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FOLDED HORN-REFLECTOR ANTENNA WHEREIN PRIMARY REFLECTOR IS NONREFLECTIVE AT PORTION WHERE SPECULAR REFLECTION TO FEED WOULD OTHERWISE OCCUR

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FIG. 1

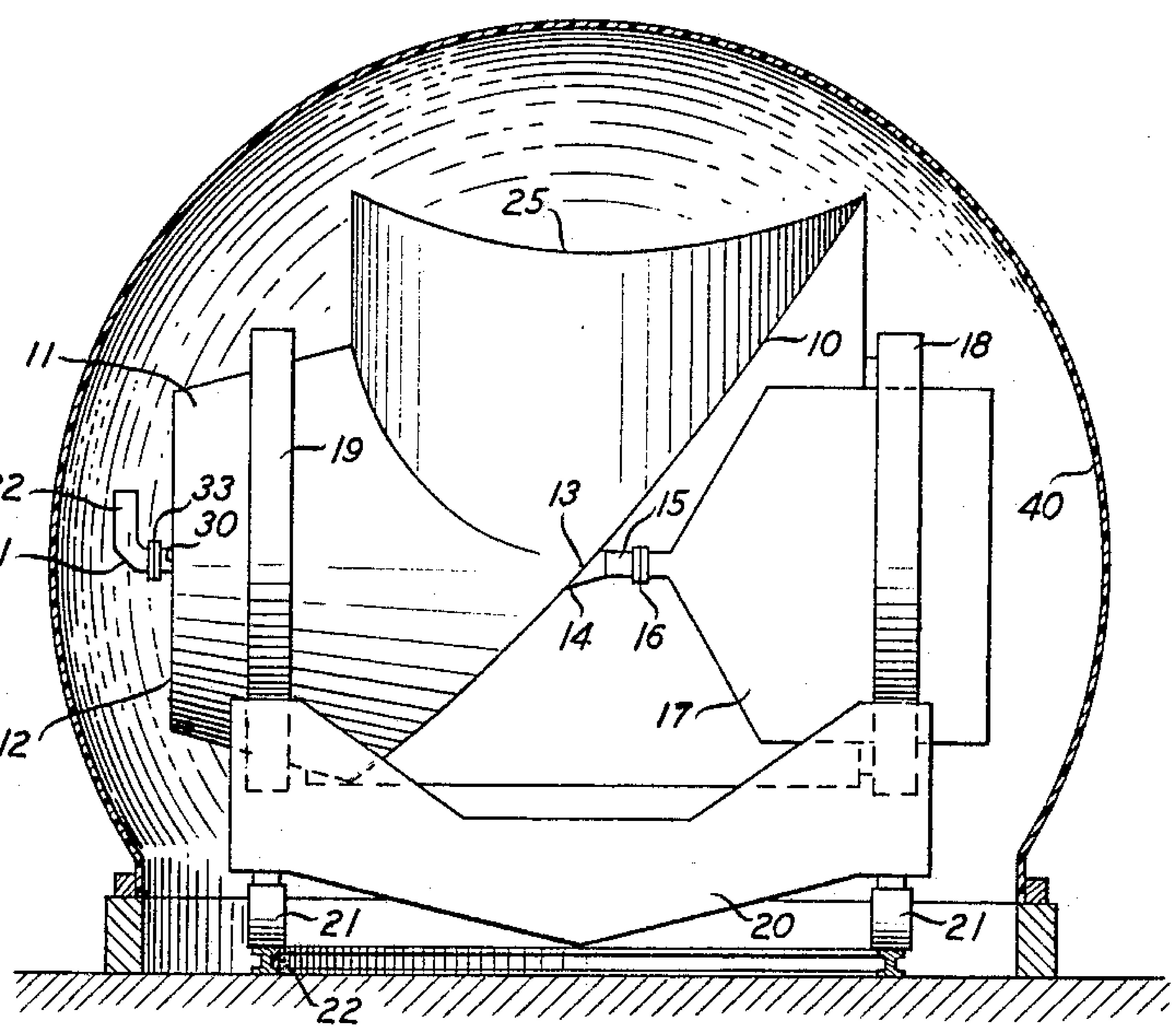
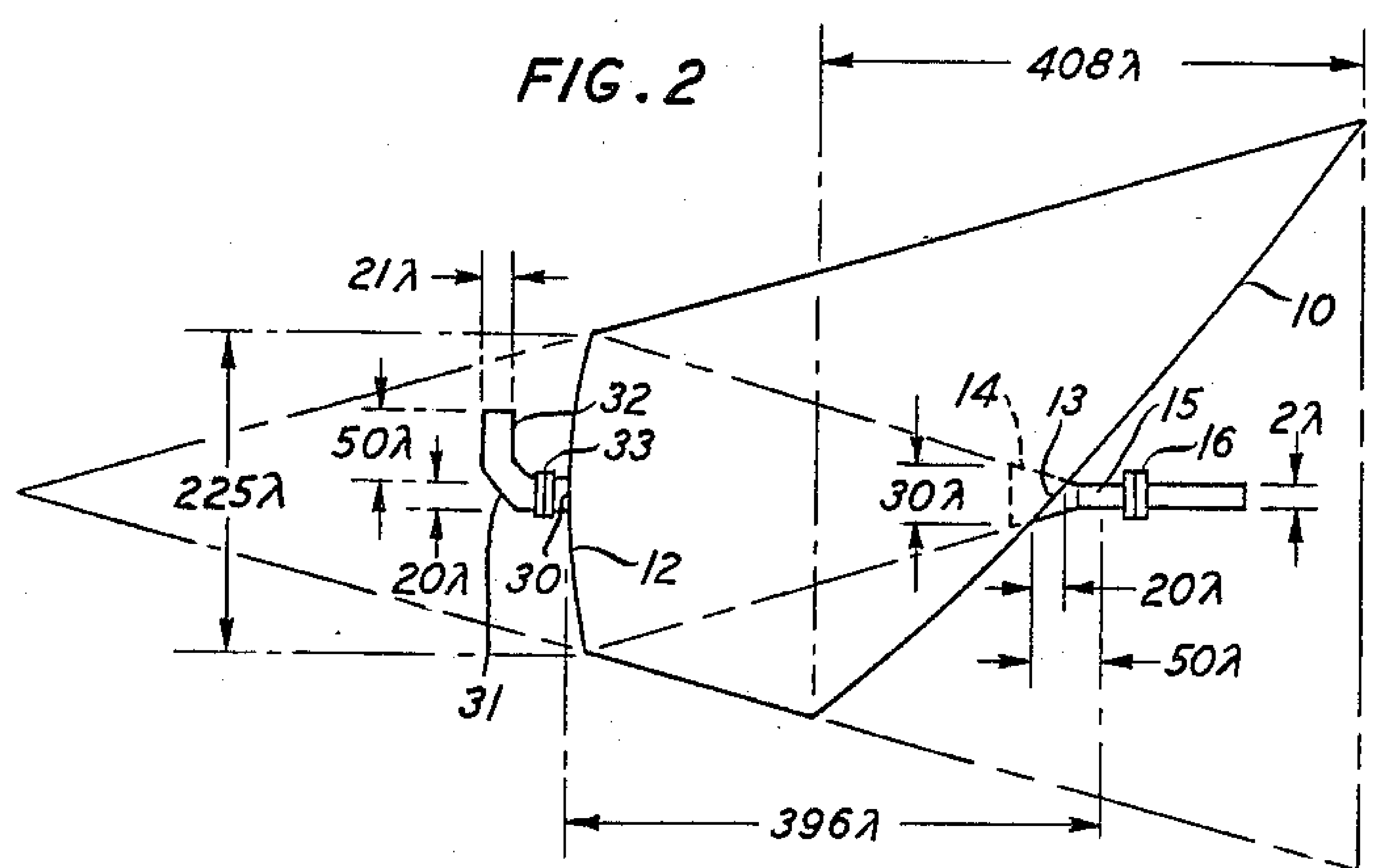


