United States Patent [19]

Schmidt

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[54] **SINGLE FREQUENCY, TWO FEED DISH ANTENNA HAVING SWITCHABLE BEAMWIDTH**

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[52] **U.S. Cl.** **343/779;** 343/837; 343/876

[51] **Int. Cl.²** **H01Q 19/12**

[58] **Field of Search** 343/779, 781, 837, 840

[56] **References Cited**

UNITED STATES PATENTS

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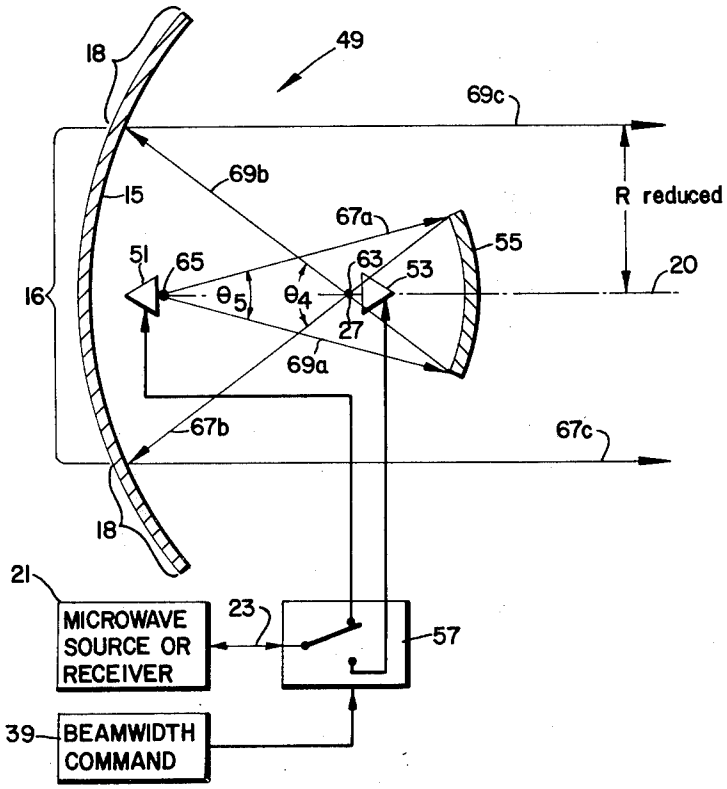
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[57] **ABSTRACT**

A switchable beamwidth antenna includes a concave parabolic main reflecting dish which has a central circular region and a surrounding coaxial annular region. A feed means selectively excites only the central region of the main dish via a truncated subreflector for wide beamwidth or substantially the entire main dish for narrow beamwidth. In the embodiment shown, the feed means comprises a truncated concave ellipsoid subreflector and separate feed terminations located at two foci of the ellipsoid. One feed termination directly views all of the main dish while the other feed termination, exciting the main dish via the subreflector, excites only the central region because of the subreflector truncation.

