343-872.
8-27-74 XR 3,832,715
SR

United States Patent [19]

Afifi et al.

[11] **3,832,715**

[45] **Aug. 27, 1974**

[54] **WIDE ANGLE SCANNING AND MULTIBEAM SINGLE REFLECTOR**

[75] Inventors: **Mostafa S. Afifi,** Rockville; **Allan Jacobs,** Potomac, both of Md.

[73] Assignee: **Page Communications Engineers, Inc.,** Washington, D.C.

[22] Filed: **Sept. 23, 1971**

[21] Appl. No.: **183,026**

[52] **U.S. Cl.** **343/761,** 312/7, 343/755, 343/775, 343/781, 343/872

[51] **Int. Cl.** **H01q 3/12**

[58] **Field of Search** 343/761, 775, 755, 781, 343/872, 748, 713, 710, 754; 312/7

[56] **References Cited**

UNITED STATES PATENTS

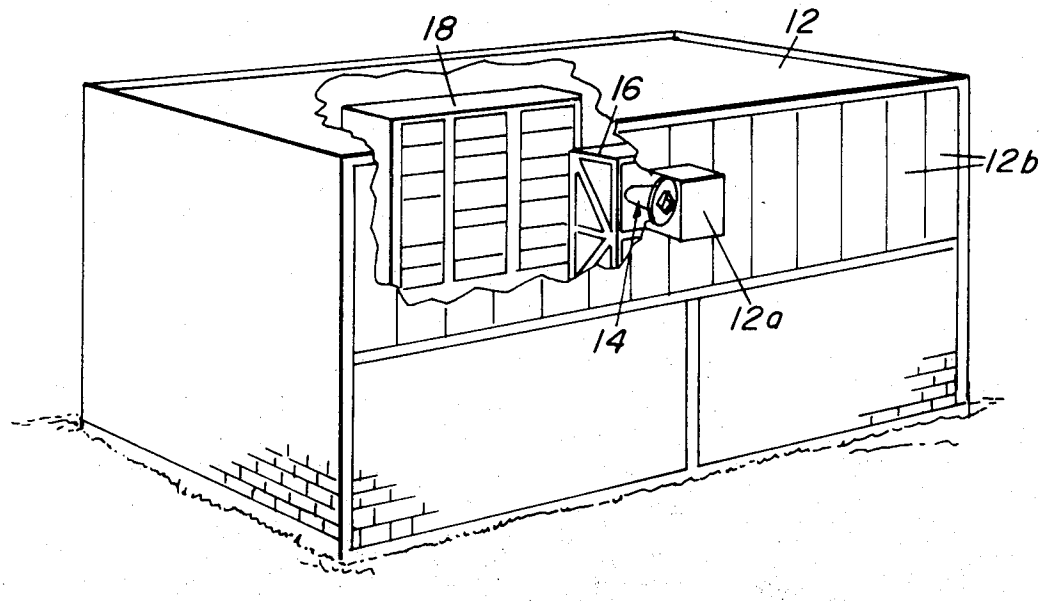
2,115,788	5/1938	Scharlau	343/761 X
2,762,041	9/1956	Dyke	343/775 X
2,961,656	11/1960	Gide	343/761 X
3,044,067	7/1962	Butson	343/781

Primary Examiner—Rudolph V. Rolinec
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney, Agent, or Firm—John J. Byrne; Edward E. Dyson

[57] **ABSTRACT**

An antenna reflector system wherein the reflector remains fixed during scanning operations and the feed, which is located in a protective equipment shelter remote from the reflector, is moved on a special trajectory in order to provide the required scanning with minimal degradation in gain. A feed positioner provides the requisite movement of the feed along *x*-, *y*- and *z*- axes. The reflector is preferably in the form of a shallow, offset parabola.