FIG. 2



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FOLDED HORN-REFLECTOR ANTENNA WHEREIN PRIMARY REFLECTOR IS NONREFLECTIVE AT PORTION WHERE SPECULAR REFLECTION TO FEED WOULD OTHERWISE OCCUR

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This invention relates to microwave antennas and more particularly to folded horn-reflector antennas which, although structurally compact, exhibit a low noise characteristic over a broad band of frequencies.

The horn-reflector antenna has received wide acceptance as a low noise, broadband microwave antenna. It is essentially a combination of a conical electromagnetic horn and a reflector formed of a section of a paraboloid of revolution, in which the feed of the antenna is located at the apex of the horn and the apex is coincident with the focus of the paraboloidal section. Aside from use as the transmitting and receiving antenna of broadband radio relay systems and the like, these antennas have, particularly because of their low noise properties, profitably been used in radio astronomy and similar applications. In such uses, it is, of course, necessary that the antenna be moved in azimuth or in elevation or both in order that a moving target may be tracked. To insure a high order of pointing accuracy, the mechanical system utilized to aim the antenna must be extremely responsive to electrical pointing direction signals. If the antenna structure is of large structural mass, physical response to control signals is sluggish. In short, the smaller the antenna, the easier it is to move accurately during a tracking operation.

Consequently, it has been proposed to reduce substantially the physical size of a horn-reflector antenna by truncating the horn with a reflecting surface introduced along the axis of the horn and perpendicular, at the horn axis, to it. In effect, the apex of the horn is folded back upon the cone axis and is established at a point just behind the paraboloidal reflecting surface of the antenna. A suitable aperture placed at the intersection of the cone axis and the reflector permits energy to travel in the general direction of the axis to and from an equipment room placed behind the reflector surface. With a folded configuration of this sort, the antenna's length is substantially reduced although the reflector aperture and horn flare angle are retained at their optimum values. The configuration permits a more efficient structural design, particularly in terms of dynamic response. Antenna pointing accuracy is improved and the mass inertia about the azimuth axis is appreciably reduced resulting in superior response to steering forces. With a shorter structure, the reflector suspension can be supported more directly and can be much stiffer so that error data compensation may be eliminated. The smaller construction also provides for easier equipment installation, a shorter transmission line, improved accessibility for maintenance, and a considerable reduction in the size of the foundation structure. And, finally, if the antenna is to be enclosed in a weatherproof structure, such as a radome, the size of the radome and its foundation may be considerably reduced.

The numerous structural advantages of the folded horn-reflector antenna are purchased, however, at the expense of electrical qualities. In particular, the noise temperature of the antenna is somewhat increased over the straight cone arrangement due, in part, to the possibility of additional spillover lobes, but primarily as a result of energy reflected between the truncating reflector and the apex of the cone which, particularly during transmission, returns to the apex of the horn and the feed system waveguide.

Although the aperture in the paraboloidal section is small as compared with the overall reflecting surface, the on-axis energy passing through the aperture from the auxiliary reflecting surface is, in a low noise antenna, nevertheless of considerable importance.

It is the primary object of the present invention to reduce substantially the noise temperature of a folded horn-reflector antenna.

In accordance with this object, the noise temperature of a folded horn-reflector antenna is appreciably improved by providing an aperture in the auxiliary reflecting surface of the truncating reflector at the intersection of the cone axis with it, and providing means for dissipating energy passing through the aperture. In a preferred form of the invention, energy passing through the aperture is directed by means of a reflecting surface, typically a section of a paraboloid, and a waveguiding system to the sky. If provision is made for rotating the antenna structure in elevation, i.e., about the cone axis, a rotary joint is provided in the waveguiding system to hold it in its assigned position notwithstanding rotation of the truncated horn structure.

