

[54] **TORUS-TYPE ANTENNA HAVING A CONICAL SCAN CAPABILITY**

2,935,745 5/1960 Kelleher et al. 343/754
3,406,401 10/1968 Tillotson 343/100

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[57] **ABSTRACT**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 44,450, June 8, 1970, abandoned.

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343/840**

[51] Int. Cl. **H01q 19/12**

[58] Field of Search **343/781, 840, 912, 914,
343/DIG. 2, 761, 100 ST**

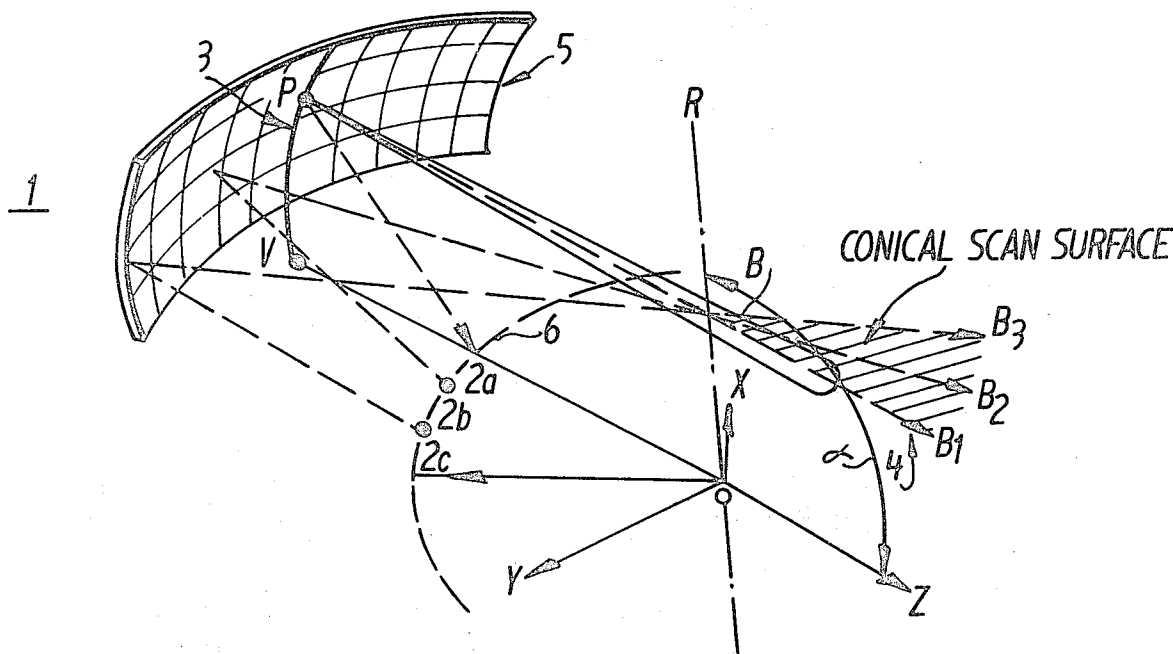
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UNITED STATES PATENTS

2,409,183 10/1946 Beck 343/779

A reflector type antenna which is formed by rotating a generating curve, having an axis of beam direction, about a fixed axis such that the axis of beam direction defines a beam scanning surface corresponding to the surface of a cone. Scanning is obtained by rotating a feed on the arc of a circle centered on the fixed axis so that, due to symmetry, radiation patterns on the beam scanning surface are identical for all feed positions. The beam scanning surface so described permits an approximation to the conical surface defined by a group of lines drawn from an earth station site to points on the geostationary arc.

