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CASSEGRAIN ANTENNA FOR SCANNING WITH ELLIPTICALLY SHAPED BEAM

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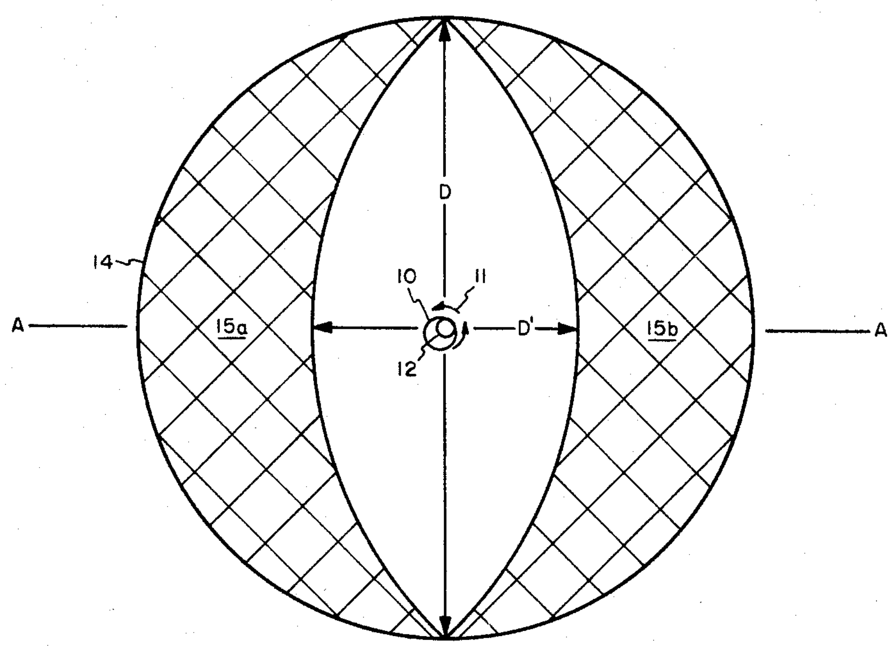

FIG. 1

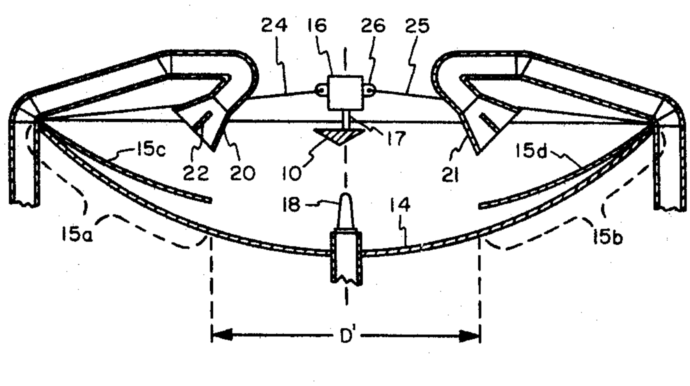

FIG. 2

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CASSEGRAIN ANTENNA FOR SCANNING WITH ELLIPTICALLY SHAPED BEAM

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The present invention relates to antennas for directionally transmitting radio frequency (RF) energy in a particular shape beam.

One aspect of the present invention relates to a novel antenna arrangement for propagating an elliptically shaped beam of RF energy.

Another aspect relates to a novel compact antenna arrangement for independently propagating each of three separate beams by a composite, compact antenna.

A further aspect relates to a novel antenna arrangement for propagating an elliptical beam and rotating the elliptical beam while maintaining the orientation of the elliptical shape.

Generally, the novel antenna system described herein directionally transmits an elliptical shaped beam which is conically scanned, thus rotating the elliptical beam in a circle. This beam is referred to as the main beam. The present state of the art is such that side lobes of RF adjacent to the transmitted beam are not eliminated by antenna design. In order to eliminate undesirable effect of the side lobes the antenna system includes the generation of two elliptical auxiliary beams positioned respectively at the sides of the main beam which may essentially blanket the side lobes of the main beam.

