

Sept. 18, 1962

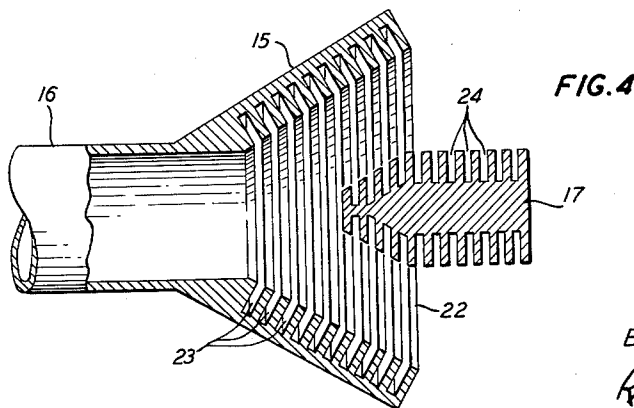
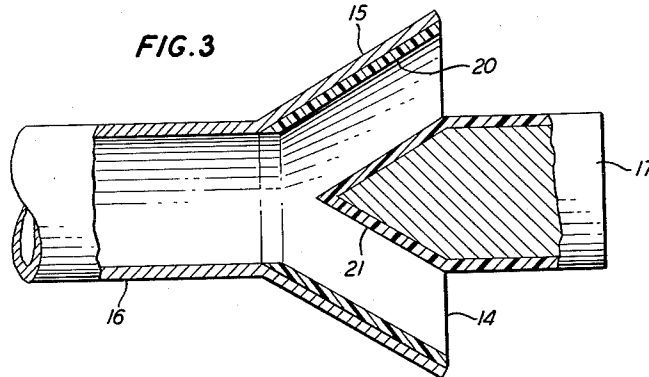
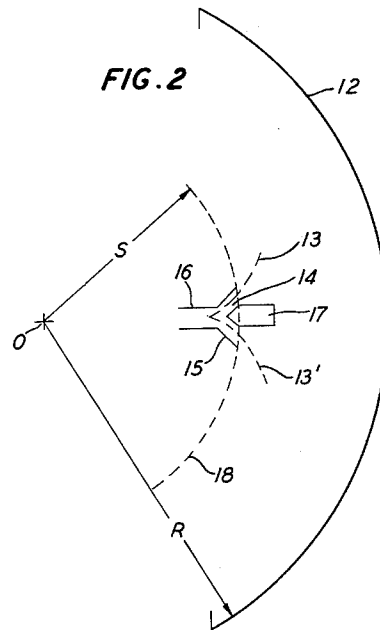
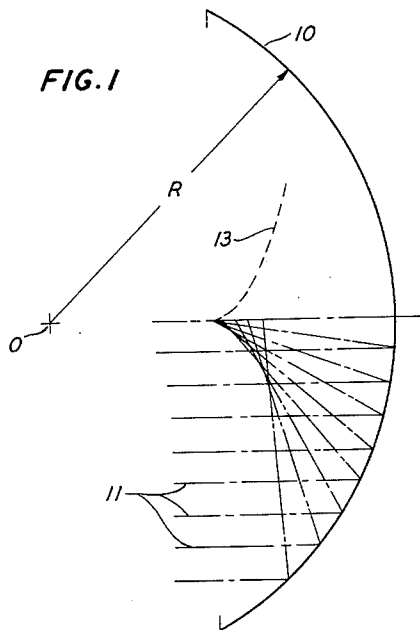
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3,055,004

