

Oct. 28, 1947.

W. W. MIEHER ET AL

2,429,640

DIRECTIVE ANTENNA

Filed Oct. 17, 1942

2 Sheets-Sheet 1

FIG. 1

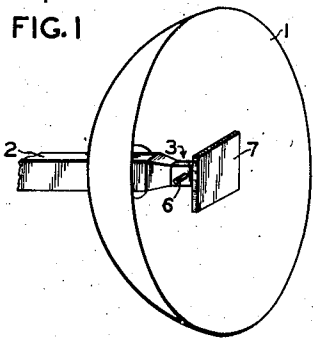


FIG. 2

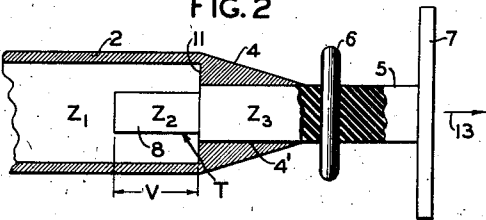


FIG. 3

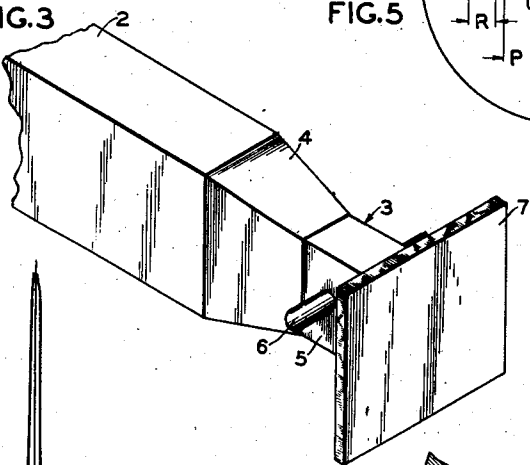


FIG. 5

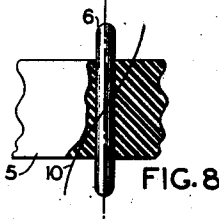
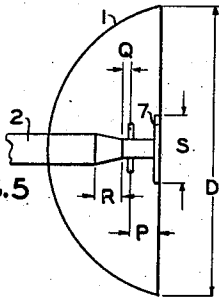


FIG. 8

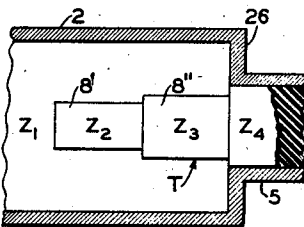


FIG. 7

FIG. 6

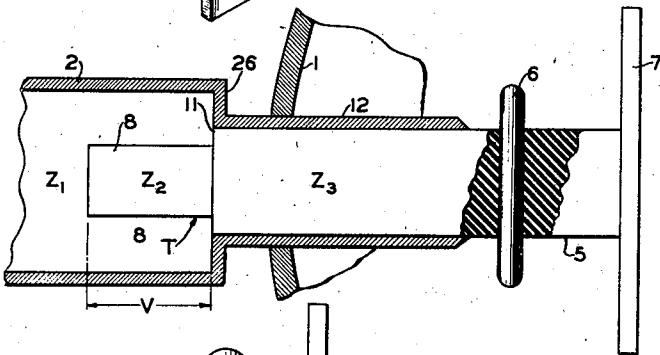
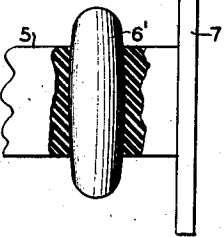


FIG. 9



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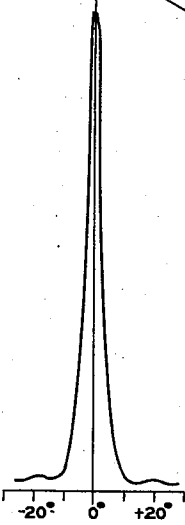