The invention will be fully apprehended from the following detailed description of an illustrative embodiment thereof, taken in connection with the drawing in which:

FIG. 1 is a greatly simplified view of a truncated horn-reflector antenna which incorporates the features of the present invention; and

FIG. 2 is a sectional view through the elevation axis of a truncated horn-reflector antenna which illustrates the features of the invention.

A simplified view of a folded horn-reflector antenna which embodies the features of the present invention is shown in FIG. 1 as it may be arranged for use in radio astronomy or similar applications. It includes primary reflector **10**, generally a paraboloidal surface, and a truncated portion of a conical horn **11** coupled thereto such that the apex of the cone coincides with the focus of the reflector. A cylindrical section **25** is shown encircling the antenna's aperture to shield it and contribute to the low noise characteristic of the antenna. The portion of the antenna including the primary paraboloidal reflector and the initial portion of the cone are of essentially the same configuration as that shown in Patent 2,416,675 to A. C. Beck et al. granted March 4, 1947.

The conical horn is truncated, in accordance with the present invention, by a reflecting surface **12** disposed about the longitudinal axes of the feed horn, the cone axis, at a point along the axis which effectively places the apex of the horn and the focus of reflector **10** at a point on the cone axis just behind an aperture **13** in reflector **10**. Since this point on the axis lies in the plane defined by the end of the truncated horn, it is convenient to refere to the reflecting surface **12** as being placed "at the plane of truncation" of the horn.

Auxiliary reflector **12** may be, in the simplest case, a plane polished surface. To secure the utmost in size reduction, it may comprise a curved reflecting surface, e.g., a concave shaped surface, with its center of curvature on the cone axis and its cavity facing reflector **10**. With suitable curvature, the reflective system may be made to fit within a length equal to the beam diameter of the primary reflector, at which length the angular aperture, known as the flare angle, becomes about seventy degrees.

A conical waveguide section **14**, which extends through aperture **13**, terminates in a transmission line, e.g., waveguide **15**, which is connected by way of a rotating waveguide coupling **16** to the terminal radio receiver or transmitter or both located in equipment enclosure **17**. A stable rotating coupling of this sort is commonly called a "choke joint." By virtue of the choke joint, enclosure

17 remains stationary as the horn-reflector structure rotates in elevation. In the illustration, the cone axis of the horn is horizontal so that with rotation in azimuth the horn section, paraboloidal reflector **10**, and enclosure **17** move in a horizontal plane.

The entire antenna structure is arranged to rotate in azimuth and in elevation. The primary support of the elevation structure is provided by wheel **18** located near the paraboloidal reflector end and wheel **19** located near the truncated end of the conical structure. Wheels **18** and **19** ride in turn on a cradle structure **20** which is arranged to rotate in azimuth. The cradle typically is of light weight space frame construction and supports both the antenna and equipment enclosure structures for rotation. The total weight of the antenna structure is thus supported on bearing means, e.g., on trucks **21**, only two of which are outlined in the illustration. The bearing members ride on track **22** to provide rotation about the vertical or azimuth axis.