HORN RADIATOR FOR SPHERICAL REFLECTOR

Filed Dec. 18, 1958

2 Sheets-Sheet 1



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FIG. 5

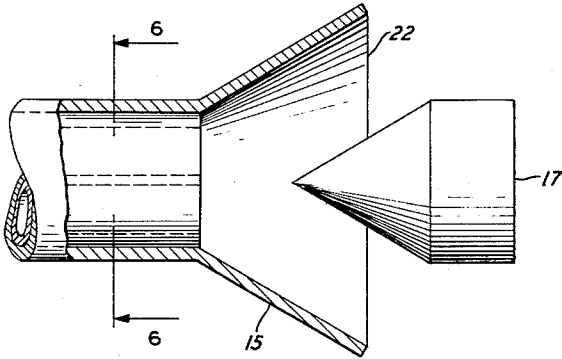


FIG. 6

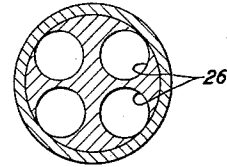


FIG. 9

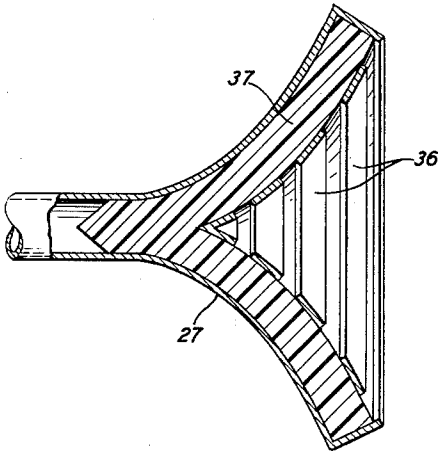


FIG. 7

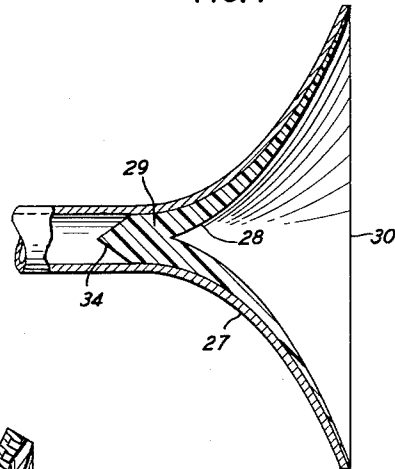
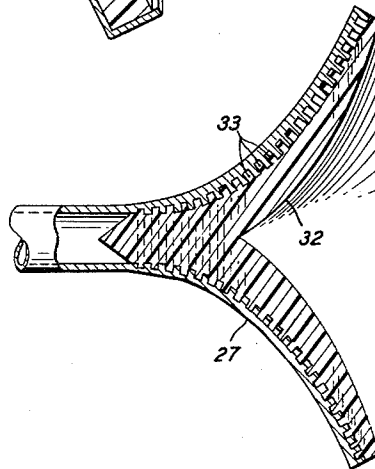


FIG. 8



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HORN RADIATOR FOR SPHERICAL REFLECTOR
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5 Claims. (Cl. 343-781)

This invention relates to antennas and more particularly to a directive antenna in which a spherical reflector is illuminated by a horn radiator.

The object of the invention is to improve the radiation pattern in a directive antenna adapted for rapid, wide-angle scanning. Related objects are to increase the directivity and reduce the minor lobes in an antenna of this type.

An antenna comprising a reflector fed by a movable primary radiator is well adapted for scanning. In such an arrangement, the use of a spherical segment as the reflector has several advantages over the use of a parabolic or paraboloidal reflector. One advantage is that the former is easier to fabricate. Another is that a wider angle can be scanned by moving only the feed, because all portions of a spherical surface are identical. However, a disadvantage is that a spherical reflector has no well-defined focal point at which to locate the primary radiator. On the contrary, incident parallel rays reflected from a spherical reflector converge to form a caustic curve, or surface, which is symmetrical with respect to a radius and is in the shape of a cusp.

In designing a reflector antenna, it is important to match the feed and reflector characteristics. For an ordinary paraboloid, a point source, or point center, of phase is required, and is easily obtained from conventional horns and dipoles. Other reflector shapes, such as the ring-focused reflector, call for a feed horn which is designed to have a center of phase which is shaped into a circle matching the reflector characteristic. The corresponding ideal source for a spherical reflector gives a distribution of phase over the caustic surface. The phase is uniform circularly, but varies radially in a way corresponding to the characteristic of the caustic. A practical antenna feed so matches a part of the caustic. An antenna which is very large, measured in wavelengths, calls for a distributed feed covering a large part of the caustic. In a small antenna, however, a simple ring focus is acceptable.

