to the prior art system of Figs. 1 and 2, reference numeral 1 denotes a translation device which may be a microwave transmitter or receiver, or a radar transceiver, and numeral 2 denotes a circular paraboloidal reflector having a vertex 3, a principal axis 4, a focus 5, a focal plane 6 and an opening or aperture 7. Numeral 8 designates a metallic wave guide extending horizontally from device 1 through the reflector vertex 3 and along the reflector axis 4, the guide 8 having an end opening 9 positioned near the focus 5. The guide 8 may be circular, square or rectangular. Numeral 10 denotes a plane metallic reflector or "disc" centered on the axis 4 and facing both the guide opening 9 and reflector 2. The plane reflector has a larger area than the guide open-

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ing 9 and is adjacent the focal plane 6 of the reflector. The guide opening 9 and the disc reflector 10 together constitute the primary antenna, and the paraboloidal reflector constitutes the secondary antenna, of the complete antenna system. Since guide 8 extends from a point at the back of reflector 2 through the reflector vertex and along the reflector axis to the primary antenna, the primary antenna is rear-fed. As shown by arrow 11, the system is arranged to utilize horizontally polarized waves. In this connection it should be understood that the waves may be polarized in any other plane as, for example, the vertical plane.

Referring to the embodiment of the invention illustrated by Figs. 3, 4, 5 and 6, wave guide 8 comprises a rectangular section 12 having a relatively large short transverse dimension, a rectangular section 13 having a smaller short transverse dimension, and a tapered rectangular section or impedance transformer 14 connecting sections 12 and 13, the three sections being colinear and having their longitudinal axes aligned with the reflector axis 4. The guide section 13 has a rectangular end opening 15 facing away from the reflector 2 and positioned near the focus 5. Numeral 16 denotes a chamber connected to guide section 13 and having a reflective wall 17 facing the guide opening 15 and a pair of rectangular antenna apertures 18 and 19 facing reflector 2. Apertures 18 and 19 have their centers spaced in the electric plane of the wave a distance 20; and these apertures constitute a dual primary antenna for the secondary antenna 2. As shown in Fig. 6, the antenna apertures 18 and 19 each have a short transverse dimension 21 and a long transverse dimension 22. Numeral 23, Fig. 3, denotes a threaded plug for tuning chamber 16 and matching the impedance of the guide opening 15 to the combined impedance of the antenna apertures 18 and 19.

In general, the long transverse dimension 22 of each aperture 18 and 19 determines the width in the vertical or magnetic plane of the major lobe of the primary antenna 18, 19; and the spacing 20 between apertures 18 and 19 determines the width in the horizontal or electric plane of the aforementioned primary antenna major lobe. For shallow paraboloidal reflectors, the dimension 22 and the aperture spacing 20 should both be relatively large whereas, for deep paraboloidal reflectors, the dimension 22 and the aperture spacing should both be relatively small. Hence, the long transverse dimension 22 and the aperture spacing 20 are related to the shape, shallow or deep, of the paraboloidal reflector, the shape being indicated or determined by the solid angle subtended by the reflector rim and having its vertex at the reflector focus, or by the ratio of the aperture diameter to the focal length. For example, in one specific embodiment designed for a wavelength of 3.2 centimeters, the paraboloidal reflector has an aperture diameter of approximately 30 inches corresponding to 76.2 centimeters and 23.8 wavelengths, and a focal length of about 12.6 inches corresponding to 32 centimeters and 10.0 wavelengths, the ratio of aperture diameter to focal length being approximately 2.38. The spacing 20 between the two apertures of the dual primary antenna used in this specific embodiment is about 0.625 inch corresponding to 1.6 centimeters and 0.5 wavelength; and each aperture has a short transverse dimension 21 of 0.125 inch corresponding to 0.315 centimeter and 0.1 wavelength, and a long transverse dimension

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22 in the order of 0.75 to 1.25 inches corresponding to 1.9 to 3.2 centimeters and to 0.594 to 1.0 wavelength, whereby the wave front produced by the primary antenna is spherical and the paraboloidal reflector is illuminated in an optimum manner. Since, for paraboloidal reflectors of certain size and shape, the transverse dimensions of each antenna aperture are smaller, respectively, than the corresponding transverse dimensions of the guide section 13 and the end opening 15, the metallic guide 8 shields, at least to some extent, each antenna aperture from the other antenna aperture and from approximately one-half the paraboloidal reflector 2.