FIG. 4

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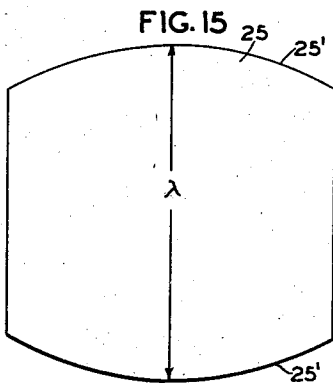
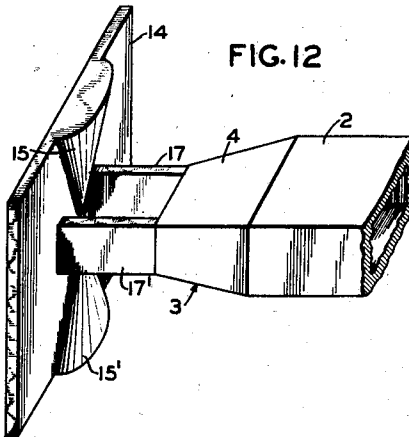
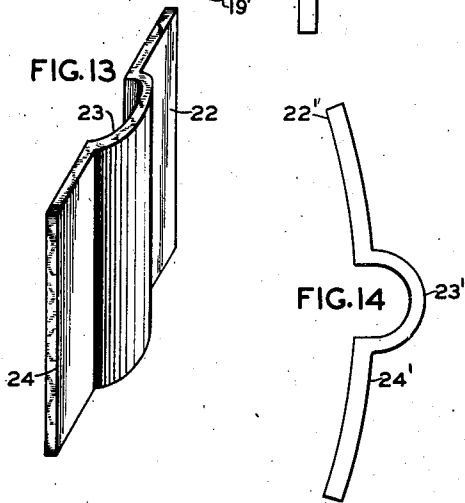
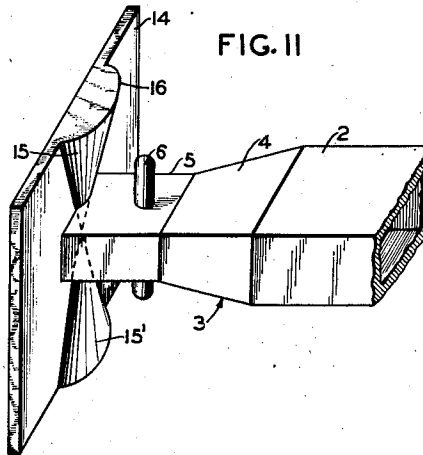
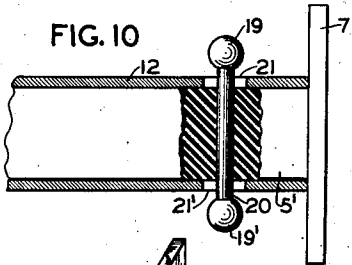
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2 Sheets-Sheet 2



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DIRECTIVE ANTENNA

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Application October 17, 1942, Serial No. 462,434

19 Claims. (Cl. 250—11)

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This invention relates generally to the transmission and reception of ultra high frequency electromagnetic energy having a wavelength of the order of one meter or less, and more specifically, to means for obtaining radiation beams and reception patterns which are highly directive and relatively very free of secondary lobes.

A well known method for exciting a metallic paraboloid antenna is by the use of a dipole terminating a concentric line, the dipole usually being located at or near the effective focus of the paraboloid. Other methods, as disclosed in the copending application, Serial No. 429,494, entitled Directive antenna structure, filed February 4, 1942, in the names of Robert J. Marshall, Wilmer L. Barrow, and Walter W. Mieher, include the use of wave guides introduced substantially axially through the back of the paraboloid with reflecting means positioned in front of the mouth of the wave guide near the effective focus of the paraboloid to reflect toward the paraboloid the energy emitted from the guide. The aforementioned application also describes the use of wave guides or small electromagnetic horns of slight taper pointed substantially axially into the paraboloid with their mouths positioned at or near the effective foci of the paraboloids.

In these prior art devices, it has been difficult to evenly irradiate the reflecting surface of the paraboloid due to the relatively large size of the wave guides and reflectors themselves whereby they obstruct the radiated energy and also due to the fact that such combinations are rather broad sources so that all of the energy does not flow toward the paraboloid as from a point source. These and other factors tend to broaden the primary beam and to introduce secondary lobe beams of considerable magnitude, which are, as is well known, undesirable in aircraft instrument landing systems, target detection, and tracking systems, and in kindred uses.

It is therefore a principal object of the present invention to provide means for excitation of paraboloid radiators so that highly directive beams of radiant energy, relatively free of secondary lobes, may be produced.

A principal object is to provide means in a receiver paraboloid whereby the reception pattern of the device is made highly directive and relatively free of gain in directions other than that of the primary pattern.