The novel antenna system is a composite antenna of at least two different types combined in compact arrangement. One of the antennas may be referred to as a Cassegrainian type antenna while another of the antennas of the composite system may be referred to as a horn-reflector arrangement.

The main beam is propagated by the Cassegrainian type antenna which employs the novel combination of a dielectric rod feed, which is tapered along the major part of its length. The feed appears through the vertix of a modified parabolic reflector or main dish and directs RF energy to an eccentrically rotated hyperboloidal reflector or subdish. The feed is particularly located at one focal point of the hyperbolic reflector and the hyperbolic reflector images the real source of RF into a virtual source at its other focal point, the "other" focal point being coincident with the focal point of the parabolic reflector.

The elliptical shape of the propagated beam may be provided in any one of several ways: feed modification; subdish modification or main dish modification, the latter being the preferred method and the arrangement with which the present application is concerned. An elliptically shaped beam may be provided by providing an unmodified feed and subdish arrangement and providing a main dish having a substantially elliptical configuration, from a plan view. The desired structure of the main dish may be provided by modifying a parabolic reflector by reducing the aperture dimension of the reflector in the azimuth plane. The resulting pattern will have a beam width equal to:

$$Y\lambda/D' \qquad (1)$$

where K is a constant determined by the illumination taper at the edge of the aperture; λ is the wave length of the RF energy and D′ is the length of the minor axis.

The main antenna of the complex, compact antenna system provides a scanned beam from a feed which produces a circular radiation pattern which illuminates an eccentrically driven hyperboloidal reflector which re-

radiates the power into a generally elliptically shaped (modified) parabolic reflector. The beam is scanned by rotating the hyperboloid or subdish so that its center makes a circle about the focus of the paraboloid. The amount of eccentricity (radius of the circle) determines the squint angle of the emerging beam.

One limitation of the Cassegrainian type antenna is the blocking effects of the hyperboloidal subdish and feed. These blocking effects reduce the antenna gain, widen the beam width and increase the side lobe level. The condition for minimum aperture blocking occurs when the front blocking of the subdish is made substantially equal to the back blocking of the feed. The minimum blocking diameter is given by the expression:

$$D_b \text{ min.} = \sqrt{\frac{2}{k}F\lambda} \qquad (2)$$

where D_b min. is the diameter of the subdish; k is the ratio of effective feed aperture diameter to its blocking diameter; F is the focal length of the parabolic reflector and λ is the operating wave length of the RF energy.

It becomes clear from the Equation 2 that to minimize the blocking diameter it is necessary to use as short a focal length as possible. In the successful practice of the invention an eighteen inch (18″) diameter parabolic reflector was used in which the focal length was 4.5 inches. Equation 2 also indicates that an optimum feed for the Cassegrainian antenna is one in which the effective feed area is equal to the blocking area, that is, where $k=1$. This condition exists for a dielectric rod antenna for which the effective receiving area is greater than its physical blocking area. This is due to the fact that the "end-fire" dielectric rod antenna achieves its gain through length rather than cross-section.

Thus, solving Equation 2 where $F=4.5''$, $k=1$ and $\lambda=.76''$ the D_b min.$=2.6''$. Therefore, for example, an 18″ parabolic reflector having a 4.5″ focal length may use a subdish of 2.6″ in diameter.

The diameter of the subdish being established, its shape remains to be determined. The equation for the equivalent focal length (F_e) of a Cassegrainian antenna is:

$$F_e = \left(\frac{\tan \frac{1}{2}\theta_v}{\tan \frac{1}{2}\theta_r}\right)F_m \qquad (3)$$

where F_m is the focal length of the parabolic reflector; θ_v is half angle subtended by the parabola from its focal point and θ_r is half angle subtended by the hyperboloid from its feed point.