The embodiment illustrated by the perspective view, Fig. 7, and the partial cross-sectional view, Fig. 8, is substantially the same as the embodiment of Figs. 3, 4, 5 and 6, the primary difference being that a tuned chamber of different construction is utilized. In Figs. 7 and 8, numeral 24 denotes an antenna head comprising the two full-size brass plates 25 and 26, the two half-size brass plates 27 and 28, the two gaskets 29 and 30 made of dielectric material, such as rubber, the two dielectric windows 31 and 32 formed of mica or similar material, and the two brass cover plates 33 and 34, all held securely together by brass screws 35. The head 24 contains a chamber formed by a large cavity 36 in plate 26, the antenna aperture 37 extending through members 27, 29 and 33, and the antenna aperture 38 extending through members 28, 30 and 34. The windows 31 and 32 extend transversely across apertures 37 and 38, respectively. As shown by arrows 40, 41 and 42, in transmission, the waves pass from the guide 13 into the cavity 36 and through the two antenna apertures 37 and 38. Numeral 43 denotes a threaded plug for tuning the above described chamber.

Figs. 9 and 10 illustrate a primary antenna or head 44, which may be utilized in place of the primary antenna 24, Figs. 7 and 8, as is indicated by the line AA in Figs. 7, 8, 9 and 10. In Figs. 9 and 10, reference numerals 45, 46 and 47 denote brass members fastened together by brass screws 35. As shown in Fig. 10, the member 46 contains a large rectangular cavity 48 and member 47 contains two spaced rectangular apertures 49 and 50. The cavity and the two apertures may be filled with a dielectric material, such as polystyrene, for pressurization. The polystyrene in each of apertures 49 and 50 extends a slight distance beyond the outer surface of the brass member 47, and the two rectangular polystyrene loaded apertures 49 and 50 constitute the primary antenna for reflector 2. Numeral 51 denotes a rectangular polystyrene protuberance which extends into the open ended guide section 13 and functions as a means for matching the guide to the primary antenna. Numeral 52 designates a rubber washer included between the E-shaped polystyrene member and the brass member 47. The chamber formed by cavity 48 and apertures 49, 50, is tuned by means of the plug 43.

Figs. 11 and 12 are perspective views of alternative heads, either of which may be used in place of the head 24, Figs. 7 and 8, as is indicated by the line AA. Referring to Fig. 11, the head 53 contains a cavity, which is similar to the cavity 48, Fig. 10, and comprises a brass member or washer 54, a central gasket 55, and a pair of front dielectric members 56, 57, the members being fastened together by means of fiber screws 58. The brass washer and the gasket each contain a pair of rectangular apertures shown by

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the dotted lines 59, 60 and corresponding to the primary antenna 18, 19 of Fig. 6 and the polystyrene dual primary antenna 37, 38 of Fig. 7. The dielectric members 56, 57 constitute separate windows for the two antenna apertures and protect the apertures from the weather. A tuning plug (not shown) is provided at the back of the brass member 54, the plug having a reflective surface facing the end opening in guide section 13.

The head illustrated by Fig. 12 comprises an air-filled rectangular chamber 61 having two rectangular apertures equipped with short rectangular wave guide sections 62 and 63, the opposite sides of each section being parallel and each of the sections having an antenna aperture 64. Sections 62, 63 hereinafter termed "horns" or "horn sections" extend at an acute angle to the main wave guide section 13 and to each other, so that the antenna apertures 64 are spaced a relatively large distance apart. Numeral 65 denotes a piston for tuning the chamber 61.