Another object is to provide, in a paraboloid, antenna and reflector means which behave as a point source or receiver.

A further object is to provide such wave guide

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means which irradiates evenly the entire reflective surface of a paraboloid.

Still another object of the invention lies in the provision of improved impedance matching means adapted for use with such wave guide means.

These and other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings, wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a perspective view of a preferred form of the present invention.

Fig. 2 is a partial cross-section view of a detail of Fig. 1.

Fig. 3 is a perspective view of a detail of Fig. 1.

Fig. 4 is an explanatory graph.

Fig. 5 is a schematic diagram of the reflector and radiator.

Fig. 6 is a partial cross-section view of an alternative form of the device shown in Fig. 2.

Fig. 7 is a cross-section view of an alternative form of a portion of Fig. 6.

Fig. 8 is an explanatory schematic diagram.

Fig. 9 is a partial cross-section view of an alternative form of a portion of Figs. 2 or 6.

Fig. 10 is a partial cross-section view of an alternative form of the invention.

Figs. 11 and 12 are perspective views of modified forms of the invention.

Figs. 13, 14, and 15 are alternative forms of details of the invention.

Similar characters of reference are used throughout the figures to indicate corresponding parts.

In Figs. 1, 2 and 3 is illustrated as a preferred form of the present invention an ultra high frequency paraboloid antenna capable of producing a highly directive beam of radiation, as shown in Fig. 4, with secondary lobes containing a minimum amount of energy. Other shapes of concave electromagnetic wave mirrors or reflectors may be used, e. g., spherical, but for simplicity in description those having surfaces of revolution formed by rotating parabolas and other similar shapes about the axis of symmetry herein will be referred to comprehensively as paraboloids. A paraboloid 1, preferably having its axial dimension substantially equal to its focal length, is irradiated with ultra high frequency energy from an antenna structure 3, which is fed in any orthodox manner from a wave guide or energy-conducting pipe 2. Referring to Figs. 2 and 3, antenna structure 3 is seen to consist of a rectangular hollow wave guide 2 joined to a tapered

metallic portion or transition member 4 in which is inserted a dielectric guide 5, in this case shown as a guide formed of material having a relatively high dielectric constant. The dielectric guide 5 and wave guide 2 are provided with discontinuous sections forming an impedance matching transformer T.

The use of a suitable dielectric material, typically a commercially available thermo-plastic composition known as "Polystyrene," permits the critical dimensions of the wave guide 2 to be reduced in the region of the antenna structure, thereby concentrating the beam energy to be radiated by the rod 6 and minimizing obstructions to the wave reflected from the paraboloid 1. Reduction of the cross-sectional dimensions of the guide in the impedance matching section T extending between the wave guide 2 and the radiator 6 also minimizes the obstruction to the energy radiated toward the paraboloid.

Extending into hollow guide 2 is a rectangular extension 8 of dielectric material whose cross-section may be somewhat reduced from that of the main portion of guide 5. The cross-sectional area of portion 8 is adjusted experimentally so that the following relation obtains:

$$Z_1 Z_3 = Z_2^2$$

where Z_1 is the characteristic impedance of hollow guide 2, Z_2 is that of the section containing dielectric portion 8, and Z_3 is that portion of 4' of the dielectric guide 5. The dielectric matching section is adjusted in length V by experiment, its length being substantially a fourth of the average of the wavelength of the electromagnetic energy within the guides.

It is seen that a series of such steps, as seen at 8', 8'' in Fig. 7, may be used as an impedance transforming means between the guides 2 and 5, as disclosed in copending application Serial No. 437,004, entitled Wave guide construction, filed March 31, 1942, in the names of Montgomery H. Johnson, William H. Ratliff, and William W. Hansen. It is therein shown that if the coefficients of $(x+1)^n$, known as binomial coefficients, are used in describe the increments in the logarithm of the characteristic impedance of successive quarter-wavelength sections of wave guide making up an impedance matching transformer between wave guides of different characteristic impedance, then, as n is increased, the frequency range over which such a wave guide transformer means is useful is increased.

