United States Patent

Zucker

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[54] **OFFSET PARABOLIC REFLECTOR ANTENNA**

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[52] **U.S. Cl.** **343/779,** 343/840, 343/854

[51] **Int. Cl.**.....**H01q 19/14**

[58] **Field of Search**.....343/776, 778, 779, 781, 786, 343/840, 854

[56] **References Cited**

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3,569,976 3/1971 Korvin.....343/779

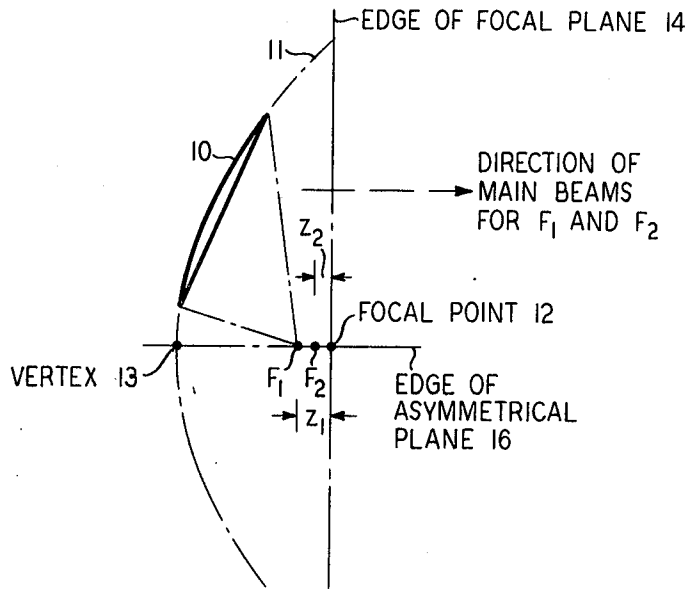
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[57] **ABSTRACT**

In accordance with the disclosure, two or more main beams of an offset parabolic reflector antenna are directed without producing second order aberrations by placing their respective feeds so that their phase centers reside at mathematically defined locations.