In all of the embodiments described above, assuming the device 1 is a transceiver, horizontally polarized microwave energy having a wavelength of 3 centimeters, for example, is supplied by device 1 to guide 8 and to the opening at the end of guide 8. In the prior art device of Fig. 1 the disc reflector 10 functions to direct at least a portion of the energy towards the paraboloidal reflector 2. In the embodiments of the invention, Figs. 3, 7, 9, 11 and 12, the waves emanating from the open-ended wave guide are redirected or projected by the reflective wall in the head through the two antenna apertures toward the paraboloidal secondary antenna. The circular paraboloidal reflector functions to direct the energy along the general direction of the reflector axis 4. As explained below, the dual primary antenna of the invention functions in a more satisfactory manner than the prior art primary antenna illustrated by Fig. 1. Before comparing, however, the characteristics of the dual primary antenna constructed in accordance with the invention and the prior art disc primary antenna, the requirements and conditions for optimum operation, for a system comprising a paraboloidal secondary antenna associated with a primary antenna at the focus, will be considered. While the case of transmitting will be discussed, it should be understood that the so-called reciprocal theory applies and that, in reception, the converse operation obtains.

First of all, since a circular paraboloidal reflector functions to convert a spherical wave front into a plane wave front extending perpendicular to the reflector axis, maximum gain and maximum directive action along the reflector axis are achieved, theoretically, only when the wave front established by the primary antenna is exactly spherical. Stated differently, for optimum operation and maximum gain, the energization or illumination should be such that the wave components supplied to all parts of the reflector are, after reflection, cophasal. Also, the polarizations of the wavelets emitted by the primary antenna in the diverse radial directions should be such that, after reflection by the paraboloidal reflector, the polarizations are parallel. Moreover, for optimum gain, the energization of a paraboloidal reflector having a circular aperture should be circularly symmetrical. It has been found in practice that a feed fulfilling the above conditions will have an intensity of illumination which decreases or tapers uniformly from a maximum at the reflector vertex to a minimum at the re-

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flector periphery. It has been found, also, that with reflectors having apertures greater than two or three wavelengths, the energy radiated per unit solid angle by the primary antenna toward the reflector rim should be between eight and ten decibels less than that radiated toward the reflector vertex. For an evenly-energized circular paraboloidal reflector, the secondary directive lobes are seventeen decibels below the primary lobe, and for a paraboloidal reflector having a uniformly tapered illumination, the secondary lobes are considerably more than seventeen decibels below the greatest intensity value of the primary lobe. For a given primary antenna fulfilling the requirements of beam shape, polarization and phase, there will be an optimum shape of paraboloidal reflector, that is, an optimum ratio of aperture diameter to focal length, the focal length being the distance between the focus 5 and the apex 3. This optimum ratio should be such that the primary energy per unit solid angle directed toward the edge of the paraboloidal reflector is of the order of 8 to 10 decibels below that directed toward the vertex. In the specific embodiment described in detail above the optimum ratio is 2.38. In addition, assuming the wave front established by the primary antenna is not exactly spherical, the surface of the paraboloidal reflector may be altered to conform with the phase characteristic of the primary antenna. Thus, if desired the reflector surface or shape may be determined by adding the length given by the following equation:

$$l = \frac{\lambda \phi}{2\pi(1 + \cos \theta)}$$

where

ϕ = phase deviation in radians from spherical radiation. That is, phase deviation at any point in the radiation field, from some reference point at the same radial distance from an assumed center of radiation.

θ = angle between any segment of the paraboloidal reflector and its axis.