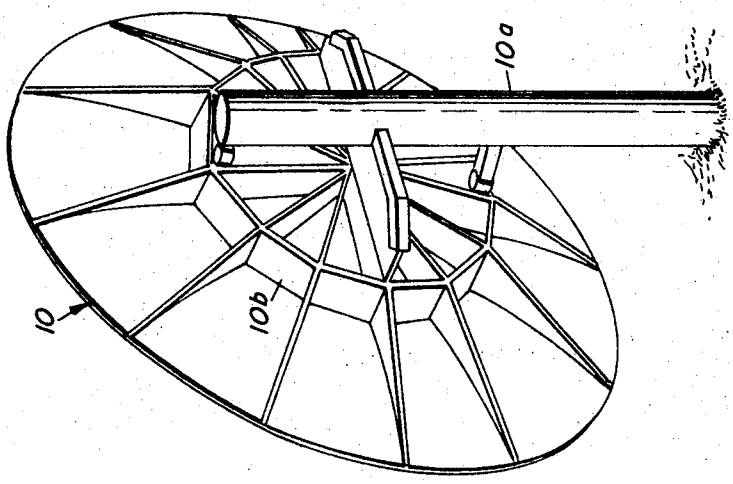
10 Claims, 11 Drawing Figures



PATENTED AUG 27 1974

3,832,715

SHEET 1 OF 6



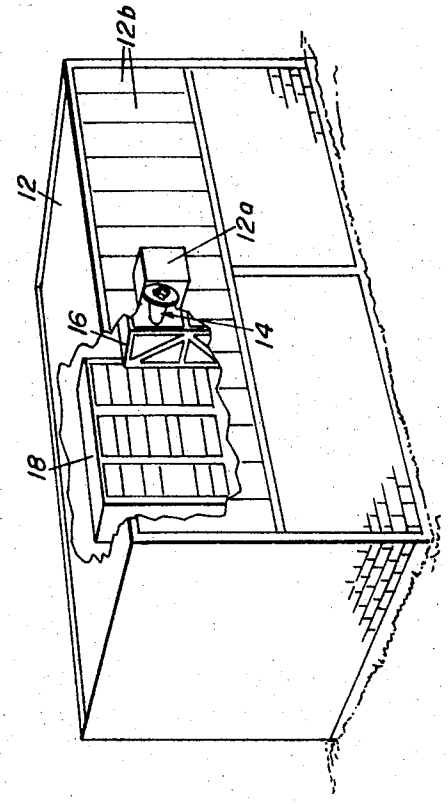


FIG. 1

INVENTORS