7 Claims, 4 Drawing Figures



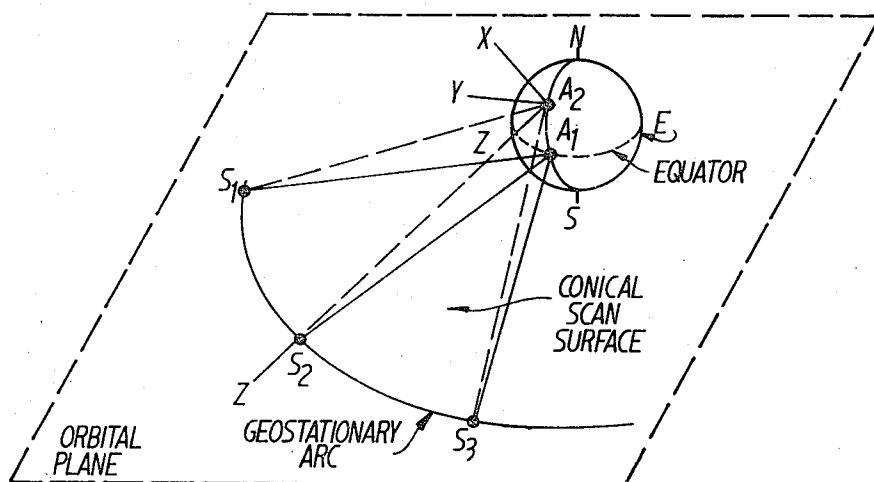


FIG. 1

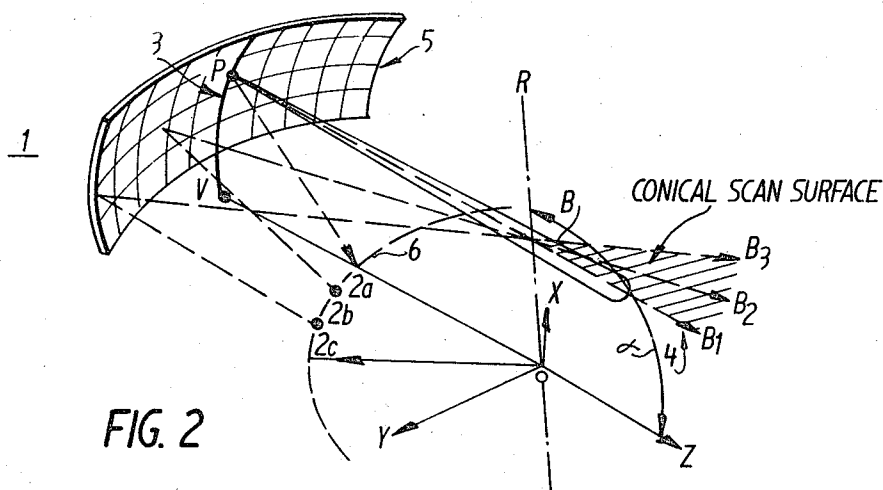
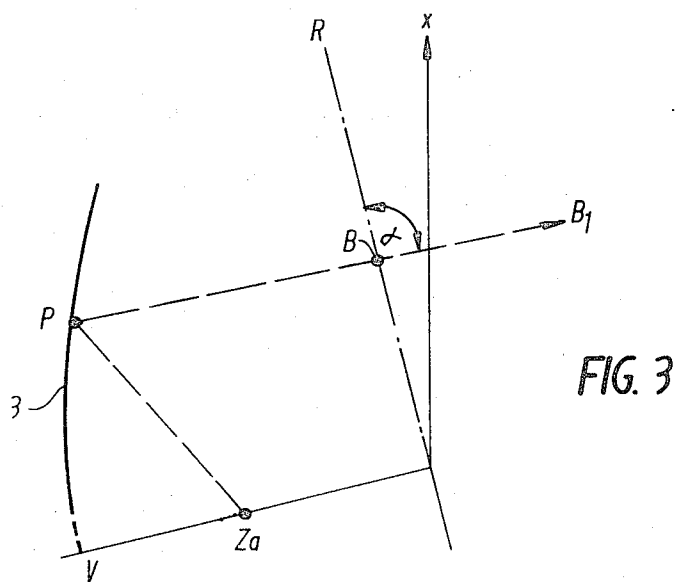
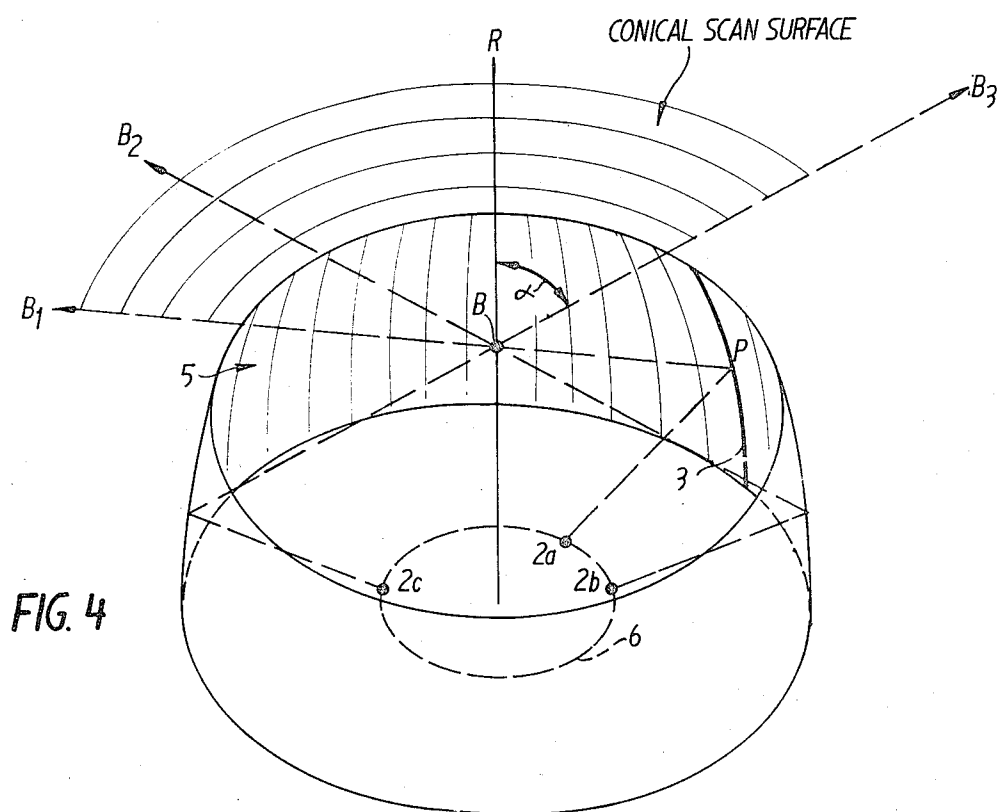