Referring now to Fig. 13, numeral 66 denotes the superimposed theoretical phase curves, in the electric or "E" plane and in the magnetic or "H" plane, of an ideal primary antenna which emits or receives a true spherical wave front. As shown by the straight line 66, for the ideal primary antenna the phases of the wavelets arriving at the circumference of a circle included in the electric plane and having its center at the focus or primary antenna, are the same. Also, as shown by the same curve 66, in the magnetic plane, the in-phase wavelets lie on the circumference of a circle. The circular electric plane wave front and circular magnetic plane wave front are represented by curves 67 and 68 in Figs. 3 and 4, respectively. In Fig. 13 numerals 69 and 70 denote, respectively, the electric and magnetic plane phase curves for the prior art primary antenna of Fig. 1, and numerals 71 and 72 denote, respectively, the electric and magnetic plane phase curves for a primary antenna constructed in accordance with the invention and resembling the primary antenna 59, 60 illustrated by Fig. 7. It will be noted that, for both the electric and magnetic planes, the phase curve, 69 or 70, for the prior art system, is highly peaked and extremely irregular, whereas the phase curve, 71 or 72, for the primary antenna of the invention is fairly flat and approaches, much more closely, the ideal flat phase curve 66. Hence, as regards the spher-

icality of the emitted wave front, the primary antenna of the invention, as illustrated by Fig. 7, for example, more closely simulates the ideal point source than the prior art antenna and, as a result, the directive action of the paraboloidal reflector considered by itself is more satisfactory.

Referring to Figs. 14 and 15, it will be seen the directive characteristic of the dual primary antenna is more satisfactory than that of the prior art primary antenna comprising a disc reflector. In Fig. 14, reference numerals 73 and 74 denote, respectively, the E and H plane directive characteristics for the prior art primary antenna of Fig. 1, and numerals 75 and 76 designate the E and H plane directive curves for a dual antenna similar to that illustrated by Figs. 7 and 11. The electric plane and magnetic plane characteristics 73 and 74 for the prior art antenna are substantially different, and are therefore undesirable. Moreover, each characteristic contains, in addition to a central major lobe or peak 77, the two side lobes 78, 79 and a dip between each side peak and the central lobe. If the solid conical angle subtended by the circular aperture is, say, 160 degrees, as indicated by the lines 80 in Fig. 14, it is apparent that more than one major lobe of the prior art antenna impinges upon the paraboloidal reflector. In the other hand, considering the electric and magnetic plane characteristics 75 and 76 for the dual primary antenna of the invention, only one major lobe 81 impinges on the reflector, and the nulls 82 are not included in the conical angle mentioned above. Also, the contour of the principal lobe is such that the intensity decreases uniformly from a maximum at the reflector axis 4 to a value about ten decibels below maximum at the reflector rim. Consequently, the intensity of the wavelets which fail to impinge upon the paraboloidal reflector is small. It follows that, as regards the contour or shape of the wave front and the shape of the maximum lobe, the dual primary antenna of the invention possesses distinct advantages not found in the prior art disc primary antenna.

Fig. 15 illustrates for purpose of comparison the directive characteristic of the dual horn primary antenna illustrated by Fig. 12 and the prior art disc antenna of Fig. 1. In Fig. 15 reference numerals 83 and 84 designate the electric and magnetic plane directive characteristics for the dual horn and, as in Fig. 14, numerals 73 and 74 denote the electric and magnetic plane characteristic for the disc primary antenna of Fig. 1. As shown in Fig. 15 the dual horn E and H plane characteristics each contain one maximum lobe and this lobe is symmetrically disposed relative to the reflector axis 4. As in the case of the dual antenna of Fig. 11, the dual horn of Fig. 12, is in all respects superior to the prior art system of Fig. 1. The characteristics 75 and 76 for a dual primary antenna similar to those shown in Figs. 7 and 11 are for certain purposes more satisfactory than the characteristics 83 and 84 for the dual horn antenna of Fig. 12 and, in general, the embodiment of Figs. 7 and 8 is preferred over the embodiment of Fig. 12.