Another requirement for an efficient feed is that the primary pattern measured in any plane through the axis should have the same amplitude and phase characteristics regardless of the polarization, and that the polarization characteristic be such that a wave from the feed after being reflected have polarization parallel at all points in the plane wave front. An ordinary flared feed does not accomplish this. However, in accordance with the present invention, it is accomplished by suitably constructing the horn surfaces. Corrugations, dielectric coatings, or both, are employed in such a way that the surface has the same characteristics for either the electric or magnetic vectors.

Therefore, in accordance with the present invention, a spherical reflector is illuminated by a radiator either having a surface which approximately coincides at least in part with this caustic surface, or having an aperture which intersects the caustic surface. One form of the radiator is a circular waveguide which flares at its end to form a horn the aperture of which intersects the caustic surface. A central baffle, preferably a cylinder with a conical end, may be provided to insure the proper phasing and distribution of the illumination. The horn and the baffle may be coated with dielectric or corrugated transversely,

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or both, to give uniform phase, polarization, and amplitude in the aperture of the radiator. Lobing may be accomplished by feeding the horn through several waveguides which terminate at different points in the throat and are energized in succession. In all of these embodiments, locating the source of primary radiation on the caustic surface improves the radiation pattern by increasing the directivity and reducing the minor lobes. In other embodiments, the flare of the horn approximately follows the curve of the caustic surface. In these, the baffle may usually be omitted, because the energy is properly constrained by the waveguiding characteristics of the flared surface of the horn. The inner surface of the horn is preferably coated with dielectric, which may taper in thickness toward the mouth of the horn and may be backed up by a corrugated surface. Or, the surface of the dielectric may be partly metallized to form a series of suitably phased radiators of the leaky-pipe type. Conductive rings may be spaced along the surface for this purpose.

The nature of the invention and its various objects, features, and advantages will appear more fully in the following detailed description of the typical embodiments illustrated in the accompanying drawing, of which

FIG. 1 is a diagram showing how the caustic surface is found for a spherical reflector;

FIG. 2 is a diagrammatic showing of a scanning antenna in accordance with the invention;

FIG. 3 is a side view, partly in section, of a primary radiator for use in FIG. 2 in the form of a conical horn with a cylindrical baffle, both coated with dielectric;

FIG. 4 is a similar view of a similar horn and baffle with corrugated surfaces;

FIG. 5 is a similar view of a horn successively fed by four circular waveguides terminating at its throat;

FIG. 6 is a sectional view of the waveguide feed taken at the plane 6-6 in FIG. 5;

FIG. 7 is a side view, partly in section, of a suitable feed horn flared to match the caustic surface and having a dielectric lining which tapers in thickness from throat to mouth;

FIG. 8 is a similar view of a similar horn in which the dielectric is backed by corrugations; and

FIG. 9 is a similar view of a horn lined with dielectric material which has conductive rings on its surface to provide a leaky-pipe feed.

FIG. 1 shows in diagrammatic section a segment 10 of a spherical surface with center at O and radius R. The section is taken in a plane which passes through the center O. Incident parallel rays 11 when reflected from the segment 10 converge about a radius to form a caustic surface which is shaped like a cusp. The broken line 13 represents the upper half of this surface as it appears in midsection.

FIG. 2 shows an antenna comprising a reflector 12 in the form of a segment of a spherical surface which is illuminated by a horn 15 formed by flaring the end of a circular, metallic waveguide 16 into a truncated cone. A metallic baffle 17 centered in the mouth of the horn 15 comprises an inner conductor which converts the horn into one of the coaxial type. The baffle 17 is cylindrical and preferably tapers at its inner end to form a cone in order to give a smoother transition. In some cases, the cone only is required and in other cases the entire baffle may degenerate into a disk. The ring aperture 14 of the horn 15 intersects the caustic surface 13, 13'. The coaxial horn insures that the primary radiator will have the correct phase characteristic and illumination pattern. When the guide 16 is energized by a source of microwaves, the reflector 12 radiates a comparatively narrow beam parallel to the radius passing through the center of the horn

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15. The beam can be made to scan by moving the aperture 14 of the horn 15 along the arc of a circle centered at O and having a radius S somewhat larger than $R/2$.