MOSTAFA S. AFIFI
ALLAN JACOBS

BY John J. Byrne
ATTORNEY

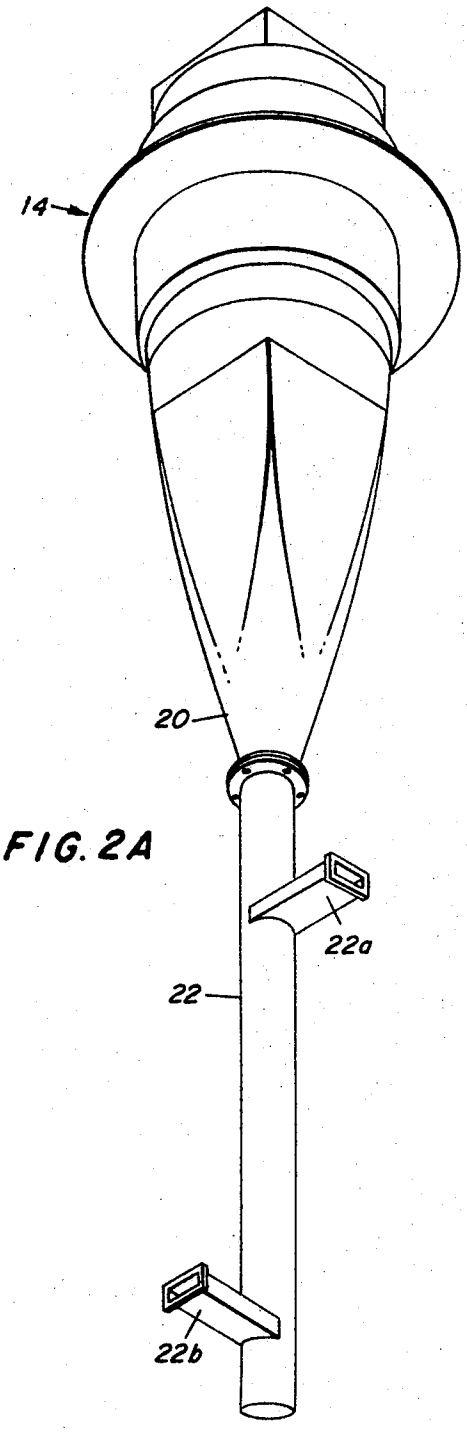


FIG. 2A

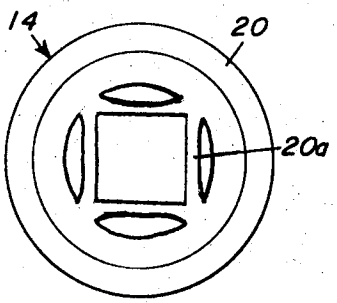
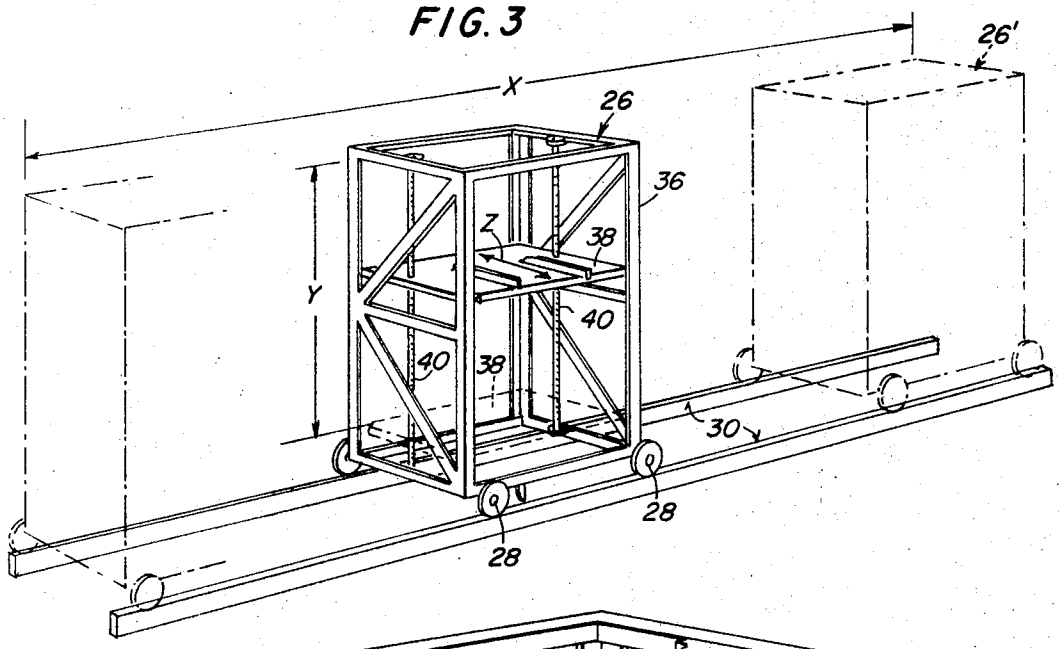