2 Claims, 4 Drawing Figures



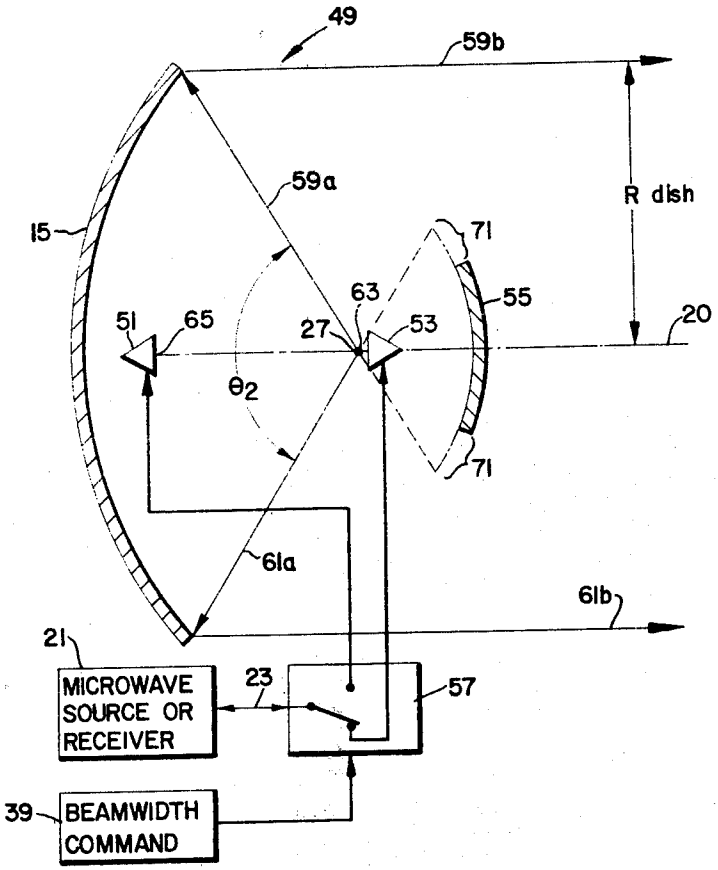

49
59b
59a
R dish
15
71
63
55
51
65
27
53
20
θ2
71
61a
61b
21
MICROWAVE SOURCE OR RECEIVER
23
57
39
BEAMWIDTH COMMAND

FIG. 1

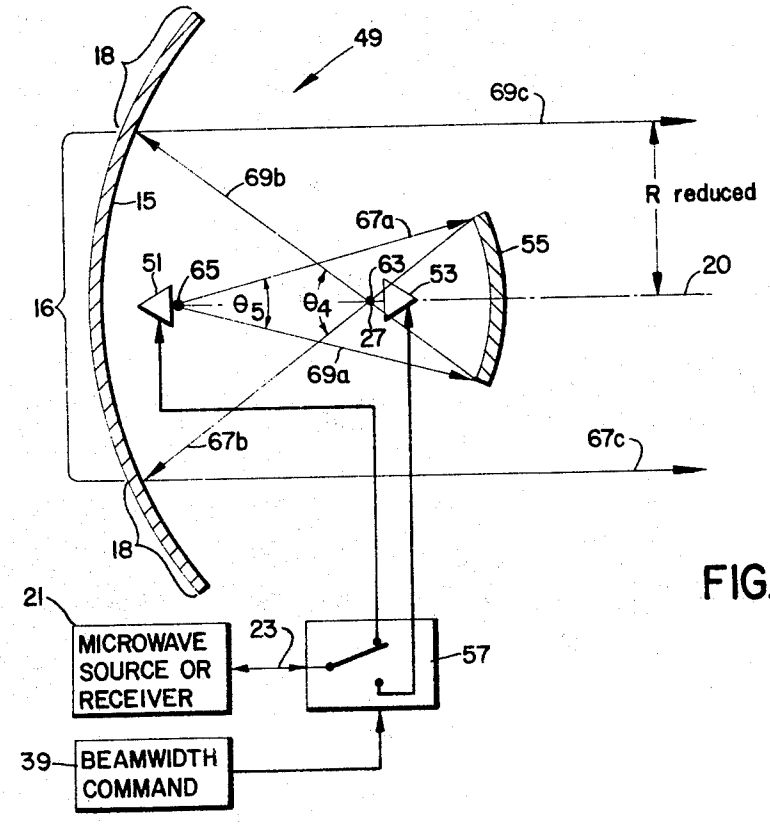
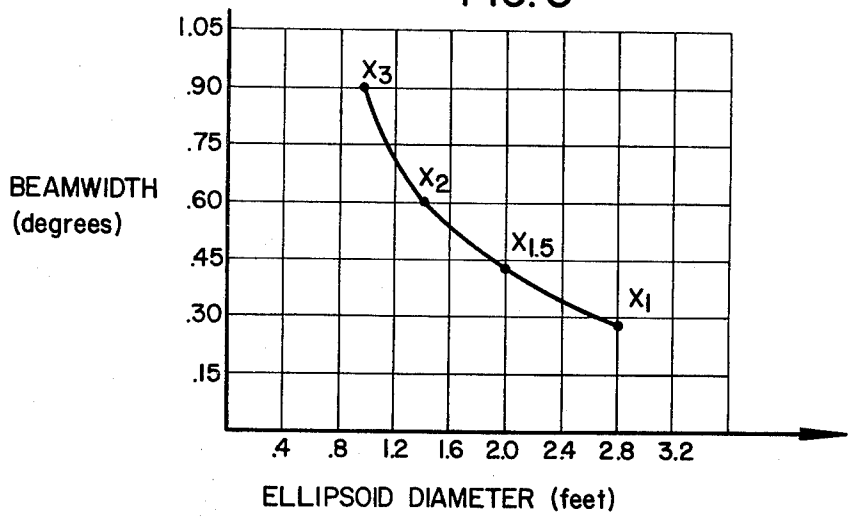