As shown in the enlarged view of FIG. 3, the inner surface of the horn 15 and the surface of the baffle 17 may be coated with layers of dielectric 20 and 21 to increase the uniformity of the phase, polarization, and amplitude in the ring aperture 14 of the horn. FIG. 4 shows an alternative structure in which the horn 15 is provided with a series of transverse, annular grooves 23, and the baffle 17 with similar grooves 24. These grooves have a depth of approximately a quarter wavelength or slightly more so that they will inhibit the flow of longitudinal currents in the metal. In this way, the surface is made to present the same characteristics to the electric and magnetic fields, and thus the surface field strength is not influenced by the local polarization. As a result, a waveguide mode having the desired uniformity of phase, polarization, and amplitude around the circumference can exist. The illumination has a cosine distribution over the radial dimension of the aperture 22, resulting in low backward radiation.

FIGS. 5 and 6 show how the emergent beam may be shifted in direction to provide a lobing characteristic without moving either the horn 15 or the reflector. Energy is fed to the horn 15 through four circular waveguides 26 which open into the throat of the horn 15 at equally spaced points and are energized in succession. Since the horn 15 is thus fed off center, the phase front of the illumination will be tilted with respect to the plane of the aperture 22 and the reflected beam will be correspondingly inclined to the normal.

The horns 27 shown in FIGS. 7, 8 and 9 are curved to match the caustic surface 13, 13' shown in FIG. 2. Also, they are constructed to provide, in effect, a series of suitably phased radiators spread over a considerable area of the caustic surface to constitute an array. The inner surface of the horn is made to guide the wave at a velocity somewhat slower than the speed of light so that the wave tends to follow the surface and no baffle at the mouth of the horn is required to provide proper illumination of the spherical radiator 12 (FIG. 2).

In FIG. 7, the proper phasing is accomplished by means of the dielectric material 28 applied to the inner surface of the horn 27. This material 28 may completely fill the horn 27 at its throat 29 and is formed into a cone 34 to improve the impedance match. The dielectric gradually decreases in thickness as the mouth 30 is approached. The rate of taper is so chosen that the phase velocity of the radiated wave matches the phase of the rays 11 (FIG. 1) when they meet the caustic surface 13. There is a natural downward tapering of the illumination strength toward the rim of the flare because of the feed geometry. This taper can be optimized to reduce side lobes by changing the dielectric thickness distribution and making a small phase-compensating variation in the shape of the feed, so that it will not exactly follow the caustic surface. In FIG. 8, the dielectric surface 32 is backed up by the quarter-wave, transverse slots 33 to inhibit longitudinal currents in the underlying conducting surface and give a more circularly symmetrical illumination pattern.

In FIG. 9, the inner surface of the dielectric material

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37 has been partly metallized to form a dielectrically loaded, leaky-pipe radiator. As shown, four metallic rings 36 are spaced along the surface.

In each of the horns shown, the diameter of the mouth of the horn is preferably greater than a wavelength in air.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A directional antenna comprising a spherical reflector and a round waveguide with flared end positioned to illuminate the reflector, the inner surface of the flared end being shaped like a cusp and approximately coinciding with the caustic surface formed by a plane wave reflected from the reflector.

2. An antenna comprising a spherical reflector and a metallic horn of circular cross section adapted to illuminate the reflector, the horn being shaped like a cusp and having a surface approximately coinciding with the caustic surface formed by incident parallel rays reflected from the reflector.

3. An antenna comprising a spherical reflector and a metallic horn of circular cross section adapted to illuminate the reflector, the inner surface of the horn being covered with a layer of dielectric and the horn including a plurality of metallic rings spaced along the surface of the dielectric to form a radiator of the leaky-pipe type.

4. An antenna comprising a spherical reflector and a metallic horn of circular cross section adapted to illuminate the reflector, the inner surface of the horn having a plurality of transverse grooves with a depth of at least a quarter wavelength at the operating frequency of the horn.

5. An antenna comprising a spherical reflector and a metallic horn of circular cross section adapted to illuminate the reflector, the inner surface of the horn having a plurality of transverse grooves with a depth of at least a quarter wavelength at the operating frequency of the horn and the grooved surface being covered with a layer of dielectric.

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