FIG. 2



TORUS-TYPE ANTENNA HAVING A CONICAL SCAN CAPABILITY

This application is a continuation-in-part of application Ser. No. 44,450 filed June 8, 1970, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is generally concerned with toroidal reflecting surfaces for electromagnetic wave transmission and reception. More particularly, the present invention is concerned with providing a stationary reflector antenna which is capable of scanning beams of electromagnetic radiation along the geostationary arc.

2. Description of the Prior Art

Toroidal reflector antennas have been well known in the art for their ability to provide rapid wide angle scanning of a narrow beam in a plane. Antennas of this type are typically employed in terrestrial point-to-point microwave communication systems wherein a beam or beams of electromagnetic radiation can be selectively or simultaneously transmitted from a common reflector surface to one or more receiving antennas spaced along a wide angle field of view. A typical system is disclosed in the U.S. Pat. No. 3,317,912 to Kelleher entitled "Plural Concentric Parabolic Antenna for Omnidirectional Coverage." The scan of the beams radiating from this class of reflecting antennas defines a planar surface for which the far field radiation patterns of all beams in the plane are identical. Such an antenna is defined as having circular symmetry in the plane of scan. Wide angle scanning can be facilitated by moving the reflector feed in a plane which is parallel to the scan plane to positions at equal distances from the reflector surface. Thus, if the beam is well focused for one feed position, it will be well focused for all similar feed positions.

The toroidal reflector surface is generally defined by a generating curve which is rotated about an axis. The concave side of the generating curve is geometrically dimensioned to collimate and direct the beam in a direction which is perpendicular to the axis of rotation. A linear representation of the direction of beam travel can be referred to as the "axis of beam direction." The locus of the several axes of beam direction radiating from a toroidal reflector is a planar surface. The equation of the generating curve used to create the reflector surface may be mathematically calculated to provide narrow beams, high gain performance with a minimum of phase error and low secondary lobe losses. The publication entitled "A Toroidal Microwave Reflector" by G. Peeler and D. Archer on pp. 242-247 of the IRE National Convention Record, Part 1 (1956) describes a typical mathematical approach to designing the generating curve. Rotation of the generating curve about an axis to define a toroidal surface will provide a reflector area useful in forming and directing electromagnetic beams originating from symmetrically disposed feeds lying in a plane perpendicular to the axis to a plurality of receivers located on the planar scan surface.

In the prior art, the generating curve is generally limited to an elliptic or parabolic conic section having a focal point interior to its concave side and lying along that axis of the parabola or ellipse which extends from its vertex. Electromagnetic energy radiated at or near

the focal point will be formed into a collimated beam and directed from the toroidal reflector surface along an axis of beam direction which is parallel to the axis of the conic section. Since the toroidal reflecting surface is created by rotating the conic section about an "axis of rotation" that is perpendicular to the axis of the parabola or the ellipse, the surface is identified as a "rectangular" torus reflector.