Equation 3 shows that as θ_r decreases, large effective focal lengths are possible. However, as θ_r decreases the gain of the feed required to correctly illuminate the subdish increases. Since part of the energy illuminating the dish is spilled over, it is desirable to keep the gain of the feed low. Assuming the spillover gain is equal to the illumination edge taper times the gain of the feedhorn with the feed gain at 10 db and the taper at 10 db the peak gain of the spillover is 0 db. With an antenna gain of 34 db, for example, the spillover power will not be a problem for a 10 db feed.

An example of a compromise between F_e (the focal length of the Cassegrainian antenna) and the spillover power may be:

$$\frac{F_e}{F_m} = 2 \qquad (4)$$

thus, the off axis scanning characteristics will be determined by the equivalent:

$$\frac{F}{D} = .5 \qquad (5)$$

where D is the major diameter of the modified main dish.

The relationships for determining the equation of the hyperboloid are:

$$\frac{1}{\tan \theta_v}+\frac{1}{\tan \theta_r}=\frac{2F_c}{D_s} \quad (6)$$

where F_c equals the distance between the focal points of the hyperboloid, D_s equals the diameter of the subdish and

$$\frac{F_c}{F_m}=\frac{e+1}{e-1} \quad (7)$$

where e equals eccentricity of the hyperboloid.

The contour of the subdish is determined by the equation

$$X_s=a\left[\sqrt{1+\left(\frac{Y_s}{b}\right)^2}-1\right] \quad (8)$$

(X_s and Y_s are unknowns)

where

$$a=\frac{F_c}{2_c} \quad (9)$$

$$b=a\sqrt{e^2-1} \quad (10)$$

and for the exemplary parameters chosen, the values of the constant are:

$e=2.946$

$a=.1697$

$b=.4702$

Employing the presented equations a Cassegrainian type antenna may be provided for propagating a conically scanned elliptical beam of energy.

It is therefore an object of the present invention to provide a novel antenna arrangement for popagating an elliptically shaped beam of RF energy.

Another object is to provide an antenna arrangement for propagating an elliptical beam of RF energy and for rotating the elliptical beam while maintaining the same orientation of the elliptical shape.

Another object is to provide a composite compact antenna system for transmitting a conically scanned elliptical beam with two auxiliary elliptically shaped beams also transmitted by the same system for covering adjacent side lobes on either side of the main beam.

These and other objects will become more apparent from reading the following detailed description of an embodiment of the invention in which:

FIG. 1 is a plan view of the main dish with details of the auxiliary antenna feeds omitted for the sake of clarity, and

FIG. 2 is a cross-section view, from the side of the composite antenna system for propagating a conically scanned elliptical beam and two auxiliary elliptical beams.

Referring more particularly to FIG. 1, the surface contour of the main dish or main reflector is illustrated with the major diameter D and minor diameter D′ indicating the major and minor diameters of the reflector, respectively. The circle **12** has its center at the axis of the diameters and illustrates the path of the center of the subdish **10** in its rotational movement. The arrows **11** represent the eccentric movement or rotation of the subdish **10**.

FIG. 1 illustrates one method of forming the elliptical structure of the reflector D/D′ from a round parabolic reflector, such as represented by **14**. The cross-hatched areas of **15*a*** and **15*b*** may be covered with a microwave absorbing material.

As shown above, the equations provided may be used for mathematically determining the minor diameter D′ and the contour of the sides of the elliptically shaped reflection area. The length and width measurements of the beam will be determined by the size of the reflector and the surface or plan and side or profile contours of the reflector. By way of example, a beam having an elevation width of 3.20 degrees and an azimuth width of 4.7 degrees has been provided by the arrangement shown where a parabolic reflector, such as 14, had a major diameter D measuring 18 inches with the sides of the elliptically shaped reflector extending to a minor diameter D′ measuring 8 inches.

It will be appreciated that the drawing FIG. 1 has omitted apparatus for propagating the auxiliary or cover beams. This has been omitted for the sake of clarity. In addition, the motor employed for rotating the subdish **10** and a network for suspending the motor and subdish have also been omitted. The dielectric rod feed is hidden by the subdish **10**. The omitted components may be seen in the profile view in FIG. 2.