Referring to Figs. 16 and 17, numerals 85 and 86, Fig. 16, denote, respectively, the electric and magnetic plane directive characteristics for a system comprising a secondary paraboloidal antenna and the prior art primary antenna of Fig. 1, and numerals 87 and 88, Fig. 17, denote, respectively, the electric plane combined directive characteristic and magnetic plane combined directive characteristic for a system comprising a paraboloidal

reflector and a dual primary antenna similar to that illustrated by Figs. 7 and 11. The paraboloidal reflector in each of these two systems has an aperture diameter of fourteen wavelengths, as illustrated by the paraboloidal reflector 2' in Figs. 1 and 3. In Fig. 18, numerals 89 and 90 denote, respectively, the electric plane combined directive characteristic and the magnetic plane combined directive characteristic for a system comprising a paraboloidal reflector and the prior art primary antenna. In Fig. 19, numerals 91 and 92 denote, respectively, the electric plane combined directive characteristic and the magnetic plane combined directive characteristic for a system comprising a paraboloidal reflector and a dual primary antenna similar to that of Figs. 7 and 11. In Fig. 20, numerals 93 and 94 designate respectively, the electric and the magnetic plane combined directive characteristic for a paraboloidal reflector and a dual horn antenna similar to that illustrated by Fig. 12. The paraboloidal reflector in each of these three last mentioned systems is twenty-four wavelengths in diameter, as illustrated by the paraboloidal reflector 2 in Figs. 1 and 3. In this connection, it may be noted that feed horns constructed in accordance with the invention may be satisfactorily employed with paraboloidal reflectors having any diameter greater than two or three wavelengths.

Considering the two systems, each comprising a small paraboloidal reflector, it will be observed that the characteristics 85 and 86, Fig. 16 for the prior art system are greatly dissimilar, whereas the characteristics 87 and 88, Fig. 17, for the system of the invention are substantially identical. Also, the secondary lobes 95 of the electric and magnetic plane characteristics, Fig. 16, are relatively large, whereas the secondary lobes 96 of the electric and magnetic plane characteristics, Fig. 17, are relatively small, as is desired. Thus, in Fig. 16, the minor lobes 95 of characteristic 85 are only ten decibels below the major lobe peak whereas, in Fig. 17, the minor lobes are down below twenty-three decibels from the major lobe peak. Hence, in radar operation, while serious ambiguous directional indications may be obtained with the prior art primary antenna, the directional indications obtained with the dual primary antenna of the invention have much less likelihood of ambiguity. Also the gain of the prior art system is 0.5 decibel (31.1—30.6) less than the gain of the system of the invention. At the so-called half-power point of the major lobe, which point is represented by line 97 and is three decibels below the greatest value of the major lobe, the lobe width is about 4.4 degrees in both the electric and magnetic planes, and a true point beam is obtained, whereas in the prior art system, Fig. 16, the beam or major lobe widths 97 in the two planes differ considerably. Similarly, in the high gain systems, Figs. 18, 19 and 20, using the large paraboloidal reflector, the secondary lobes 95, Fig. 18, for the prior art system are large whereas the secondary lobes 96, Figs. 19 and 20, for the dual primary antenna are relatively small, the minor lobes 95, Fig. 18, being down only ten decibels, whereas the minor lobes 96, Figs. 19 and 20, are down twenty-three decibels. The gain for the dual primary antenna is, as shown in Fig. 19, greater than that of the prior art system. Note that the beam width at the half-power point 97, Fig. 19, for a system similar to the system of Fig. 7 or Fig. 11, is about 2.8 degrees in both the electric and magnetic planes. Hence in accordance with the invention, a high gain microwave an-

tenna, especially suitable for use with decimetric, centimetric or millimetric waves, is obtained having an optimum point beam and negligible minor directive lobes.