FIG. 2B

FIG. 3


X
26
26'
36
Z
38
Y
40
40
38
30
28
28

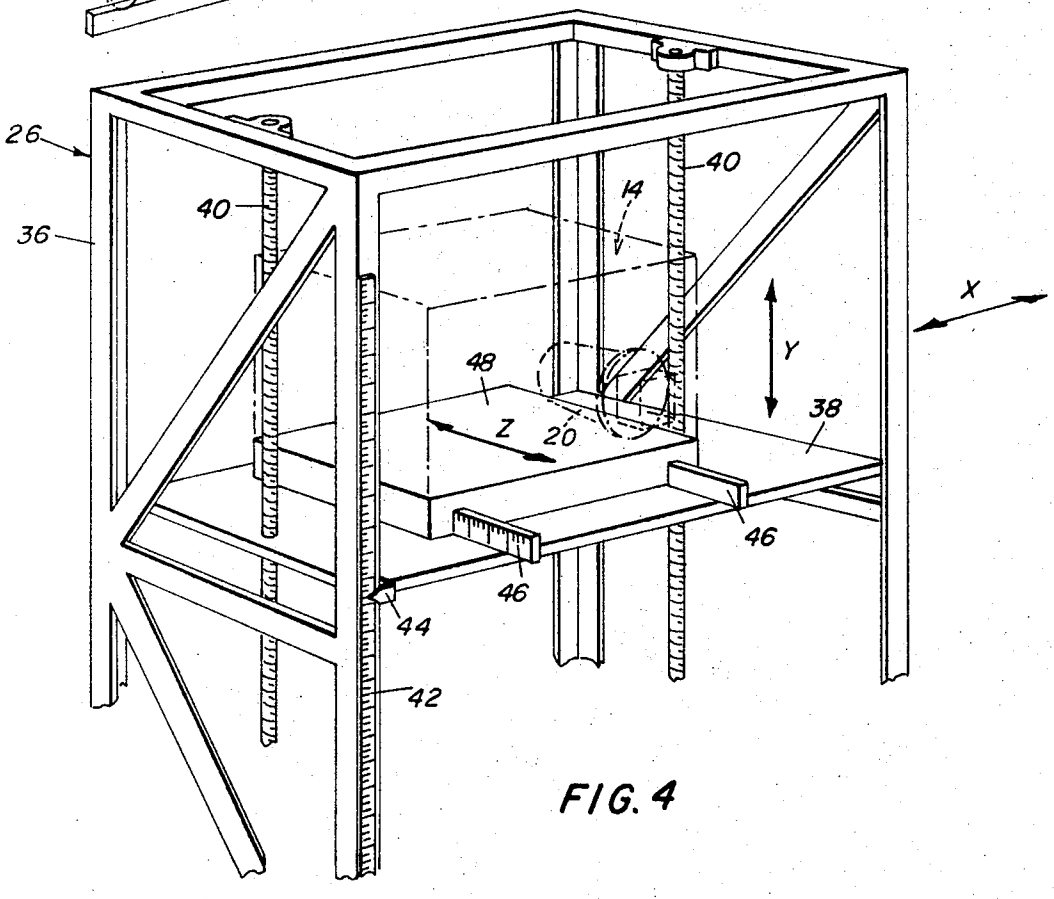

26
40
36
40
14
X
Y
48
Z
20
38
46
46
44
42

FIG. 4

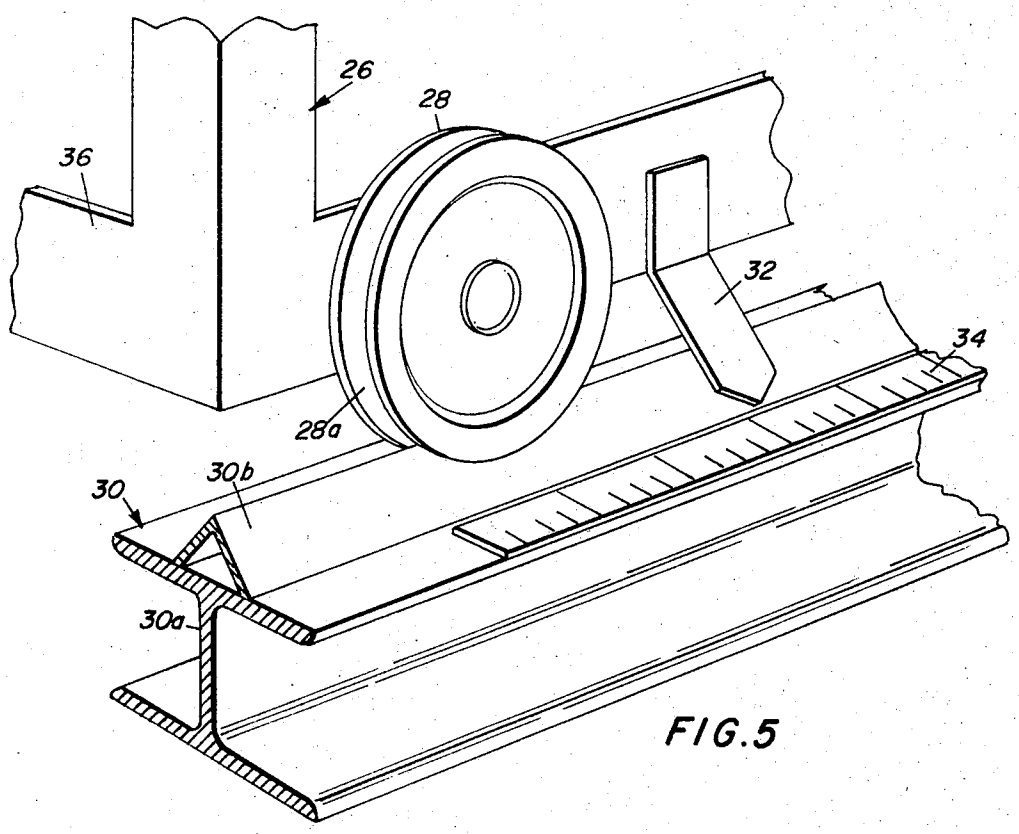


FIG. 5

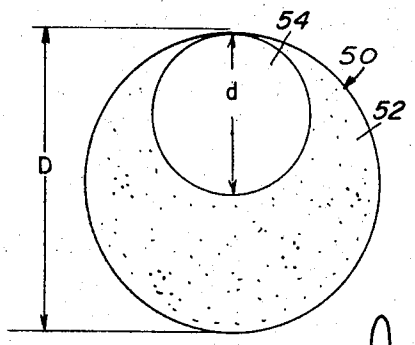