The prior art also teaches that the generating curve for a torus antenna may be the arc of a circle. However, because of the focusing properties of an arc of a circle, the torus reflector generated by rotation of the arc about an axis will not be a rectangular torus. For example, the surface generated by the revolution of a semi-circle about an axis through the vertex of the semi-circle will define a sphere. It is well known in the art as described in U.S. Pat. No. 3,406,401 to Tillotson, that a sphere has an infinite number of axes and that the concave side of a spherical reflector has an infinite number of focal points that define the surface of a smaller sphere, or focal surface, of one half the radius of the larger sphere. Rays incident on the reflector will be focused at unique points on the focal surface depending on the direction of such rays. For the special case of the spherical reflector, the axes of beam direction will cross the axis of rotation at angles which need not be 90°. Accordingly, the locus of the axes of beam direction will define a scan volume rather than a scan surface.

A description of the geometry and operation of the spherical torus, parabolic torus and elliptic torus reflector antennas may be found in the following prior art publications: (1) *Antenna Engineering Handbook*, Jasik, McGraw-Hill, Inc., 1961, (2) *Antenna Analysis*, Wolff, John Wiley & Sons, 1966.

For the rectangular torus reflector antenna, the feed point is typically on a line which is perpendicular to the axis of rotation and at a given distance from the axis of rotation. Scanning is obtained by rotating a feed to positions along an arc of a circle which has a radius centered at the axis of rotation and which lies in a plane perpendicular to the axis of rotation. Alternatively, the prior art teaches that a plurality of feeds may be located along the arc of this circle to provide the scanning function through selective energization of one or more of these feeds. The same feed at different positions along any feed arc that is circular, centered on the axis of rotation and lying on a plane perpendicular to the axis, will create identical beams. Since the prior art restricted the axis of rotation to a direction perpendicular to the axis of the conic section, the beams formed by the rectangular torus for similar feeds at similar feed points will necessarily lie in a common plane which is perpendicular to the axis of rotation.

Rectangular torus reflectors have an aperture-plane-phase distribution which can provide gain comparable to parabolic dish antennas. The gain is known to be a function of wave length, variation of the toroidal parameters and point feed location. The prior art rectangular torus has wide field of view capability through its planar scan, and hence is well adapted for many terrestrial point-to-point and radar applications. A low inertia moveable feed or a plurality of deployed feeds provides the toroidal antenna with an ability to produce a rapid scan throughout a wide field of view. The stationary reflector antenna has obvious advantages over moveable dish antennas which, because of their size

and weight are difficult to scan mechanically. In addition, the torus is capable of simultaneously reflecting a plurality of beams from a plurality of feeds over a wide field of view.

However, despite these attendant advantages, it has been found that the inherent limitation of the rectangular torus antenna to a planar scan severely limits the ability of the stationary reflector antenna in many other areas of communications technology. One area of limited application is that of terrestrial transmission to or reception from space satellites having communications or terrestrial observation applications which are typically located in geostationary orbit. The geostationary orbit is essentially a circle, having a 22,800 nautical mile radius, which is concentric and coplanar with the circle defined by a plane passing through the equator of the earth (orbit plane). It is characterized by a satellite orbital period of 24 hours, the earth's period of rotation.

The transmission of information to these synchronous satellites is provided through earth terminal antennas whose beams are fixed on the stationary satellite. Beams from the earth terminals require steering only to the degree that the geostationary satellite positions cannot be held in the face of orbital perturbations or to the extent that the synchronous satellites are either moved in the geostationary arc or are selectively illuminated by a single earth station antenna.

Present earth stations use single-beam, dish or horn antennas whose positions are continuously variable over large portions of the visible hemisphere by virtue of a multiple axis, high precision, servo controlled antenna mount which generally uses an automatic tracking system. These antennas are necessarily expensive, and if a plurality of beams are needed, more than one antenna must be placed at the site.

Future earth stations, which will be widely deployed across the United States, will require low cost, high gain antennas with one or more beams pointed at satellites in the geostationary arc. The primary beam positioning requirement of the majority of future earth terminal antennas will be along the geostationary arc. The rectangular toroidal reflector antenna described above would appear to offer many of the desirable characteristics which future earth stations will be required to have. Among these are simplicity, low cost construction, multiple beam capability as well as high gain and narrow beam width characteristics.

If the geostationary arc is viewed from a point on the equator (i.e., a point in the orbital plane) then the required antenna field of view is planar, that is, beams to satellites anywhere in the geostationary arc will necessarily lie in the orbital plane. The antenna beam positioning capability could be planar in this particular case.