18
49
69c
69b
15
R reduced
67a
55
51
65
63
53
20
16
θ5
θ4
27
69a
67b
67c
18
21
MICROWAVE SOURCE OR RECEIVER
23
57
39
BEAMWIDTH COMMAND

FIG. 2

FIG. 3


1.05
.90
.75
.60
.45
.30
.15
BEAMWIDTH
(degrees)
X3
X2
X1.5
X1
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
ELLIPSOID DIAMETER (feet)

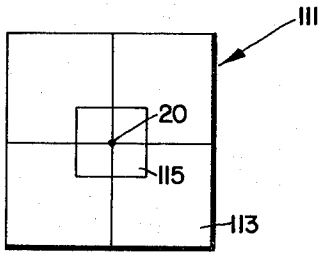

111
20
115
113

FIG. 4

SINGLE FREQUENCY, TWO FEED DISH ANTENNA HAVING SWITCHABLE BEAMWIDTH

FIELD OF THE INVENTION

The invention relates generally to switchable beamwidth or zoomable antennas and more particularly to a switchable beamwidth antenna employing a common main reflecting dish operable in at least two different beamwidth modes.

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

The need frequently arises to augment narrow beamwidth (narrow field of view) transmitting and/or receiving antennas with a wide beamwidth "acquisition" mode. Since it is well known that antennas are reciprocal, having the same characteristics for transmitting as for receiving, the meaning of acquisition shall be detailed with respect to a receiving antenna with the understanding that acquisition for narrow beamwidth transmitting antennas and for narrow beamwidth transmitting/receiving antennas such as a radar, is substantially similar.

In the case of a narrow beamwidth (also referred to as high antenna gain) receiving antenna there is great difficulty in pointing the antenna's narrow field of view in the direction of a transmitting station which must be done in order for the antenna to receive. If, at the sacrifice of antenna gain or efficiency, the antenna is initially switched to a wide field of view (wide beamwidth), the antenna is more easily pointed to subtend the transmitting station in the wide field of view. Then, an indication of pointing error may be derived by simultaneous lobing techniques, for example, to more precisely point the antenna. Once the antenna is pointed so that the transmitting station would be in its narrow field of view, "acquisition" is said to have occurred and the antenna may be switched to its narrow beamwidth mode to take advantage of greater antenna gain or efficiency. This narrow beamwidth may then be maintained, subtending the transmitting station (or "tracking") by simultaneous lobing techniques. Similar acquisition may be done to point a radar antenna at a target or a transmitting antenna at a receiving station.

The acquisition problem is particularly acute for narrow beamwidth antennas having large main reflector dishes of the type considered by the National Aeronautics and Space Administration for Tracking and Data Relay Satellites to relay to earth the data collected from orbiting earth observation satellites. These antennas, operating at 15 Gigahertz, would have a main dish on the order of 12.5 feet in diameter with a consequent narrow beamwidth of only 0.3 degrees. Initial pointing of the narrow beamwidth antenna of the Data Relay Satellite toward an Earth Observation Satellite would be quite difficult to achieve because of significant relative motion between these satellites. Thus, a means for increasing the beamwidth of the antenna to effect acquisition is required.

Numerous techniques were considered and found to be unsatisfactory.