3 Claims, 3 Drawing Figures



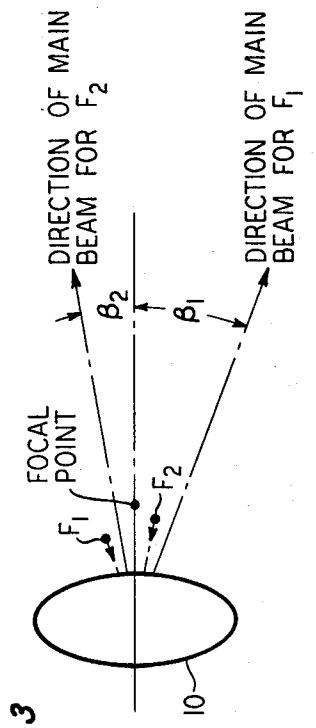


FIG. 3

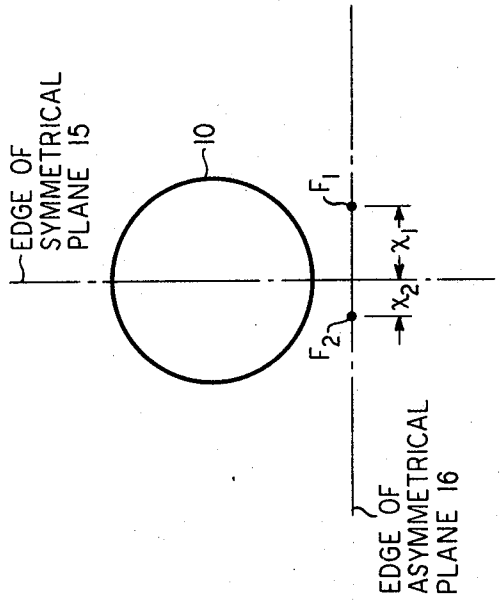


FIG. 2

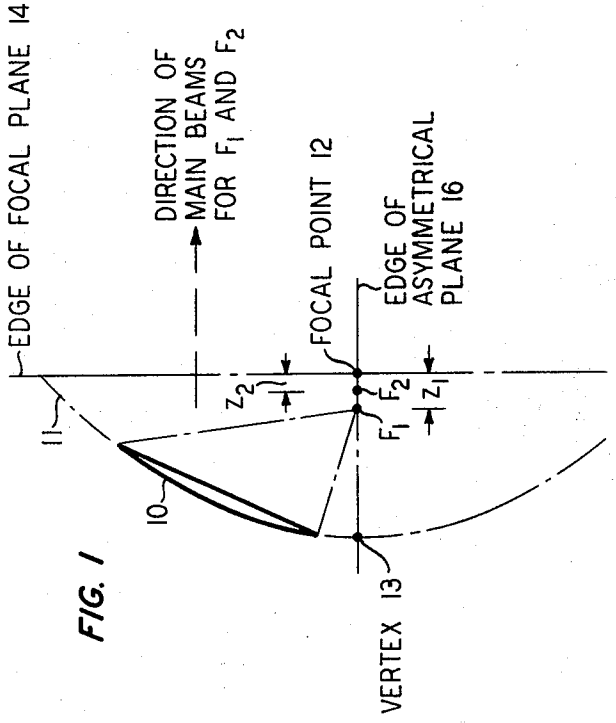


FIG. 1

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OFFSET PARABOLIC REFLECTOR ANTENNA

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to offset parabolic reflector antennas.

2. Description of the Prior Art

An offset antenna has an advantage over a symmetrical antenna in that blocking of the antenna aperture by the antenna feed is not present. Elimination of such blockage results in better control of unwanted sidelobes when transmitting or receiving and, when transmitting, of unwanted radiation back into the feed. These advantages are discussed in U.S. Pat. No. 2,644,092, issued to J. R. Risser on June 30, 1953; U.S. Pat. No. 3,407,404, issued to J. S. Cook et al. on Oct. 22, 1968; and U.S. Pat. No. 3,500,427, issued to S. Landesman et al. on Mar. 10, 1970.

Each of the above-mentioned patents discloses an offset parabolic reflector having a single feed and a radiation pattern having a single main beam. Antennas having multiple feeds to provide multiple independent main beams are, on the other hand, sometimes desirable. U.S. Pat. No. 3,406,401, issued to L. C. Tillotson on Oct. 15, 1968, for example, shows the use of a multiple feed, spherical reflector antenna for satellite communication use. To the best of applicant's knowledge, however, a low aberration multiple feed antenna which includes the advantages offered by the offset parabolic reflector antenna in the on-axis position has not been available.

SUMMARY OF THE INVENTION

An object of the invention is to provide multiple feeds in an offset parabolic reflector antenna in such a manner as to produce multiple main beams having relatively low aberration levels.

This and other objects of the invention are achieved in an offset parabolic reflector antenna by locating each of two or more feeds so that their respective phase centers reside at mathematically defined locations with respect to the offset parabolic reflector. In particular, multiple main beams having substantial zero second order aberrations are achieved by locating two or more feeds so that their phase centers reside substantially on a line unique to the particular reflector.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 shows a side-elevation view of an embodiment of the invention; and

FIG. 2 and 3 show end-elevation and top views, respectively, of the embodiment.

DESCRIPTION OF THE DISCLOSED EMBODIMENT

The side-elevation view of Fig. 1 includes a reflector **10**. This reflector comprises an off-axis sector of a paraboloid of revolution formed by the intersection of the paraboloid and a right angle cone whose vertex is located at the focal point of the paraboloid. In FIG. 1 the outline of the paraboloid of which reflector **10** is a sector is shown by a broken line **11** while its focal point and vertex are identified by symbols **12** and **13**, respectively. In the end-elevation view shown in FIG. **2**,

reflector **10** has a circular projection. In the top view shown in FIG. **3**, reflector **10** has an elliptical projection. Although an off-axis sector formed in this manner has advantages from a radiation pattern standpoint, offset sectors of other configurations may be used in practicing the invention.

Reflector **10** and subsequently mentioned feeds may be positionally related through the use of three reference planes. The first plane is a focal plane **14** which includes focal point **12** and, furthermore, is perpendicular to the paraboloid line of symmetry which passes through focal point **12** and vertex **13**. The second of the planes is a symmetrical plane **15** which includes the paraboloid line of symmetry and, furthermore, bisects reflector **10**. The last of the three planes is referred to as asymmetrical plane **16**. This plane passes through focal point **12** and is mutually perpendicular to the other planes.

Two feeds F_1 and elevation F_2 are schematically represented by a pair of dots in the drawing. These feeds may comprise horns or other conventional feeds directed so as to subtend solid angles with reflector **10**. Furthermore, because of the reciprocal nature of antennas, they may be used for either transmitting or receiving.