The dielectric guide 5 projects on past the end of tapered metallic portion 4, and has transversely extending through such projecting portion adjacent to the principal focus of the paraboloid a round conducting rod or antenna 6, which extends out of the guide equally on each side of the guide. Rod 6 is approximately a half-wavelength long and acts as the chief source of radiation to irradiate the paraboloid reflecting surface. As seen in Fig. 8, rod 6 is excited as shown by the graph 10, so that voltage anti-nodes appear at its opposite ends. At the end of guide 5 is placed reflector plate or element 7, which is dimensioned so as to act not only to reflect energy toward paraboloid 1, but also, in conjunction with radiating rod 6, to act to cancel out all energy traveling in the direction of the arrow 13 of Fig. 2 directly from rod 6. The diameter of rod 6 is not critical, and as seen at 6' in Fig. 9, is also not critical as to shape, although it preferably is made effectively a half-wavelength long. The length of rod 6 also has been

found to be not critical, since excellent results were obtained with a rod whose actual length was slightly in excess of one-half wavelength in free space. In general, shapes of rod 6 having larger diameter have lower loss and are less sharply resonant, thereby having more constant gain over larger frequency ranges.

The preferred geometrical relationship of the parts may be discussed by referring to Fig. 5. In general, reflector element 7 is placed in the plane of the front of the paraboloid, and is made thin-walled and square, of dimensions (S) about equal to one wavelength. Substantially one quarter-wave (P) behind reflector element 7 is placed the half-wave long radiating rod or antenna 6. A very short distance (Q) further along the dielectric guide 5 begins the substantially quarter-wave long (R) tapered portion 4, which joins directly to hollow rectangular guide 2. The distance Q is experimentally adjusted to make the distance from rod 6 to the shoulder 11 such that it transforms the impedance looking in the direction of hollow guide 2 into a pure resistance. For example, for a paraboloid of diameter 30 cm., focus 7.5 cm. and a wavelength of substantially 3 cm. and a dielectric guide of substance known commercially as "Polystyrene," the following set of dimensions has yielded good results: dielectric guide 0.62 cm. by 1.45 cm.; S, 2.37 cm. square; P, 0.82 cm.; Q, 0.32 cm.; and R, 0.79 cm., where the antenna 6 is 0.24 cm. in diameter and 1.64 cm. in length. A structure made according to the foregoing provides a highly directive pattern of the general shape shown in Fig. 4, which pattern indicates the results obtained during experimental tests.

In general, however, the length R of tapered portion 4 may be any odd number of quarter-wavelengths and is chosen to be of sufficient taper so as not to cast a shadow on the reflecting surface of paraboloid 1; i. e., so that substantially none of the reflecting surface of paraboloid 1 is hidden from the effective source, at or adjacent to the rod 6. Tapered portion 4 is introduced so that the transformation means between hollow guide 2 and dielectric guide 5 can be located as close as possible to radiating rod 6, whereby dielectric guide 5 is of minimum length, and attenuation is minimized.

The discontinuities in the waveguides may produce undesirable reflections toward the energy source. This difficulty might be overcome by adjusting the distances R and V until reflections from the discontinuity at 11 are neutralized by reflections from the outer end region of the guide 5. Additional slight adjustment may be made by adjusting the dimension Q, or telescoping the entire guide in or out of pipe 2.

If desired, as shown in Fig. 6, tapered portion 4 can be eliminated and the impedance matching transformer T and shoulder 26 formed by the abrupt reduction in dimensions of the casing can be located behind the paraboloid 1, in which case the shoulder cannot produce undesirable radiation. The metallic envelope of hollow guide 2 is decreased in size at point 11 where the matching transformer T begins and extends into the paraboloid 1, the decrease in size of guide 5 being proportional to

$$\frac{1}{\sqrt{\epsilon}}$$

where ϵ is the dielectric constant of the dielectric material. The distance between point 11 and radiating rod 6 is again made such that the im-

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pedance seen looking in the direction of hollow guide 2 is purely resistive. It is obvious that the transformer described in Fig. 7 can be substituted for the one shown in Fig. 6 as can any other well known type of wave guide impedance matching means be substituted in any of the embodiments shown in the drawings.

Fig. 10 discloses a modified form of construction wherein the casing 12 of the dielectric filled wave guide 5' extends to the reflector 7. A modified antenna rod 20 having spherical caps 19, 19', extends through apertures 21, 21' formed in opposite sides of the casing 12, the rod being held in position by the dielectric material. The caps 19, 19' provide some measure of capacitive antenna coupling and permit the use of a shorter antenna rod, thereby reducing the size of the radiator more nearly to a desirable point source of energy.