In one technique either a feed or a subreflector is axially shifted in position to defocus the antenna. This technique is not acceptable because, though the beamwidth is generally widened, the antenna pattern amplitude and phase characteristics are distorted. In another technique, a polarization sensitive grating is placed in front of the main dish to serve as a smaller main dish for a wide beamwidth mode. This grating, though smaller than the dish, is sufficiently forward to intercept all radiation coming from a feed. The grating passes, for example, vertically polarized radiation to the main dish, producing a narrow beamwidth but reflects horizontal polarization producing wider beamwidth. Thus, beamwidth can be switched by switching feed polarization. This technique suffers from restrictions on feed polarization; in particular, it does not permit the use of circular polarization which has both horizontal and vertical polarization components.

Another technique for increasing the beamwidth of the antenna is to change the frequency of operation. Since beamwidth is inversely proportional to the area of the main dish measured in wavelengths, the beamwidth may be decreased by decreasing frequency (increasing wavelength). This is an undesirable antenna system complication for satellite users which may also necessitate additional antenna feeds and consequent increased blockage of the satellite main dish, which causes a decreased antenna gain or efficiency of the antenna. Moreover, it is desirable to interface with existing user single frequency equipment.

Still another technique for increasing beamwidth is to provide two feeds at one feed point with one feed exciting the entire main reflector for narrow beamwidth and a second feed exciting a smaller region of the main reflector for wide beamwidth. There are many difficulties with this approach the chief one being that if the second feed is to be sufficiently directive to excite only a portion of the main reflector, it would have to be geometrically large; such a large feed would significantly increase blockage of the main dish reflector decreasing antenna gain or efficiency. Furthermore, there are obvious difficulties in placing two feeds at the same point; the second feed must be displaced from the antenna axis if the first feed is located on the axis. It is desirable to have the capability of positioning the feed or feeds in both wide and narrow beamwidth modes on the axis of the antenna.

OBJECTS OF THE INVENTION

It is an object of the present invention to provide a new and improved switchable beamwidth antenna in which beamwidth switching is independent of feed polarization, feed directivity, or feed frequency.

It is a further object of the present invention to provide a new and improved switchable beamwidth antenna employing a main reflecting dish and feed therefor with a narrow beamwidth mode and a wide beamwidth acquisition mode wherein the feed or feeds in both modes can excite the main reflecting dish from the antenna axis.

It is yet a further object of the present invention to provide a new and improved switchable beamwidth antenna allowing flexibility in feed design, for example, permitting the use of electronically or mechanically scanned feed arrays for scanning the viewing direction of the antenna.

SUMMARY OF THE INVENTION

The present invention includes a switchable beamwidth antenna having a main reflecting concave parabolic dish and feed means effectively at a focal point on the dish boresight axis. Since the beamwidth of an antenna of this type is inversely proportional to the main dish area, the beamwidth can be increased by operatively using only a portion of the main dish. For wide beamwidth operation, the feed means excites only a central circular region of the main dish via a truncated subreflector while for the narrow beamwidth mode the entire dish is excited by the feed.

The invention has one main embodiment.

In this embodiment, electrical beam switching is attained by providing a Gregorian configuration wherein a truncated concave ellipsoid subreflector has a major axis located on the boresight axis of the parabolic dish. The ellipsoid subreflector has two foci in front of the subreflector, whereby the subreflector focus nearest the subreflector is coincident with the focus of the main dish. A separate feed is provided at each subreflector focus and may be selectively activated to provide beam switching. Another method of beam switching or zooming using a single feed is disclosed in U.S. Pat. No. 3,866,233. A first feed, located at the main dish focal point, faces the main dish and excites its entire surface. The second feed, located at the focus of the ellipsoid furthest from the subreflector, faces the subreflector and excites the main dish via the subreflector. The ellipsoid has the characteristic that a real image of the second feed is formed at its nearer focus whereby, to the main dish, the second feed also appears to be at the focus of the main dish. Because of the effective truncation or reduction in size of the ellipsoid subreflector, the second feed excites only a central region of the main dish via the subreflector.