However, if the earth station site is moved from the equator, then the antenna beam positions required to illuminate satellites in the geostationary arc depart from planar scan. The prior art limitation to planar scan, therefore, prevents the toroidal reflector antennas from fully utilizing its desirable wide field of view capability. At points above and below the equator, lines drawn from an earth station to satellite positions along the geostationary arc trace out a conical surface as is seen in FIG. 1. Assuming a narrow beam width for high gain, the scan plane from the toroidal reflector antenna would obviously be able to contact only a small portion

of this conical surface. It may lie tangentially along the cone, contacting the arc at one point, or it may subtend the cone and thereby contact the geostationary arc at two points. In either event, the field of view is typically limited to about 20 degrees of the geostationary arc. A system based on such a narrow field of view would place significant limitations on satellite position and connectivity. Bearing in mind that the contiguous 48 states of the U.S.A. subtend about 60° longitude, and that Alaska and Hawaii add significantly to this range, an antenna with the field of view more nearly covering the entire geostationary arc offers some advantages.

SUMMARY OF THE INVENTION

The present invention is a toroidal reflector antenna formed by rotating a smooth generating curve, which is not an arc of a circle, about an axis that is at an angle α to the axis of beam direction of a reflected beam. Within the spirit of this invention, the angle α may be any angle not equal to 90°. The resultant reflector will have circular symmetry about the axis of rotation. The feed points of the several generating curves describe a locus of points which is a circle centered on the axis of rotation and lying in a plane perpendicular to the axis of rotation. The axes of beam direction, and hence the scan surface of the beams reflected from the toroidal surface will describe the surface of the cone. The half angle of the cone will be α for $\alpha < 90^\circ$ and will be $180^\circ - \alpha$ for $\alpha > 90^\circ$.

Because of the circular symmetry, the reflector presents the same shape to, and hence has the same beam forming capability for identical feeds located at all points on the arc described by the rotation of the feed point of the generating curve about the axis of rotation. A single moveable feed or a plurality of selectively energizable feeds located along the feed arc, when illuminating the reflector surface, will form identical beams, the locus of whose axes of beam direction describe the surface of a right circular cone.

By properly selecting the angle between the axis of beam direction and the axis of rotation of the toroidal reflector, the beams transmitted from the antenna will define a conical surface which closely approximates the actual conical surface subtended by the earth station site and the geostationary arc.

Within the continental and contiguous United States, an angle α of approximately 95.5° is optimum. It results in a reflector whose beams depart by less than a beam width for a proposed reflector size, from the field of view required by the exact scan cones for sites in the contiguous United States.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the field of view considerations for an earth station antenna located in the northern hemisphere and focused along the geostationary arc.

FIG. 2 shows a preferred embodiment of the invention.

FIG. 3 illustrates a geometrical representation of a section of the invention in FIG. 1 taken through the axis of rotation.

FIG. 4 illustrates a three dimensional embodiment of the invention which would be capable of an omnidirectional scan of 360°.

PREFERRED EMBODIMENT OF THE INVENTION

FIG. 1 illustrates the field of view considerations of an earth station antenna when transmitting to satellites in a geostationary arc. The earth is illustrated as a sphere E with the polar north-south axis identified as a line N-S. The equator of the earth is defined by a plane (denoted as the orbital plane) which is perpendicular to the N-S axis of the earth and intersects the axis at a point midway between the north and south poles. The intersection of the orbital plane and the sphere E results in a circle which lies in the orbital plane. Additionally lying in the orbital plane and concentric with the equatorial circle is the geostationary arc, essentially a circle with a 22,000 mile radius. Satellites orbiting the earth at this distance have an orbital period of 24 hours, the same as the earth's rotation period. Earth station antenna sites A1 and A2 are shown on the surface of the earth. Station A1 lies on the equator at a given longitude and is in the orbital plane. Earth station A2 lies in the northern hemisphere at the same longitude as station A1 but is located above the orbital plane in the drawing. Although the illustrated example is limited to a consideration of the continental United States, the basic principles apply to earth stations located in either the northern or southern hemispheres of the earth over a wide range of latitudes.

Beams transmitted from earth station A1 to satellites S1, S2 and S3 in various positions along the geostationary arc are shown as solid lines which lie within the orbital plane. However, beams from earth station A2 to similar positions in the geostationary arc are shown as segmented lines and describe a surface which is conical in shape, with the vertex of the cone at the earth station position. The axis of the cone is tilted at an angle with respect to the polar N-S axis, the angle varying with respect to the latitude of the earth station A2. In the northern hemisphere, as shown, the angle is a small negative angle, varying as a function of latitude.

