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WAVE GUIDE TERMINATING DEVICE

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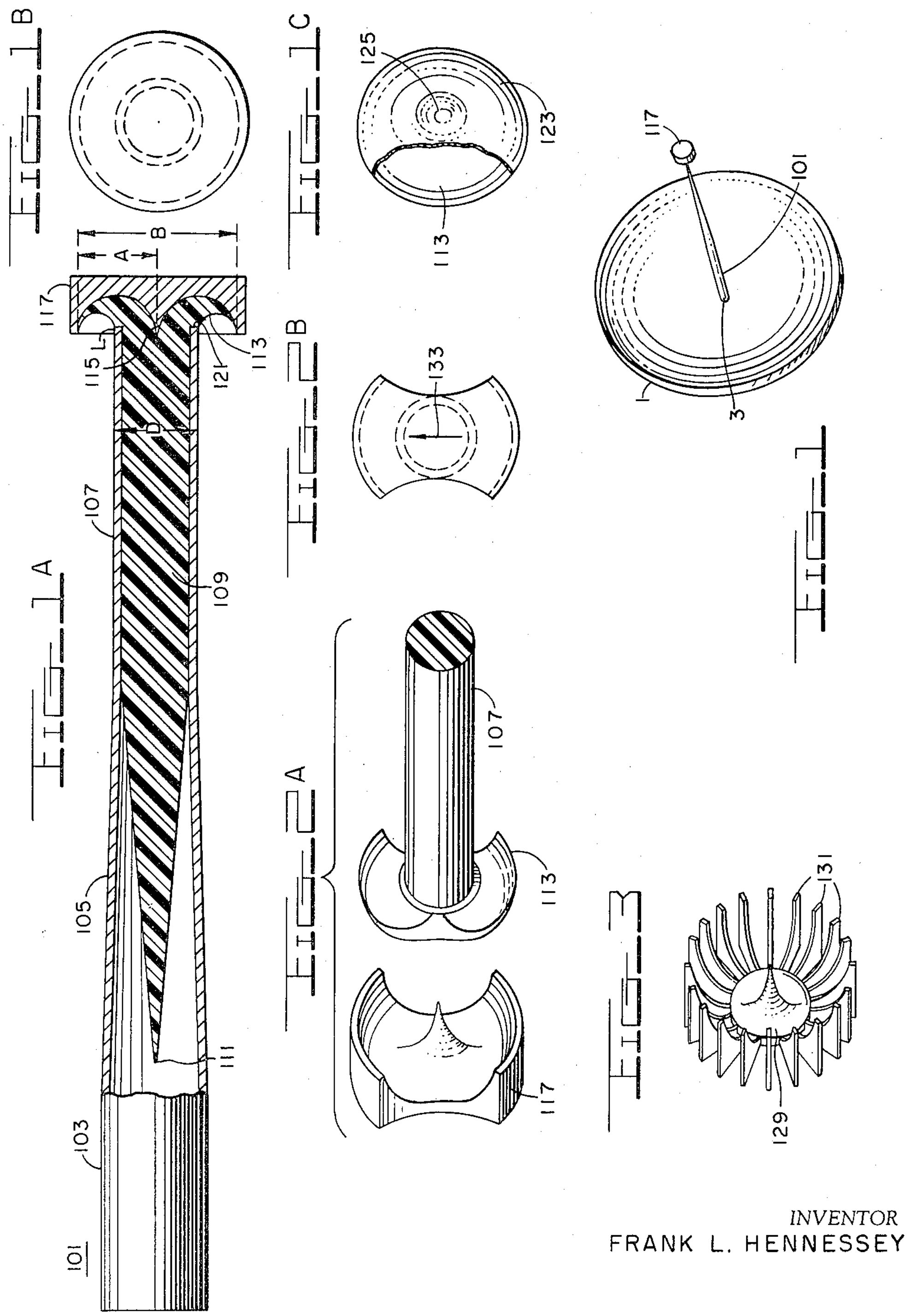

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WAVE GUIDE TERMINATING DEVICE

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This invention relates to broad band feed systems for microwave antennas utilizing beam concentration reflecting surfaces, and more particularly to terminations for such feed systems.

More specifically this invention concerns itself with the provision of a vertex feed system for microwave antenna systems that utilize a focal-fed parabolic reflecting surface. This type of antenna feed system generally comprises a straight section of waveguide projecting through the vertex of the reflector and terminated at the focus of the reflector by a radiating element that directs the energy back to the reflector. Such a system is shown and described in the test Principles of Radar, by Reintijis and Coate (McGraw-Hill), pp. 956–957, wherein a rectangular waveguide is shown terminated in a so-called "Cutler feed."