The above and still further objects, features, and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially where taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic drawing in cross-section of the embodiment of the switchable beamwidth antenna having a main dish and a truncated subreflector, wherein the antenna is shown in the narrow beamwidth mode;

FIG. **2** is a schematic illustration of the embodiment of FIG. **1** in the wide beamwidth mode;

FIG. **3** is a design graph indicating the antenna beamwidth for the embodiment of the switchable beamwidth antenna in the wide beamwidth mode of FIG. **2**, versus the subreflector diameter (or degree of truncation); and

FIG. **4** is a schematic drawing in front view of a multifrequency feed.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. **1** and **2** are cross-sectional illustrations of an embodiment **49** of the switchable beamwidth antenna of the invention wherein two feeds **51** and **53** and a truncated or reduced size concave ellipsoid subreflector **55**, located on the antenna boresight axis **20**, cooperate with the main reflecting concave paraboloidal dish **15** in a Gregorian configuration. Feed **53** is located at the main dish focal point **27** facing the main dish. In FIG. **1**, source **21** supplies the feed **53** with radio frequency or microwave radiation via conduit **23** and microwave switch **57** in response to a narrow beamwidth command issued to switch **57**. Feed **53** directly illuminates the main dish **15** with a cone of radiation having the included angle θ_2, bounded by rays **59***a* and **61***a*, which optimally just illuminates the entire main dish. Upon reflection of this cone by main dish **15**, a collimated output beam, bounded by rays **59***b* and **61***b*, is produced having an initial large radius, equal to the dish radius, and a corresponding narrow beamwidth given by diffraction theory.

In FIG. **2**, feed **51**, facing the ellipsoidal subreflector **55**, illuminates the main dish via the subreflector to produce a wide beamwidth. The ellipsoidal subreflector has a major axis that is coincident with boresight axis **20**, and on which lie a near focus **63** and a far focus **65** that are positioned between the concave sides of the subreflector and main dish **15**. The subreflector **55** is positioned with its near focus **63** coincident with the main dish focal point **27**, and the feed **51** is positioned at the subreflector far focus **65**. Microwave source **21** supplies energy to feed **51** via conduit **23** and switch **57** in response to a wide beamwidth command issued to the switch **57**. The feed **51** illuminates the subreflector with a cone of radiation having a small included angle, θ_5, which optimally just subtends the subreflector. This cone of radiation is bounded by rays **67***a* and **69***a*. Due to the concavity of the subreflector, the radiation reflected therefrom, defined by rays **67***b* and **69***b*, goes through a focus at the subreflector near focal point **63**. Therefore, a cone of radiation with included angle θ_4 aimed at the main reflector appears to be initiated from the focal point **63**, providing that the feed **53** at focus **63** does not excessively obstruct the passage of rays through point **63**. Either mechanical or electrical means of achieving this are admissible. In particular, it was found experimentally that a 4-wavelength displacement of the feed toward the ellipsoidal subreflector was adequate. This cone of radiation strikes the dish **15** at a reduced radius. A reduced radius collimated beam bounded by rays **69***c* and **67***c* is produced because the subreflector is truncated or of too small a size for the feed to illuminate the outer annular region **18** of the main dish. To illuminate the entire main reflector from feed **51** via subreflector **55**, the subreflector would have to be larger by an annular region **71**, shown in FIG. **1**. Thus, in this embodiment, beamwidth switching is accomplished by electrically switching microwave excitation from source **21** between feed **53** for wide beamwidth and feed **51** for narrow beamwidth.

Practical dimensions for the inventive embodiment have been determined in conjunction with a five foot focal length, 12.5 foot diameter main parabolic dish **15** for 15 Gigahertz (0.0656 foot wavelength) operation. The narrow beamwidth of such a dish without subreflector truncation is approximately 0.30°.

For this embodiment, the near focus **63** of ellipsoid subreflector **55** is 1.25 feet in front of the subreflector, and its further focus **65** is 5.00 feet in front of the subreflector. If the subreflector were not truncated, it would be 2.8 feet in diameter. Truncation of the feed to approximately two feet in diameter yields a 50% increase in beamwidth.