A rectangular toroidal antenna having a planar beam scan will be incapable of accurately approximating the conical surface subtended by the visible portion of the geostationary arc as seen from the earth station site A2. In the case where the center of scan is co-longitudinal with the earth station, that is the planar scan tangential to the conical surface, it has been found that for beam widths of the order .08° to .12°, fields of view of the order of 15° to 20° are available. It is also possible to overcompensate by having the scan plane intersect the geostationary arc at two points having longitudes different from that of the earth station. In either event, fields of view of about 20° are typically available with planar scan, allowing some margin for satellite motion. Since the contiguous 48 states of the U.S.A. subtend about 60° longitude and that Alaska and Hawaii add significantly to this range, an antenna with a field of view more nearly covering the geostationary arc is desirable.

FIG. 2 illustrates a toroidal reflector antenna 1 having a simple point feed 2 which is capable of providing a conical scan along the geostationary arc. For purposes of the description of FIG. 2, and in order to enable one of ordinary skill in the art to make the present invention, an orthogonal coordinate system will be utilized. The torus antenna will be presumed to lie within the orthogonal coordinate system shown in FIG. 1 in

which the z axis is parallel to a line extending from the antenna at the earth station to a co-longitudinal point on the geostationary arc. The z axis will also be coplanar with the generating curve 3 and the related axis of beam direction 4 for the generating curve 3, as shown in FIG. 2, however, as the generating curve 3 and the feed 2 are rotated about an axis to form the toroidal reflector surface 5 and the feed arc 6, the axis of beam direction will shift to points along the geostationary arc which are not co-longitudinal. It should be obvious to one of ordinary skill in the art, therefore, that in practice the axes of beam direction will extend from the antenna to points on the geostationary arc having longitudes different from that of the antenna.

The reflector section 5 is mounted in the orthogonal coordinate system such that electromagnetic radiation from the point of feed 2a lying in both the xz and yz planes will be formed into a collimated beam and directed from the toroid surface in a direction PB along the axis of beam direction 4 which is, by definition, within the xz plane and parallel to the z axis. An axis R which is the axis of rotation of the conical section is shown to be lying in the xz plane at an angle α to the z axis and the axis of beam direction 4.

A planar section of the reflector taken in the xz plane in FIG. 2 will result in the profile shown in FIG. 3. FIG. 3 illustrates the geometrical optics of the toroidal reflector antenna of FIG. 2.

The generating curve 3 seen in FIG. 3 has a shape which provides the desired beam forming or beam shaping characteristics. The prior art previously mentioned, teaches techniques for selecting the proper curve geometry. Assuming the placement of a feed 2a or source of electromagnetic radiation, at an optimum point on the concave side of the generating curve, electromagnetic radiation incident upon the concave surface is formed into a beam and directed from the surface in a direction which is coplanar with the feed 2a and the axis of rotation R. For purposes of describing the preferred embodiment of the invention, the generating curve will be assumed to be a parabola which, by definition well known in the art, has an axis radiating from its vertex that is parallel to the axis of beam direction of the beam formed from a radiation source at the focal point of the conic section. Within the orthogonal coordinate system defined in FIG. 2, the axis of the parabola is parallel to the z axis of the orthogonal coordinate system and is perpendicular to the xy plane. Viewing the radiation emitted from the feed 2 as a bundle of rays, the parabolic section collimates a fan of rays originating at the point of feed 2a and lying in the xz plane, so that they travel parallel to the z axis.

In the prior art, an axis of rotation perpendicular to the axis of beam direction and coincident with the x axis was used to create the rectangular toroidal section. The angle α shown in FIG. 3 would be 90° and the axis of rotation would be coincident with the x axis. Rotation of the feed point about this same axis provided toroidal circular symmetry. However, for a generating curve that is an ellipse, a parabola or other smooth curve not an arc of a circle, by defining the axis of rotation as being perpendicular to the axis of beam direction all beams formed would lie in a common plane for all symmetrically displaced positions of the feed.

In accordance with the present invention, the axis of rotation of the generating curve is defined as being at an angle of which is not equal to 90°. That is, the direc-

tion of beam travel is not perpendicular to the axis of rotation R. Referring to FIG. 3, the axis of rotation R is shown at an angle α to the axis z, the axis of beam direction, where α is greater than 90° . Since the curve is the section of a parabola, a feed reflects a beam parallel to the axis of the parabola. The axis of beam direction as well as the axis of the parabola are, therefore, at an angle of greater than 90° with the axis of rotation. Since the angle α may be one of two complementary angles formed by the intersection of the axis of beam direction and the axis of rotation, a further limitation on the angle is appropriate.