In accordance with the invention, an aperture **30** is provided in auxiliary reflector **12** at the intersection of the axis of cone **11** with it. On-axis energy components, which after reflection during transmission, would again follow the axis path and pass through aperture **13** in the paraboloidal reflector and enter the coupling waveguide system as signal interference are, instead, transported by way of a waveguiding system, coupled to reflector **12** at the aperture **30**, to a radio frequency energy absorber. The absorber may take any one of a number of forms, for example, a labyrinth or maze, an accumulation of dissipative material, a dummy antenna, or the like which terminates the waveguiding system. The absorber must not, however, give rise to noise since this would raise the noise temperature of the system. A preferred dissipation system which provides nearly perfect absorption, and virtually no noise or reflections, comprises an open-ended wave directive system, preferably including a guide member an integral number of wave lengths long, pointing away from the pointing direction of the antenna. The directive system advantageously includes a reflector surface **31**, e.g., a paraboloidal reflector, placed to direct energy to the sky as an absorber, and is adjusted in length and cross-sectional dimensions to assure a reflectionless termination, e.g., by means of a tapered section or the like. So that the noise absorber system is always directed at a selected portion of the sky as the antenna system is moved in tracking a target, a choke joint **33** is provided and the outer portion of the guiding system is structurally held in position.

Since the portion of the horn nearest the apex must be smooth within at least 30 wave lengths, and to provide shielding against external radiation, the conical waveguide section **14** is allowed to extend in front of paraboloidal reflector **10** to about 50λ from the focus. The extension of the horn section **14**, whose aperture at the widest point is typically 30λ, additionally establishes a sufficiently large initial radiating aperture to limit the radiated beam width and side lobes to acceptable values. The horn extension itself, of course, reduces slightly the capture area of the antenna, but the slight loss is a small price to pay for the drastic reduction in physical size and mass, of the antenna which is made possible by the overall folded horn construction. The more efficient structural design, particularly in terms of dynamic response, in turn yields improved reception due to better pointing accuracy. Because of somewhat limited beam width and side lobes, random noise components entering the waveguide **32** from the sky are not easily coupled through the system to the receiver.

Radome **40**, of any desired construction, may be used if desired to protect the structure. By virtue of the shortened horn configuration, the antenna may be installed in a radome of considerably smaller dimensions than would be required for the nonfolded horn. Further, the noise pattern resulting from the radome construction is held more constant during scanning since the antenna aperture is more nearly concentric with the rotational center of the radome.

Turning now to a somewhat more detailed description of the configuration of the antenna of the invention, FIG. 2 illustrates schematically a cross-sectional view of an antenna showing a primary reflecting surface **10**, an aperture **13** in the primary reflector, an aperture **30** in auxiliary reflecting surface **12**, and a radio frequency energy directive system **32** which diverts on-axis energy away from the antenna.

In this view, it is apparent that the antenna consists of a paraboloidal reflecting section illuminated by a conical horn. The apex of the horn coincides with the focus of the paraboloidal section and the axis of the horn is perpendicular to the axis of the primary reflector. The paraboloidal section thus acts as a combined right angle reflector and phase corrector for the diverging spherical wave so that waves appear at the aperture **30** of the antenna as a plane wave front. The conical horn is truncated by auxiliary reflecting surface **12**, which in effect, folds the truncated cone of the horn back upon the cone axis to place the virtual apex at a point just behind the paraboloidal reflecting surface. Preferably, the horn is truncated at a point along the cone axis at which the diameter of the cone is approximately 225 wave lengths (λ) at the primary frequency of the antenna. This brings the apex of the cone to a point approximately 396λ away from the reflecting surface at a point just behind the paraboloidal mirror. Consequently, the initial portion of the horn which protrudes through the paraboloidal section has a nominal dimension along the conical axis of 50λ. It should be noted that all dimensions are given in terms of wave length merely by way of illustration since they are largely dependent on the flare angle of the horn or angular aperture of illumination. The dimensions given are illustrative of one antenna in which the flare angle has been selected to be optimum for both electrical and geometrical-structural considerations.

Aperture **30** on the cone axis, approximately 20λ in diameter, is sufficiently large for removing on-axis reflections without appreciably altering the efficiency of the antenna or changing its primary lobe pattern. It is coupled by means of choke joint **33** and preferably is folded by means of a reflecting surface **31** to waveguiding system **32** fixed with respect to the rotation of the antenna structure to a point of high radio frequency absorption. Typically, a paraboloidal secion reflector complementary to that at the on-axis intersection of the cone with the primary paraboloidal reflector (the portion removed at aperture **13**) is satisfactory. It directs on-axis energy to a circular guiding system which, typically, is approximately 21λ in diameter. It has been found that a length of 20 to 50λ for the open ended cylindrical guide is satisfactory if a paraboloilad reflector is used; a length of 100 to 150λ is preferred if a plane reflector is used.