Figs. 11 through 14 illustrate embodiments of the present invention wherein use is made of a reflector plate having at least a portion forming a partial surface of revolution about an axis generally parallel to the direction of the lines of electric force within the wave guide 2 and to the axis of radiator 6. Such reflector plates are located with their convex surface facing the paraboloid and may be substituted for the plane plate 7 shown in the preceding views of the drawing.

Figs. 11 and 12 illustrate in perspective, antenna structures 3 incorporating such a modified form of reflector plate. In Fig. 11 a preferably flat reflector plate 14 is provided on its reflecting surface with oppositely positioned half conical sections 15, 15' disposed along a common vertical axis with their apices meeting at a common point located on the longitudinal axis of the guide 5. The curved surfaces of the conical sections 15, 15' form an antenna array composed of an infinite number of individual rods extending through the apex and between opposite bases of the conical members. For optimum performance, the distance between bases should be of the order of a multiple of one-half wavelength to increase reflection of energy in the range of operating frequencies, and the surfaces should extend through approximately half a revolution. As will be observed in the drawings, the axis of the conical members 15, 15' extends perpendicularly to the broader sides of the waveguide 2, and to the waveguide axis, and parallel to the electric lines and to the axis of the rod 6. Better results were obtained with a reflector element having a surface curved about a single axis, as described, than were obtained with spherical or other convex surfaces of compound curvature. If desired, the dielectric guide may be dispensed with and, as shown in Fig. 12, two arms 17, 17' of dielectric material may be used to support the plate 14.

Figs. 13 and 14 illustrate reflectors which likewise curve about an axis in a single plane, e. g., vertical, for use with the guide 2 positioned as shown in Fig. 11. In Fig. 13, the reflector plate comprises a metal member 22 having coplanar end portions 24 and an intermediate convex portion 23 preferably comprising a half section of a cylinder, the diameter of which is of the order of the width of the wave guide 2. The reflector 22' shown in Fig. 14 differs from that shown in Fig. 13 in that the coplanar portions 24 are replaced by convex surface portions 24' having a larger radius of curvature about a vertical axis than portion 23. It appears that reflectors with surfaces having simple curvatures, e. g., revolved

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about a single axis, of the type shown in Figs. 11 through 14, disperse the energy over a wider area of the paraboloid than plane reflectors, and that they operate in a manner superior to surfaces having compound curvatures. The shape of the plate 22 may be roughly square, with edges of the order of a multiple of one-half wavelength. In use, the plates are positioned with their convex sides facing the paraboloid.

In Fig. 15, a reflector plate 25 comprises a plane plate having top and bottom edges 25' that approach one another from a maximum separation distance equivalent to a wavelength or other multiple of half wavelengths. The plate 25 therefore comprises an antenna array formed of an infinite number of vertical rods having natural oscillation frequencies in the operating range.

The central portion resonates with the principal frequency used in the system and successively adjoining portions have natural frequencies that are higher as the distance between the opposite edges 25' decreases. As shown in Fig. 15, the edges 25' may have a shape determined by a radius of curvature equal to the maximum separation distance, e. g., one wavelength, and swinging about a median line.

It is evident to one skilled in the art that components herein disclosed can be interchangeably used; and, although the use of the present invention has been described largely for the transmission of highly directive beams of electromagnetic energy, that the invention is equally useful as a receiver antenna.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A directive antenna system comprising a paraboloid reflector, a wave guide comprising a pipe extending axially through said paraboloid reflector and including a dielectric guide of reduced cross-section having an end within said reflector, a radiating rod extending through said dielectric guide at approximately the focus of said paraboloid reflector, and a reflector element at the end of said dielectric guide.

2. A directive antenna system comprising a paraboloid reflector, a wave guide comprising a pipe extending axially through said reflector, said guide also including a dielectric guide section, a rod antenna extending through said dielectric guide section at approximately the focus of said reflector, and a reflector element at said end of said dielectric guide remote from said pipe.

3. A directive antenna system comprising a wave guide comprising a pipe and including a dielectric guide of reduced cross-section extending from the end of said pipe, a rod antenna extending through said dielectric guide, and a reflector element at the end of said dielectric guide remote from said pipe.

4. A directive antenna system comprising a wave guide including a pipe having an open end and a dielectric member extending from said pipe, and a rod antenna supported by said dielectric member and spaced from said end.

5. A directive antenna system comprising a wave guide and a rod antenna mounted rigidly with respect to said guide in front and spaced from the end thereof and electromagnetic wave-

conducting means coupling said wave guide and rod.