FIG. **3** is a design curve for the embodiment with the beamwidth in degrees as ordinate and the diameter of the subreflector **55** as abscissa. As can be seen, a smooth curve is obtained which can yield a multiplica-

tion of the beamwidth by a factor up to three as the subreflector is truncated. This Gregorian embodiment **49** is particularly attractive because of the instantaneous and reliable nature of the electronic switching of microwave switch **57.**

As mentioned earlier, geometric optic principles are approximate in nature and diffraction theory must be resorted to in order to fully describe the invention. The numerical embodiments of the invention were verified using a computer simulation which accounted for the diffraction effects between the subreflector and the main dish and for the diffraction effects at the main dish. The subreflectors were divided up into plural square regions, each having sides of 0.3 wavelengths, and the main dish was also divided into plural square regions having sides of 2 wavelengths. The square regions were considered to be coherence areas. The radiation from a feed with assumed radiation patterns was collected in each square region on the subreflector and a resultant source obtained for each square. The radiation from each of these sources was collected in each square of the main reflector and a second set of sources on the main reflector was thereby obtained. The pattern of far field radiation from these second sources was then calculated to obtain the far field pattern of the antenna with various sized subreflectors. These patterns verified that the design curve of FIG. **3** is indeed a smooth curve.

FIG. **4** shows a nested multifrequency feed **111** adapted to be used with the invention. Four large S band horns **113** abut to define a square four feed array centered about axis **20.** Nested at the interior corners of the horns **113** are four smaller X-band horns **115** which abut to form a smaller square array centered about axis **20.** The antenna of the invention is adaptable to multifrequency operation by using such a nested feed. Also, the square four feed array is adaptable to either amplitude or phase simultaneous lobing or monopulse techniques for determining antenna pointing errors. For simultaneous lobing, it is important that the phase and amplitude of signals received at each of the four horns be equal when the transmitter of the signal is located on axis **20.** It is further important that these parameters smoothly vary as the transmitting source departs from the antenna axis by an angle. Computer simulation has verified that these parameters vary smoothly for source angles ranging from zero to well in excess of half the beamwidth.

Having described an embodiment of my invention it is clear that numerous modifications of this embodiment are possible within the invention's spirit and scope. Of particular import is the fact that antennas are reciprocal devices useful for transmitting, receiving, or both. It is intended that the invention not be limited except by the following claims which are generic to transmitting and/or receiving antennas.

What is claimed is:

1. A switchable beamwidth antenna having a wide beamwidth state and a narrow beamwidth state at a single predetermined frequency, said beamwidth state being responsive to a beamwidth selection command source comprising:

a main reflecting dish having a boresight axis and a direction of view along said axis, wherein said dish may be divided with an imaginary contour coaxial with the boresight axis into a central portion and an outer portion bordering the central portion; and

single frequency means responsive to the beamwidth selection command source, exciting at said single predetermined frequency substantially only the central portion of the main dish in the wide beamwidth state, and exciting both the central and outer portions of the main dish in the narrow beamwidth state, said single frequency means including in the wide beamwidth state a truncated subreflector positioned to excite the main dish and further including a first feed positioned to view said truncated subreflector the truncated subreflector having a concave reflecting surface facing the main dish, being positioned to be excited by the first feed, and being of a size that only the central portion of the main dish may be viewed by the first feed via the subreflector, said single frequency means including in the narrow beamwidth state a second feed located between the main reflector and the subreflector and positioned to directly view substantially all of the main dish.

A radio frequency conduit coupled to a microwave source or receiver and a radio frequency switch means responsive to the beamwidth selection command for coupling the radio frequency conduit to the first feed in the wide beamwidth state and to the second feed in the narrow beamwidth state.

2. An electronically selectable beamwidth antenna comprising:

a concave paraboloid main reflector having an axis and a focal point, and where said main reflector has a central circular region and an outer annular region bordering the central region;

a concave ellipsoid subreflector coaxial with and facing the concave main reflector, the subreflector having a first focus substantially coincident with the main reflector focal point for directly exciting the main reflector and a second focus on the axis for exciting the main reflector via the subreflector, the subreflector being of such size that only the central portion of the main reflector can be viewed via the subreflector;

first feed means, located at the first focus of the subreflector for directly exciting the main reflector at a predetermined frequency;

second feed means, located at the second focus of the subreflector for exciting, via the subreflector, only the central portion of the main reflector at said predetermined frequency; and

switch means for operatively selecting the first or second feed means.

* * * * *