In order to provide a composite antenna system for propagating a main beam and two auxiliary or cover beams, the reflectors for each of the auxiliary beams may be positioned in the unused areas **15*a*** and **15*b*** of the parabolic reflector **14**. The feed may be in the form of a wave guide horn, one horn for each reflector, positioned to illuminate the particular reflector for providing the auxiliary beams.

This may be seen in FIG. 2 which illustrates a profile view along line A—A of a composite, compact antenna system positioned within a parabolic reflector, part of which is used as part of the antenna for transmitting the main beam.

The sections **15*a*** and **15*b*** in FIG. 2 correspond to the identically labeled sections in FIG. 1. The minor diameter D′ is shown in profile location on the parabolic reflector **14** and corresponds to the minor diameter D′ in FIG. 1.

In utilizing the areas **15*a*** and **15*b*** for positioning reflectors for the auxiliary beams, sectors of another parabolic reflector may be positioned above the areas **15*a*** and **15*b*** such as shown by **15*c*** and **15*d***, respectively. The "other" parabolic reflector, from which the sectors, represented by **15*c*** and **15*d***, may be cut, would be a reflector substantially physically similar to reflector **14**.

The sectors may be inserted over the unused reflection areas with each sector **15*c*** and **15*d*** being tilted, for example, some 7°. Radio frequency energy is fed by open wave guide horns **20** and **21**, respectively, each positioned above the reflector sector with which it is associated and each tilted some 30°, for example, in opposite directions.

Since each of the auxiliary beams, propagated by the auxiliary antennas, are intended to be stable beams, as opposed to the scanned or rotated main beam, the sector forming the reflector (**15*c*** or **15*d***) need not be exactly physically symmetrical, in plan form, as is desired of the main dish of the main antenna. Thus the sectors **15*c*** and **15*d*** may be substantially corresponding to the shape of the areas **15*a*** and **15*b*** respectively.

In order to provide a wide azimuth pattern of auxiliary or cover beam, each of the horns **20** and **21** may be in the form of a dual horn. In the preferred form, each of the horns **20** and **21** is in the form of a pyramidal horn with an E plane bifurcation. This may be formed by a septum **22** which serves to split the power propagating into the horn into two equal parts so that at the exit aperture there are essentially two-in-phase horns side-by-side. This construction positions the phase center of each horn of the dual horn at different offset distances from the focal point of the parabola sector so that the peak of each beam propagated by the dual horn arrangement will occur at a different azimuth angle producing a wider pattern than obtainable from a single horn of the same combined aperture.

Each of the horns, **20** and **21**, also includes its respective wave guide line for conducting microwave energy from a source (not shown) to the horn.

Also shown in FIG. 2 is a representation of a motor **16** for driving the subdish **10**. A shaft, **17**, couples the motor **16** to the subdish **10** and, as will be readily seen, such coupling is at an off-center position of the subdish. Thus the subdish is rotated eccentrically about the axis of the diameters D and D′ as indicated in FIG. 1.

The dielectric rod feed **18** is also shown, positioned at the center position along diameters D and D'.

The composite, complex antenna assembly may also include a radome, not shown, for protecting the apparatus from the elements.

It will be obvious that the motor **16** and subdish **10** must be suspended in some manner so as to hold the motor and subdish in position. This may be accomplished by a cross network of rods which are sufficiently small in diameter so as not to undesirably interfere with energy radiated from the antenna assembly, but sufficiently strong to support the motor and subdish and hold such components in place.

A preferred network may consist of at least four support rods (two of which **24** and **25** are shown) supporting a collar or frame **26** which may support the motor **16**. The subdish **10** would then be supported by the shaft **17** which serves also to rotate the subdish.

It thus becomes obvious that an antenna for transmitting an elliptical beam (an unscanned beam) may be made by slightly modifying the arrangement shown.