Referring to Fig. 21, which illustrates the embodiment of Fig. 3 modified for lobe-switching operation, the tuned antenna apertures 18 and 19 of the chamber 16 are equipped, respectively, with movable detuning plungers or relay armatures 98 and 99. Numerals 100 and 101 denote, respectively, a spring assembly and a relay winding associated with plunger 98; and numerals 102 and 103 designate, respectively, a spring assembly and a relay winding associated with plunger 99. The windings 101 and 103 are connected in parallel to each other and are connected through contacts 104 and a reversing switch 105 to a battery 106. The reversing switch comprises the discs 107, 108 and the sectored disc 109, all of which are mounted on shaft 110 and driven by motor 111.

In operation, Figs. 21 and 22, the currents flowing in the two windings are at any instant in the same direction, as is indicated by the arrows 112, one plunger being in the "in" or detuning position and the other plunger being in the "out" or tuning position. In other words, at any instant, one antenna aperture is detuned so that no energy flows therethrough and the other aperture is tuned and permits the flow of energy. During one revolution of the motor the direction of flow of the current in the windings is reversed, as shown by arrows 113, so that each of the antenna apertures 18 and 19 is successively tuned and detuned, and energy is directed toward the paraboloidal reflector 2, alternately, by antenna apertures 18 and 19. As shown in Fig. 22, with only one off-focus antenna aperture 18 or 19 energized, the direction of maximum action for the entire system is, as is well known, at an angle α to the reflector axis 4. As switch 105 actuates the plungers, the maximum lobe switches back and forth between the positions represented by numerals 114 and 115, Fig. 22, whereby the lobe-switching operation obtains.

Although the invention has been explained in connection with specific embodiments it is to be understood that it is not to be limited to the embodiments described inasmuch as other apparatus may be successfully employed in practicing the invention.

What is claimed is:

1. In a directive radio system, means for transmitting or receiving a wave having in a given plane a circular wave front substantially, said means comprising a dielectric chamber having a flat wall containing a pair of apertures spaced in said plane a half wavelength apart and a dielectric guide comprising a metallic tube for supplying to, or receiving from, said apertures isophased wave components, said guide extending in said plane perpendicular to the plane of said apertures and connected to said wall at a point midway between said apertures.

2. In a directive radio system, means for transmitting or receiving wave components forming in a given plane a semi-circular wave front, said means comprising a dielectric guide connected to a translation device and having a plurality of rectangular antenna apertures spaced in said plane approximately a half wavelength apart, the transverse or short side of each aperture being included in said plane and having a dimension in the order of 0.1 wavelengths, and the paths extending in said guide between said device and said apertures being electrically equal.

3. A system in accordance with claim 2, the long transverse dimension of each aperture being in the order of 0.5 to 1.0 wavelengths, whereby the wave front is semi-spherical, substantially.

4. In an antenna system, a concave reflector having a focus, a dielectric guide connected to a translation device, said guide extending through said reflector and having an end opening near said focus, a dielectric chamber or cavity completely enclosing the end of said guide, said chamber having a reflective wall facing said opening and an aperture facing said reflector, said aperture being smaller than said opening.

5. In an antenna system, a paraboloidal reflector and means including a translation device and a guide for supplying energy to, or receiving energy from, one-half of said reflector, substantially, said guide comprising a metallic tube filled with a dielectric and having a rectangular antenna aperture facing one-half of said reflector, the long transverse dimension of said aperture being parallel to the greatest aperture dimension of said half of said reflector.

6. An antenna system comprising a concave reflective antenna member having a finite focus, a given focal length and a circular opening of given diameter, a primary antenna therefor comprising a dielectric chamber having a pair of spaced apertures for supplying to, or receiving from, said member radiant energy, said focus being positioned between said apertures, the spacing between said apertures being a function of the ratio of said diameter to said focal length, and a dielectric guide comprising a metallic tube for connecting said chamber to a translation device.

7. An antenna system in accordance with claim 6, said reflective member having a principal axis passing through its mid-point or apex, said guide extending along said axis and constituting a means for shielding one aperture from one-half and the other aperture from the other half of said reflective member, substantially.