When it is desired to rotate the beam produced by such an antenna in a narrow cone in space by rotating the focal end of the waveguide in a small circle about the focus, such as shown in Patent No. 2,617,029 to Plummer et al., the use of a waveguide of circular cross-section in a vertex feed system is peculiarly advantageous. The circular waveguide may be readily rotated while maintaining a fixed orientation of polarization so that it is only necessary to cock the guide slightly off the axis of the reflector near the focus to achieve the desired conical beam. The feed systems that have been developed in the past are generally restricted to use at a given frequency or at best over a narrow band of frequencies. Reflections back into the waveguide that produce a large mismatch and loss of power have invariably resulted when the operating frequency is only slightly removed from the design frequency.

One object of this invention is to provide an improved vertex feed system for use with a focal-fed reflecting surface wherein a circular waveguide projects through the vertex of the reflecting surface.

Another object of this invention is to provide such a vertex feed system suitable for use over a wide range of frequencies.

A still further object of this invention is to provide a vertex feed system for use with a focal-fed reflector, producing essentially a point source of radiation to the reflector.

Other objects and features of the present invention will become apparent upon consideration of the following detailed description when taken in connection with the accompanying drawings which illustrate various embodiments of the invention. It is to be expressly understood, however, that the drawing is designed for purposes of illustration only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

Figure 1 is a perspective view of an antenna system suitable for practicing the present invention.

Figures 1*a* and 1*b* show side sectional and end elevation views respectively of one embodiment of the present invention.

Figure 1*c* shows a partial perspective view of a modification of the embodiment of Figures 1*a* and 1*b* resulting in a more simplified construction.

Figure 2*a* shows an exploded view of another embodiment of the present invention suitable for use when a sharper point source is desired. Figure 2*b* is an end view of this embodiment.

Figure 3 is a perspective view of still another embodiment of the invention that is useful where it is desired both to rotate the feed and to decrease the size of the point source of radiation to the paraboloid.

Briefly the antenna feed structure of the present invention comprises a conducting surface of unique efformation disposed at the focal end of the feed waveguide so as to intercept and split the wave emanating from the guide, and to redirect it around the terminating edges of the guide back to the reflector. In more particular the conducting surface may be described as being a figure of revolution generated by rotating a semi-circle about an axis which is coaxial with the waveguides axis and which is perpendicular to a line connecting the ends of the semi-circle at, or very near, one end thereof. Such a figure of revolution may be further defined as semi-toroidal in shape containing an apex-like protuberance at the axis of revolution. The apex of the generated conducting surface is positioned on the longitudinal axis of the guide so that the annular concave conducting surface of the semi-toroid is disposed about the end of the guide and is facing the antenna reflector. The apex of the conducting surface is thus placed in a region where the magnetic flux of electromagnetic radiation of transverse electric mode of propagation emanating from the guide is very weak. A linearly polarized wave of TE_{11} mode has a concentration of electric lines of force at the axis of the guide, which lines are divided by the conducting surface as the waves progress out of the guide, terminating thereafter on the annular concave face of the semi-toroidal conducting surface and on the edge of the guide until the energy is launched into space toward the antenna reflector. When the conducting surface is appropriately spaced from the end of the guide, it has been found that the wave propagation through the guide is not disturbed, and that electromagnetic energy is directed toward the antenna reflector with an impedance match that will give unexpectedly small standing wave ratios over a wide variation in operating frequencies. Furthermore it has been discovered that for optimum operation the radius of the semi-circle of revolution above-described must be very nearly equal to the radius of the waveguide. While satisfactory operation may be obtained when the ratio of the radius of the semi-circle of revolution to the radius of the guide is other than very nearly unity, there will be a decrease in the frequency spectrum over which a given maximum standing wave ratio can be obtained.

Additionally, it has been found that a circularly polarized wave may be redirected toward the antenna reflector with a standing wave ratio equally low as that obtained with linearly polarized waves. The reason for this is that orthogonally polarized modes may be readily redirected by the feed system because of the axial symmetry of the conducting surface. Inasmuch as a circularly polarized wave may be considered to be the sum of two orthogonal linearly polarized waves, circular polarization may thus be utilized with the present invention.

Figure 1, to which reference is now made, shows in a general manner how the novel feed of the present invention may be incorporated in a parabolic type of microwave antenna structure. Projecting through the vertex 3 of paraboloidal reflector 1 is a waveguide **101** for transmission of electromagnetic energy from a conventional external source. The waveguide is terminated at the focus of the paraboloid by the conducting surface provided by the present invention and indicated in general at **117**.