If, for example, the hyperboloid reflector **10** were positioned so that its center were in coincidence with the axis or crossing point of the diameter D and D' of the parabolic reflector **14** and the means for rotating the hyperboloid reflector **10** were eliminated then an antenna for propagating a highly directional elliptically shaped beam is provided.

Considering this latter arrangement two ways have been shown for providing an elliptically shaped beam.

Thus there has been described and shown the preferred arrangement for practicing the invention. Obviously, other arrangements and structure employing the same principles disclosed herein may be used, as will be familiar to those skilled in the art, without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A microwave energy antenna for directionally transmitting a conically scanned elliptically shaped beam of microwave energy including;

a modified parabolic reflector having the aperture dimension of said reflector reduced in the azimuth plane for providing a beam width equal to

$$K\lambda/D'$$

where K is a constant determined by the illumination taper at the edge of the aperture, λ is the wave length of said microwave energy and D' is the length of the minor axis,

a hyperboloidal reflector positioned above said modified reflector and at the focal point thereof for radiating energy to said modified reflector.

a dielectric rod feed positioned on the axis of said modified reflector for radiating microwave energy to said hyperboloidal reflector, and

means for revolving the hyperboloidal reflector eccentrically about the axis of said modified parabolic reflector.

2. A microwave energy antenna as in claim **1** and in which said dielectric rod feed is tapered along its length for disturbing microwave energy over the radiating surface of said hyperboloidal reflector.

3. A microwave energy antenna system for directionally transmitting a conically scanned elliptically shaped beam of microwave energy and at least two auxiliary beams azimuthly positioned for covering side lobes of the conically scanned elliptically shaped beam including;

a modified parabolic reflector having the aperture dimension thereof reduced in the azimuth plane for providing a beam width equal to

$$K\lambda/D'$$

where K is a constant determined by the illumination taper at the edge of the aperture, λ is the wave length of the microwave energy and D' is the length of the minor axis,

a hyperboloidal reflector positioned at the focal point of the said modified reflector for radiating microwave energy to said modified reflector,

a dielectric rod positioned on the axis of said modified reflector for radiating microwave energy to the radiating surface of said hyperboloidal reflector,

means for revolving said hyperboloidal reflector so that the center of the radiating surface of said hyperboloidal reflector revolves about the axis of said modified parabolic reflector,

first and second auxiliary reflectors each having substantially the same configuration as said modified reflector, the minor axis of said first and second auxiliary reflector and said modified reflector being substantially parallel and aligned,

means including a wave guide horn for radiating microwave energy on to the reflecting surface of said first auxiliary reflector for propagating a beam of microwave energy in an elliptically shaped configuration and positioned adjacent one side of the said scanned beam, and

means including a second wave guide horn for radiating microwave energy on the reflecting surface of said second auxiliary reflector for propagating a second beam of microwave energy in an elliptically shaped configuration and positioned adjacent the other side of the said scanned beam.

4. A microwave energy antenna system as in claim **3** and in which said wave guide horn and said second wave guide horn are each in the form of,

a pyramidal horn with an E plane bifurcation for dividing each said horn into two in-phase horns.

5. A microwave energy antenna system as in claim **3** and in which said modified parabolic reflector is formed by covering part of a round parabolic reflector with microwave absorbent material so that only an elliptically shaped portion of said round parabolic reflector serves to reflect energy radiated from said hyperboloidal reflector.

6. A microwave energy antenna system as in claim **3** and in which said modified parabolic reflector is formed by covering part of a round parabolic reflector with microwave energy absorbent material so that an elliptically shaped portion of said round parabolic reflector centered about the axis of said round parabolic reflector serves to reflect energy radiated from said hyperboloidal reflector and in which said first auxiliary reflector is supported by a portion of said round parabolic reflector covered by microwave energy absorbent material and said second auxiliary reflector is supported by another portion of said round parabolic reflector covered by microwave energy absorbent material so that the three antennas are essentially contained within the confines of a single round parabolic reflector.

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ELI LIEBERMAN, *Primary Examiner.*