What is claimed is:

1. An antenna which comprises, a truncated feed horn, a mirror-like reflecting surface at the plane of truncation of said horn, a curved primary reflector spaced from said reflecting surface along the longitudinal axis of said feed horn, and aperture in said primary reflector at the intersection of the axis of said feed horn therewith whereby the effective apex of said horn and the focus of said primary reflector coincide at a point on the side of said primary reflector remote from said reflecting surface, an aperture in said mirror-like reflecting surface substantially on the axis of said horn, the aperture areas in said primary reflector an in said mirror-like reflecting surface being small as compared with the areas of said corresponding reflecting surfaces, and means coupled to said aperture in said mirror-like reflecting surface for dissipating energy incident on said aperture.

2. An antenna as defined in claim **1** wherein said mirror-like reflecting surface at the plane of truncation of said horn comprises a curved reflecting surface disposed about and with its center on the longitudinal axis of said feed horn and with its cavity facing said primary reflector.

3. An antenna which comprises, a paraboloidal reflector, a truncated horn coupled to said paraboloidal reflector, an auxiliary reflector secured at the plane of truncation of said horn whereby the effective apex of said horn is made to coincide with the focus of said paraboloidal reflector on the side of said paraboloidal reflector remote from said auxiliary reflector, an aperture in said paraboloidal reflector at the intersection of the axis of said horn therewith, waveguide feed means coaxial with said aperture in said paraboloidal reflector coupled to said remote side of said paraboloidal reflector, an aperture in said auxiliary reflector substantially on the axis of said horn, and means coupled to said auxiliary reflector on the side thereof remote from said paraboloidal reflector in substantially coaxial alignment with the axis of said horn for dissipating energy directed along the axis of said horn which passes through said aperture in said auxiliary reflector.

4. An antenna as defined in claim **3** wherein said means for dissipating energy directed along the axis of said horn comprises, an open ended wave directive system coupled to said auxiliary reflector on the side thereof remote from said paraboloidal reflector in substantial alignment with the axis of said horn, and means for continuously directing the open end of said directive system toward an energy-dissipating medium.

5. A folded conical horn-reflector antenna system comprising,

a paraboloidal reflecting section illuminated by a truncated conical horn, the apex of which horn coincides with the focus of the said paraboloidal section and the axis of which horn is perpendicular to the axis of the paraboloidal reflecting section,

an auxiliary reflecting surface supported at a point along the axis of said cone at which the diameter of said cone is approximately 225 wavelengths wide at the primary frequency of said antenna, whereby the truncated cone of said horn is effectively folded back

upon said cone axis to place a virtual apex of said horn at a point just behind said paraboloidal reflecting surface,

a waveguide feed horn supported to protrude through said paraboloidal section at the intersection thereof with said horn axis, said waveguide feed horn having an effective aperture diameter of approximately 30 wavelengths,

a symmetrically located aperture in said auxiliary reflecting surface with a diameter of approximately 20 wavelengths for removing on-axis energy without appreciably altering the efficiency of said antenna or changing its primary lobe pattern, and

means coupled to said auxiliary reflecting surface coaxial with said aperture on the side thereof removed from said paraboloidal section for directing on-axis energy to a point of high radio frequency absorption.

6. An antenna as defined in claim **1** wherein said means coupled to said aperture in said mirror-like reflecting surface for dissipating energy incident on said aperture includes a waveguide system coupled to said mirror-like reflecting surface coaxially with said aperture, and radio frequency energy absorbing means for terminating said waveguide system.

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