As the feed is rotated about the axis R to positions 2b and 2c, the beams formed by the reflecting surface no longer lie in the yz plane but trace out the shape of a cone whose vertex is identified as B in the orthogonal coordinate system. For α greater than 90° and less than 180° , the half cone angle of the traced cone will be $180^\circ - \alpha$ while for α less than 90° , the half cone angle of the traced cone will be α .

By properly selecting an angle α to be slightly greater than 90° , beam scanning along the conical surface will approximate the positions on the geostationary arc. It has been found that for areas in the northern hemisphere, for a 40° field of view and locations between 30° and 50° north latitude, an angle of α equal to 95.5° between the axis of the conic section and the axis of rotation of the torus reflector is optimum. It results in a reflector whose beams depart from the desired position by less than a beam width for the proposed reflector size and for the field of desired view, from the exact scan cones having a half-angle of 95.5° required in the contiguous United States. In a typical communication satellite system antenna which embodies the principles of the present invention, the generating curve will be rotated about the axis R over an arc of less than 180° . The visible portion of the geostationary arc can be scanned by a limited segment of a torus.

However, should the angle α be less than 90° due to the conical scan of the torus, a reflector surface formed by rotating the generating curve by 360° would provide an omnidirectional scan. Such scan could be useful for many radar applications. A three dimensional representation of such antenna is shown in FIG. 4. There, the reflector surface is shown as a closed toroid which is formed by a 360° rotation of parabolic generating curve 3 about the axis of rotation R. The feed at point 2a, located on a plane that is perpendicular to this axis of rotation, illuminates the reflector surface with radiation. The surface cuminates and directs the beam, shown for convenience as a line PB1, from the generating curve toward a target. The beam PB1, will intersect the axis of rotation at an angle α which approximates but is less than 90° . The feed, when positioned at points 2b, 2c, etc. on a circle, lying in a plane perpendicular to the axis of rotation and having a radius equal to the distance from the axis of rotation to point 2a, will result in the generation of identical beams along beam axes B₂ and B₃. As shown in FIG. 4, each of the several beams all intersect the axis of rotation at an angle α . The beam axes together define the surface of a cone having a half cone angle α and having a cone axis coincident with the axis of rotation. By comparison and in order to further understand the invention, a rectangular torus antenna, as known in the prior art, would result in a planar scan since all beams would intersect the axis of rotation at 90° .

The beam direction for both cases of angle α greater than and less than 90° respectively is along the axis of the parabolic section and makes an angle α with the axis of rotation. Due to circular symmetry, all planar sections of the torus taken through the axis of rotation will show the axis of beam direction at an angle α to the axis of rotation. However, within the orthogonal coordinate system, the direction of the beam varies from the horizontal. As the parabolic section and the feed are rotated about the axis R, the direction of the beam PB generates a surface having the shape of a right circular cone. Sections of the reflector surface obtained by plane cuts which include the axis of rotation are all identical. Also, sections obtained by planar cuts perpendicular to the axis of rotation are circular. However, for the parabolic reflector of the preferred embodiment, sections of the reflector obtained by plane cuts perpendicular to the x axis will not be identical but, in fact, will yield sections which differ from each other.

The focal point of the generating curve when also rotated about the axis R will generate a locus of points which is a circle. In practice the feed point and the focal point will not be coincident. For example, to realize the greatest useable area for a specified phase tolerance, it has been found that the feed should be placed closer to the reflector than the focus. For the general case of a nonparabolic generating curve, the reflecting surface may not have a focal point. However, the position of the feed in these cases may be optimally determined by one of ordinary skill in the art and is not necessarily confined to any particular position. For example, a plurality of reflected surfaces can be used, as is known in the art. The feed in such case would be located at some point of the optical system which is not the focal point of the toroidal reflector 6. Typically, the focus of the parabola, the radius of the curvature of the torus as well as the feed location are parameters which are available to create a phase distribution which is most nearly uniform.

Based upon the present invention, a plurality of stationary conical scan, torus antennas may be deployed across a large geographical area such as the United States and used to communicate singly or simultaneously, with satellites located in geostationary orbit. It should be obvious to one of ordinary skill in the art that plurality of such terrestrial antennas could become a part of a communications distribution system useful in providing simultaneous communications between one terrestrial antenna and a plurality of other antennas via satellites in geostationary orbit.

It should be obvious to one of ordinary skill in the art that the principle of the present invention, though discussed with respect to terrestrial transmission to satellites in geostationary orbit by diverging electromagnetic radiation from a feed, are also applicable to the reception of electromagnetic radiation by the antenna. The parameters of the system would be varied to facilitate the convergence of electromagnetic radiation by the reflector antenna.