8. An antenna system comprising a secondary reflective antenna member having a focus and a principal axis, a primary antenna therefor comprising a resonant chamber having a pair of spaced apertures facing said member, a dielectric guide having an open end extending into said chamber at a point intermediate said apertures, a translation device connected to said guide, whereby the waves emitted or collected by said apertures are cophasal.

9. A system in accordance with claim 8, said chamber being filled with a dielectric material.

10. A system in accordance with claim 8, and a dielectric window covering said apertures.

11. An antenna system comprising a paraboloidal reflector having a focus and a principal axis, a primary antenna member therefor comprising a chamber having a pair of spaced apertures facing said reflector, a pair of angularly related horns attached to said apertures, a dielectric guide comprising an air-filled metallic tube positioned between said horns and having an open end extending into said chamber at a point intermediate said apertures, and a translation device connected to said guide.

12. An antenna system comprising a paraboloidal reflector, a primary antenna therefor comprising a resonant chamber having a pair of rectangular apertures facing said reflector and spaced in a given plane, an open-ended rectangular wave guide extending along the reflector axis between said reflector and chamber and

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projecting into said chamber at a point midway between said apertures, the linear dimensions of each aperture being less than the linear wave guide dimension in a plane perpendicular to the above-mentioned plane.

13. In an antenna system, a paraboloidal reflector, and means for energizing said reflector comprising a T-shaped dielectric guide extending through said reflector and aligned with the reflector axis, said guide having two antenna apertures each for energizing a different half portion of said reflector.

14. In an antenna system, a paraboloidal reflector, a dielectric guide comprising a metallic tube filled with a dielectric, said guide extending through said reflector and along the reflector axis, said guide having an opening at its end, a plane reflector facing said opening, and a pair of short dielectric channels included between said reflectors and each having an aperture facing said paraboloidal reflector.

15. An antenna system in accordance with claim 14, said guide being included between one aperture and a portion of said paraboloidal reflector and between the other aperture and a different portion of said paraboloidal reflector.

16. An antenna system comprising a paraboloidal reflector, a pair of wave guide rectangular apertures spaced in a given plane for simultaneously energizing different halves of said reflector, a short transverse dimension of each rectangular aperture being included in said plane, and a wave guide connecting said apertures to a transmitter, whereby in said plane the energization of said paraboloidal reflector is tapered from a maximum near the reflector apex to a minimum at the reflector edge and substantially all energy emitted by said apertures impinges upon said reflector.

17. In combination, a paraboloidal reflector having a focus and a principal axis, a rectangular dielectric guide extending through said reflector and along said axis, said guide having an end rectangular opening positioned substantially at said focus, a resonant chamber enclosing the end portion of said guide and having a reflective wall facing said opening, said chamber having a pair of spaced rectangular apertures each facing a different portion of said paraboloidal reflector, said opening being included between said

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apertures, the long dimensions of said apertures and said opening being substantially parallel, and a translation device connected to said wave guide.

18. In combination, a concave reflector having a focus and a principal axis, an open-ended rectangular wave guide extending through said reflector and along said axis, said guide having an end opening at said focus substantially, a chamber for receiving said guide, said chamber having a reflecting wall facing said opening and a pair of spaced rectangular apertures facing said concave reflector, said end opening being positioned between said apertures and the corresponding sides of said opening and apertures being parallel.

19. In combination, a substantially paraboloidal reflector having a point focus, a primary antenna at the focus for emitting a substantially spherical wave front, the difference between the shape or contour of said reflector and a true paraboloidal reflector being dependent upon the difference in phase between said wave front and a true spherical wave front and such as to compensate for said difference in phase.

20. In combination, a transceiver for supplying or utilizing waves electrically polarized in a given plane, a paraboloidal reflector having a circular opening of given diameter, a T-shaped dielectric guide connected to said transceiver and having a pair of rectangular antenna apertures facing said reflector, the long and short dimensions of said apertures and the spacing between said apertures each being a function of said diameter.

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