Feeds F_1 and F_2 are positioned so that their phase centers are displaced to the vertex side of focal plane **14** by perpendicularly measured distances substantially equal to z_1 and z_2, respectively, and to either side of symmetrical plane **15** by perpendicular distances substantially equal to x_1 and x_2, respectively. On the other hand, the phase centers lie substantially in asymmetrical plane **16**. Furthermore, feed F_1 subtends a substantially solid angle with reflector **10**. As shown in FIG. **3**, the direction of the main beam for feed F_1 makes an angle β_1 with respect to the paraboloid line of symmetry. Similar but unidentified angles having a subscript of two applied thereto relate to feed F_2.

In accordance with the invention, second order aberrations in the radiation patterns are substantially eliminated when the values of x and z for each feed are substantially defined by the following:

$$x = mf \sin \alpha \tag{1}$$

$$z = f(m \cos \alpha - 1) \tag{2}$$

where f is the distance from focal point **12** to vertex **13**, and

m and α satisfy the expressions:

$$\left[1+\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]^2+2\,[1-m\cos\alpha]\left[2-\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]+m^2-1-\left[\frac{m\sin\alpha}{\sin\beta}\right]^2=0 \tag{3}$$

and

$$\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2-m\cos\alpha\right]^2-\left[4\left(\frac{\sin A}{\cos A+\cos B}\right)^2(1-m\cos\alpha)\right]+\frac{(m\sin\alpha)^2}{(1-m\cos\alpha)}\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2-m\cos\alpha\right]=0 \tag{4}$$

where angle A is the angle between the axis of the right angle cone and the line of symmetry and angle B is one half of the angle sustained in symmetrical plane **15** by reflector **10** with focal point **12**.

(The above relationships are derivable from a spherical coordinate system centered about a point located on the paraboloid line of symmetry and at two focal lengths from the vertex, where the focal length is, of course, the distance between focal point **12** and vertex **13**. The angle α is the angle between the line of symmetry and the line drawn between the coordinate system center and the phase center of the feed. Furthermore, m is the ratio of the distance of the phase center from the coordinate system center to the focal distance.)

An embodiment of the invention for operation at 16 GHz was constructed and successfully operated. The embodiment parameters are:

Antenna aperture diameter	$= 48.4\lambda$,
Focal length	$= 40.0\lambda$,
Angle A	$= 47.5°$, and
Feeds displaced to either side of the line of symmetry by α	$= 4.2°$,

where λ equals the wavelength at 16 GHz.

Measurements showed that the main beams produced by the feeds were displaced to either side of the line of symmetry by $\beta = 3.4°$. There was some broadening of the beams, mainly below the 10 db level, and also higher first sidelobes. However, these sidelobes were at the 30 db level. For all practical purposes, there was no significant increase in sidelobe levels for off-axis positions in comparison to the on-axis, focal-point position.

It should be noted that scanning is possible by moving feeds F_1 and F_2 through an arc defined by a continuous set of values for x and z. If only one main beam is desired, one of the feeds may be eliminated.

Further appreciation of the invention may be obtained by selecting the values of angles A and B so that:

$$\sin A/(\cos A + \cos B) = 1 \qquad (5)$$

When this is done, expressions (3) and (4) become:

$$\sin \beta = \frac{m \sin \alpha}{\sqrt{5+m^2-2m \cos \alpha}} \qquad (6)$$

and

$$\cos \alpha = \frac{5+3m^2}{(7+m^2)m} \qquad (7)$$

Ratio m therefore determines the values of angle α and angle β as follows:

m	α	β
1.000	0	0
1.001	1.810	0.906
1.005	4.040	2.024
1.010	5.696	2.869
1.015	6.956	3.517
1.020	8.010	4.065
1.025	8.930	4.548
1.030	9.754	4.986
1.035	10.500	5.300

What is claimed is:

1. A directive antenna for producing at least two main beams, said antenna comprising

a reflector which is an off-axis sector of a paraboloid of revolution having a focal length f, and

at least two feeds where each feed is directed to subtend a solid angle with said sector and its phase center is located at a point substantially defined by

$$x = mf \sin \alpha,$$

$$y = 0, \text{ and}$$

$$z = f(m \cos \alpha - 1)$$

where

z = a distance perpendicular to the focal plane of said paraboloid and measured only from the sector side thereof,

x = a distance perpendicular to a second plane and measured from either side thereof where said second plane includes the focal point of said paraboloid and bisects said sector,

y = a distance perpendicular to a third plane where said third plane passes through said focal point and is mutually perpendicular to the other two planes, and m and α satisfy the expressions

$$\left[1+\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]^2 + 2\,[1-m \cos \alpha]\left[2-\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right] + m^2 - 1 - \left[\frac{m \sin \alpha}{\sin \beta}\right]^2 = 0$$

and

$$\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2 - m \cos \alpha\right]^2 - \left[4\left(\frac{\sin A}{\cos A+\cos B}\right)^2 (1-m \cos \alpha)\right] + \frac{(m \sin \alpha)^2}{(1-m \cos \alpha)}\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2 - m \cos \alpha\right] = 0$$

where:

β = the off-axis steering angle between the main beam related to that feed and the line of symmetry of said paraboloid,

B = one-half of the angle sustained in said second plane by said reflector with said focal point, and

A = the angle formed by a line which bisects said last-mentioned angle and said line of symmetry.

2. A directive antenna for producing at least two main beams, said antenna comprising

a reflector which is an off-axis sector of a paraboloid of revolution having a focal length f,

said sector definable with respect to three planes where the first plane is the focal plane of said paraboloid, the second plane includes the focal point of said paraboloid and bisects said sector, and the third plane passes through said focal point and is mutually perpendicular to the other two planes, and

at least two feeds where each feed is directed to make a solid angle with said sector and is located so that its phase center is substantially in said third plane at a point substantially defined by

$$x = mf \sin \alpha$$

$$z = f(m \cos \alpha - 1)$$

where:

x = a distance perpendicular to said second plane and measured from either side thereof,

z = a distance perpendicular to said focal plane and measured only from the sector side thereof, and

m and α satisfy the expressions

$$\left[1+\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]^2+2\,[1-m\cos\alpha]\left[2-\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]+m^2-1-\left[\frac{m\sin\alpha}{\sin\beta}\right]^2=0$$

and

$$\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2-m\cos\alpha\right]^2-\left[4\left(\frac{\sin A}{\cos A+\cos B}\right)^2(1-m\cos\alpha)\right]+\frac{(m\sin\alpha)^2}{(1-m\cos\alpha)}\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2-m\cos\alpha\right]=0$$

where:

β= the off-axis steering angle for the main beam related to that feed and the line of symmetry of said paraboloid,

B = one-half of the angle sustained in said second plane by said reflector with said focal point, and

A = the angle formed by a line which bisects said last-mentioned angle and said line of symmetry.

3. A scanning antenna comprising

a reflector which is an off-axis sector of a paraboloid of revolution having a focal length f,

said sector definable with respect to three planes where the first plane is the focal plane of said paraboloid, the second plane includes the focal point of said paraboloid, the second plane includes the focal point of said paraboloid and bisects said sector, and the third plane passes through said focal point and is mutually perpendicular to the other two planes, and

at at least one feed which is directed to make a solid angle with said sector and is movable so that its phase center may be moved substantially in said

third plane along an arc substantially defined by

$$x=mf\sin\alpha$$

$$z=f(m\cos\alpha-1)$$

where:

x = a distance perpendicular to said second plane and measured from either side thereof,

z = a distance perpendicular to said focal plane and measured only from the sector side thereof, and m and α satisfy the expressions

$$\left[1+\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]^2+2\,[1-m\cos\alpha]\left[2-\left(\frac{\sin A}{\cos A+\cos B}\right)^2\right]+m^2-1-\left[\frac{m\sin\alpha}{\sin\beta}\right]^2=0$$

and

$$\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2-m\cos\alpha\right]^2-\left[4\left(\frac{\sin A}{\cos A+\cos B}\right)^2(1-m\cos\alpha)\right]+\frac{(m\sin\alpha)^2}{(1-m\cos\alpha)}\left[2+\left(\frac{\sin A}{\cos A+\cos B}\right)^2-\mathrm{m}\cos\alpha\right]=0$$

where:

β= the off-axis steering angle for the main beam with respect to the line of symmetry of said paraboloid,

B = one-half of the angle sustained in said second plane by said reflector with said focal point, and

A = the angle formed by a line which bisects said last-mentioned angle and said line of symmetry.

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