With reference now to Figure 1*a*, there is shown in detail one embodiment of the present invention wherein components corresponding to those of Figure 1 bear corresponding identifying numerals. Circular waveguide **101** is of three distinct sections, two cylindrical sections **103** and **107** being joined by a truncated conical section **105**, cylindrical section **103** having a larger inner diameter than cylindrical section **107**. Fitted within waveguide section **107** is a dielectric plug member **109**, typically made of polystyrene. The outer diameter of this member is the same as the inner diameter of waveguide section **107** along the length of waveguide section **107**, but tapers to a point **111** within conical section **105**. At the end of dielectric member **109** opposite the tapered point **111** is an end section **113** of rather critical dimensions. End section **113** is of semi-toroidal shape, the radius of curvature of the surface of the toroid being approximately half the outer diameter "D" of the waveguide section **107**. As has been previously indicated, the semi-toroidal surface may be considered to have been generated by revolving around the axis of the guide a semi-circle of diameter "A" tangent to said axis so as to form an apex thereat. Fitted snugly over end section **113** is a metal cap **117**, of Monel metal or any other metal that is a good electrical conductor. It should be noted that waveguide **101**, dielectric member **109** and metal cap **117** are distinct members, and may be readily disassembled each from the other.

The outer dimensions of cap **117** are not particularly critical but the inner curved dimensions are quite critical; for optimum results the cap must fit very snugly over dielectric end section **113** and its central point, or apex, **115** must be very exactly positioned on the axis of waveguide section **107**. The diameter "A" of the curved surface of metal cap **117** and dielectric end section **113** (twice the radius of curvature of the toroidal surface of end section **113**) need not be exactly the same as the outer diameter of waveguide section **107**, but it has been found that this relationship gives optimum results. For every dimension of diameter "A" there is a distance "L" between the tip of the apex **115** of metal cap **117** and the transverse plane of terminating edge **121** of the waveguide that will give optimum results as described below. This dimension "L" must be determined experimentally for every metal cap by axially moving dielectric member **109** within guide **107** until the best impedance match is obtained. Generally, as the ratio of "A" to "D" is increased, it has been found that the apex **115** should project farther into the waveguide **107**. Typically at an operating frequency of 9,375 mc., a distance "L" of .043 inch has been found satisfactory for a cap having a radius of curvature of .33 inch, and a major or outer diameter "B" of 1.345 inches, using a waveguide of .685 inch outer diameter and .05 inch wall thickness. It has been found that a difference of 7% between "A" and "D," or of .02 inch in the axial positioning of a cap of the dimensions given above is enough to produce a decided adverse effect on the impedance match.

Using a waveguide and a metal cap of the dimensions and relative positioning given above, a standing wave ratio of less than 1.4 was obtained over a frequency range of about 7800 to about 10,800 mc. Prior art devices could be operated with a standing wave ratio of less than 1.4 only over a 3% frequency range, typically of 9150 mc. to 9450 mc.

The function of the dielectric member **109** is primarily to provide both mechanical support for metal cap **117** and a means to axially position said metal cap **117**. It should be noted however that another useful purpose is served by member **109** in that its presence in the feed guide **101** permits a reduction in the permissible diameter of the waveguide section **107** where the dielectric member is positioned over the diameter of guide section **103** where an air dielectric is employed. The significance of this reduction in diameters is that a point source of radiation is more nearly achieved at the focus of the reflector. The tapered section **111** of the dielectric plug **109** and conical waveguide section **105** are utilized to provide a good impedance match between waveguide sections **103** and **107**. Dielectric member **109** including end section **113** may be eliminated if desired so long as other means are provided for positioning the metal cap **117** which do not adversely affect the propagation of the radiation.

The operation of the embodiment of Figure 1 is believed to be as follows. Assume that a vertically polarized TE_{11} wave is being propagated in the waveguide. Upon reaching the point of the metal cap **117**, electric lines of force of the wave will be progressively divided by the metal cap starting at the tip **115**. Effectively, the wave is then transmitted around terminating edge **121**, the electric lines of force being terminated on edge **121** and on the interior of the toroidal conducting surface of the metal cap **117**. It has been found that the waves are divided and swung around terminating edge **121** in such a manner as to be almost entirely redirected toward the paraboloidal reflector.

The metal cap **117** may be eliminated if desired by coating the exterior surface of dielectric end section **113** with a metal film. Such a device is shown in Figure 1*c*, wherein numeral **123** denotes the metal film or coating over the end section **113**. Care must be taken to insure that the conductive coating goes to the tip of cavity **125** so that the waves will be properly divided and redirected. The operation of the device is the same as described above for Figure 1*a*, conductive coating **123** performing the function of the concave, interior surface of metal cap **117**.