It also should be obvious that the generating curve as well as the feed and reflective characteristics of the conical torus antenna may be varied in accordance with the teachings of the prior art to provide the desired beam widths, beam shapes or scanning capabilities required by a transmitting or receiving system. The prior art recognizes that for a rectangular torus reflector

tor the generating curve may be a paraboloid, an ellipse or any other smooth planar curve that allows beam shaping in the plane normal to the plane of scan. The fundamental principles of curve selection applicable to the rectangular torus reflector are applicable to the torus reflector capable of a conical scan which is the subject of the present invention.

We claim:

1. A torus-type reflector antenna wherein the reflector surface is described by a substantially smooth generating curve rotated about an axis of rotation which is coplanar with the generating curve and disposed on the concave side of said curve and wherein the reflector surface, when illuminated with electromagnetic energy from a feed means lying at a feed point in the plane defined by said generating curve and said axis of rotation forms a substantially focused beam along an axis of beam direction defined by a line lying in said plane and drawn between the reflecting surface and a remote target point, the improvement comprising:

- a. said generating curve substantially comprising a conic section, except a conic section which is the arc of a circle;
- b. said reflector surface being formed by rotating said generating curve about an axis of rotation which intersects the axis of beam direction at an angle α which is not equal to 90° ;
- c. said feed means being capable of illuminating said reflector surface from one or more points on an arc, defined by the rotation of said feed point about the axis of rotation, whereby the axes of beam direction of beams formed and directed by the reflecting surface intersect the axis of rotation at said angle α and define the surface of a cone having a half angle of $180^\circ - \alpha$ for $90^\circ < \alpha < 180^\circ$.

2. A torus-type reflector antenna wherein the reflector surface is described by a substantially smooth generating curve rotated about an axis of rotation which is coplanar with the generating curve and disposed on the concave side of said curve and wherein the reflector surface, when illuminated with electromagnetic energy from a feed means lying at a feed point in the plane defined by said generating curve and said axis of rotation forms a substantially focused beam along an axis of beam direction defined by a line lying in said plane and drawn between the reflecting surface and a remote target point, the improvement comprising:

- a. said generating curve substantially comprising a conic section, except a conic section which is the arc of a circle;
- b. said reflector surface being formed by rotating said generating curve about an axis of rotation which intersects the axis of beam direction at an angle α which is not equal to 90° ;
- c. said feed means being capable of illuminating said reflector surface from one or more points on an arc, defined by the rotation of said feed point about

the axis of rotation, whereby the axes of beam direction of beams formed and directed by the reflecting surface intersect the axis of rotation at said angle α and define the surface of a cone having a half angle of α for $\alpha < 90^\circ$.

3. The invention recited in claim 1 wherein the generating curve is a conic section having a unique section axis which is parallel to the axis of beam direction and lies in the plane defined by the generating curve and the axis of rotation.

4. The invention recited in claim 3 wherein the feed means comprises a plurality of selectively energizable electromagnetic feeds disposed along an arc centered about the axis of rotation and lying in a plane of the circular cross section of said reflecting surface.

5. The invention as recited in claim 2 wherein the reflecting surface defines a 360° toroid and said feed means is deployed to provide a conical scan over 360° .

6. A terrestrial reflector antenna for scanning along a target arc comprising:

- a. a toroidal reflector surface, described by the rotation of a substantially smooth generating curve, which substantially comprises a conic section, except a conic section which is the arc of a circle, and has an axis of rotation which intersects the axis of beam direction at an angle α which is greater than 90° and less than 180° ; and
- b. a plurality of sources of electromagnetic energy for illuminating said surface, each source being located on an arc at an identical distance from said surface to form and direct beams along said axes of direction whereby the surface described by the axes of beams from said antenna to points on the target arc approximates the surface of a right circular cone having a half angle of $180^\circ - \alpha$.

7. A satellite communication system, comprising a plurality of satellites located in a geostationary arc, terrestrial antenna mean, said terrestrial antenna means including stationary reflector means for scanning along a target arc, which reflector means comprises a toroidal reflecting surface having an axis of rotation and a generating curve which approximates a conic section, except a conic section which is the arc of a circle, and feed means symmetrically deployable on an arc about said axis of rotation and lying in a plane perpendicular to said axis of rotation, said feed means illuminating said reflecting surface to form and direct one or more beams along axes of beam direction from said reflecting surface to said satellites, each of said axes of beam direction intersecting said axis of rotation at an angle α greater than 90° , wherein said target arc approximates the geostationary arc and the locus of said axes of beam direction is the surface of a cone having a half angle of $180^\circ - \alpha$.

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