6. A directive antenna system comprising a concave electromagnetic wave mirror; a wave guide comprising a pipe extending through said mirror, a dielectric guide of smaller cross-section than said pipe, and a tubular transition member surrounding said dielectric guide and connecting with said pipe; a radiating rod located adjacent to the principal focus of said mirror and extending through said dielectric guide substantially perpendicularly to the axis of said pipe; and a reflector element at the end of said dielectric guide remote from said pipe.

7. A directive antenna as claimed in claim 6, wherein said tubular transition member has tapered outer surfaces sloping from the walls of said pipe to said dielectric guide.

8. A directive antenna system comprising a concave electromagnetic wave mirror; a wave guide comprising a pipe extending through said mirror, a dielectric guide of smaller cross-section than said pipe, and a tubular transition member surrounding said dielectric guide and connecting with the end of said pipe; a radiating rod extending through said dielectric guide at a point adjacent to the focus of said mirror, and a reflector element at the end of said dielectric guide remote from said pipe, said transition member extending from said pipe for a distance electrically neutralizing reflected energy from points adjacent to the end of said dielectric guide remote from said pipe.

9. An electromagnetic wave radiator comprising an elongated wave guide adapted to propagate high frequency electromagnetic energy therealong and having an open end, and a radiating rod disposed perpendicularly to the axis of said guide in front of said open end, said rod being substantially bigger in cross-section at its middle than at its ends.

10. An electromagnetic wave antenna comprising a wave guide, a rod antenna disposed perpendicularly to the axis of said guide and adjacent to but spaced from the end of said guide, and electromagnetic energy-conducting means coupled to said wave guide and supporting said antenna rigidly with respect to said guide.

11. An antenna as in claim 10, wherein said rod antenna is substantially one-quarter wavelength long at the operating frequency.

12. A radiator as claimed in claim 9 wherein said radiator is substantially elliptical in shape.

13. An electromagnetic wave radiator comprising a wave guide having an outer conductive casing, and a radiating rod extending through but insulated from said casing, said rod having capacitive coupling members thereon spaced from said casing.

14. A radiator as claimed in claim 13 wherein said coupling members comprise spheroids adjacent to the extremities of said rod.

15. A directive antenna system comprising a concave electromagnetic wave mirror; a wave guide comprising an electrically conductive pipe extending axially through said mirror and a dielectric guide of smaller cross-section than said pipe and having an end extending from said pipe within said mirror; a radiating rod extending through said dielectric guide at a point adjacent to the focus of said mirror, a reflector element at the end of said dielectric guide, an electrically

conductive transition member having tapered walls extending from said pipe to said dielectric guide, said radiating rod being spaced along said dielectric guide from the end of said member a distance sufficient to balance out undesirable reflection of radiant energy from said end of said dielectric guide.

16. A directive antenna system comprising a concave electromagnetic wave mirror, a wave guide comprising an electrically conductive pipe extending axially through said mirror, a dielectric guide of smaller cross-section than said pipe and having an end within said mirror, a radiating rod extending through said dielectric guide at a point adjacent to the focus of said mirror, a reflector element at the end of said dielectric guide, an electrically conductive transition member comprising a tube of smaller cross-sectional area than said pipe and being filled with dielectric material and interconnecting said pipe and said guide, the length of said member and the spacing of said radiating rod from the end of said member adjacent said rod being such as to cancel out reflections from the end of said guide.

17. A directive antenna system comprising a concave electromagnetic wave mirror; a wave guide comprising an electrically conductive pipe extending axially through said mirror, a dielectric filled guide and a dielectric guide of smaller cross-section than said pipe extending from said pipe and having an end within said mirror; a radiating rod extending through said dielectric guide at a point adjacent to the focus of said mirror, a reflector element at the end of said dielectric guide, and an impedance matching transformer adapted to couple said pipe and said dielectric guide.

18. A directive antenna system comprising a hollow metal pipe having an open end, a dielectric member extending coaxially outwardly from said end and fixed to said pipe, an antenna member supported by said dielectric member in spaced relation to said open end, and a reflector member also supported by said dielectric member and spaced from said antenna member on the side thereof opposite said open end.

19. A directive antenna system comprising a hollow metallic pipe having an open end, a dielectric member mounted coaxially with respect to said pipe and extending outwardly from said open end, and an antenna member supported by said dielectric member in spaced relation to said open end.

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