It should be noted that apex **115** need not come to a sharp point, but may be blunted somewhat. In the specific example given above it will be noted that there is .025 inch difference between the outer diameter "B" of the toroidal surface and the diameter "A" of the figure of revolution. This difference is the diameter of the blunted apex.

It has been found that if linearly polarized waves are used a point source of radiation may be more nearly achieved and the antenna gain considerably increased by cutting away part of the end section **113** and metal cap **117** in the manner shown in Figure 2. For satisfactory results, the cut-away sections have a radius of curvature the same as that of the outside diameter "B" of dielectric end section **113**, but this dimension is not critical. The radii of curvature are centered so as to cut only to the outer surface of waveguide section **107**. For correct operation using this feed, it is necessary to polarize the radiation along the major axis of the resulting end-section, as shown by polarization indicating arrows **133**. Under this condition the section of the full feed of Figure 1*a* that is cut-away in the cut feed of Figure 2 would have little effect on the incident wave.

The spoked cap embodiment shown in Figure 3 combines the better features of the cut feed of Figure 2 with the ability of the full feed of Figure 1 to transmit radiation of any polarity. In this embodiment the metal cap **117** comprises a solid base member **129** snug-fitted over end section **113** and having a diameter essentially equal to the outer diameter of waveguide section **107**. Uniformly radially extending from the base member **129** are a number of spokes or fins **131** snug-fitting on the outer portion of end section **113**. It has been found that the spokes nearly perpendicular to the E-vector have little effect on this incident wave, only the spokes more nearly parallel to the electric field direction through the axis of the guide being effective to redirect the radiation.

Although the embodiments disclosed in the preceding specification are preferred, other modifications will be apparent to those skilled in the art which do not depart from the scope of the broadest aspect of the present invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereof or therefor.

What is claimed is:

1. In a vertex feed system for an antenna having a beam concentrating reflector and a section of tubular waveguide projecting through the vertex thereof to the focus thereof; a conductive member disposed at the end of said waveguide, said member having a concave surface facing the reflector, said surface being generated as a figure of revolution formed by revolving a semi-circle about an axis perpendicular to the diameter of said semi-circle and coaxial with the waveguide axis thereby to form an apex on said axis; and adjustable positioning means operable to position the apex of said surface along the axis of said waveguide at the focal end thereof with said apex pointing toward said beam concentrating reflector.

2. In a vertex feed system for an antenna having a beam concentrating reflector and a section of tubular waveguide projecting through the vertex thereof to the focus thereof; a conductive member disposed at the end of said waveguide, said member having a concave surface facing the reflector, said surface being generated as a figure of revolution formed by revolving a semi-circle about an axis perpendicular to the diameter of the semi-circle and coaxial with the axis of the waveguide thereby to form an apex at said axis, said conducting member being symmetrically cut away on two opposite sides thereof up to the projection of said waveguide on said conducting surface, and adjustable positioning means operable to position the apex of said surface along the axis of said waveguide at the focal end thereof with said apex pointing toward said reflector.

3. A termination for a tubular waveguide for redirecting electromagnetic radiation around an end thereof comprising a conductive reflecting surface having a concave reflective surface configuration substantially that of a surface of revolution derived by rotating a semi-circle about an axis tangential to said semi-circle at a diametric end thereof forming an apex at the said axis, and means operative to position said reflecting surface at the end of said waveguide symmetrically with respect to the axis thereof with said apex pointing toward said waveguide.

4. A termination for a tubular waveguide for redirecting electromagnetic radiation around an end thereof comprising a conductive reflecting surface having a concave reflective surface configuration substantially that of a surface of revolution derived by rotating a semi-circle about an axis tangential to said semi-circle at a diametric end thereof forming an apex at the said axis.

5. In a vertex feed system for an antenna having a beam concentrating reflector and a section of tubular waveguide projecting through the vertex of the reflector to the focus thereof; a conductive member disposed at the end of said waveguide, said member having a concave surface facing the reflector, said surface being generated as a figure of revolution formed by revolving a semi-circle having a diameter substantially equal to the outer diameter of said waveguide about an axis perpendicular to the diameter of said semi-circle and coaxial with the waveguide axis thereby to form an apex on said axis; and adjustable positioning means operable to position the apex of said surface along the axis of said waveguide at the focal end thereof with said apex pointing toward said beam concentrating reflector.

6. The feed system described in claim 1 wherein the said conductive member is a finular member with the fins thereof radially extending from the waveguide axis and said fins are individually shaped to collectively form the described surface configuration.

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