FIG. 7A

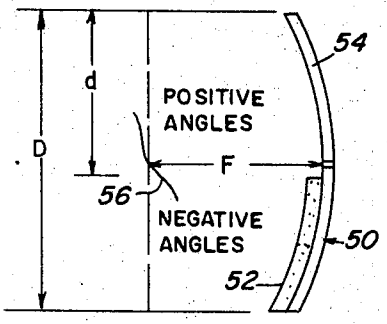
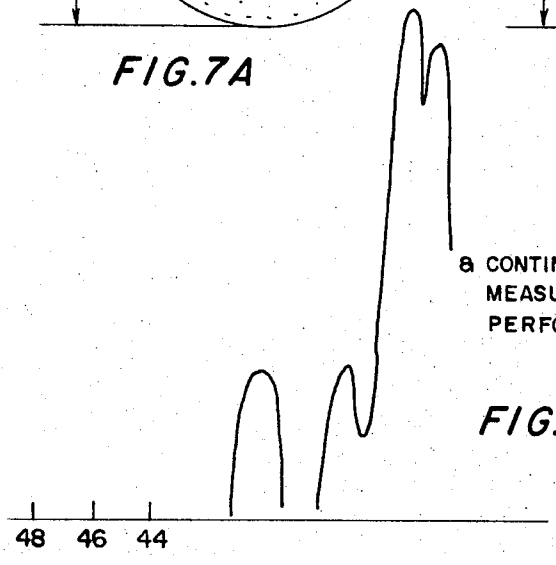


FIG. 7B



8 CONTINUES CORRESPONDING TO MEASUREMENTS FOR SCANNING PERFORMANCE OF AN OFFSET PARABOLA

FIG. 8

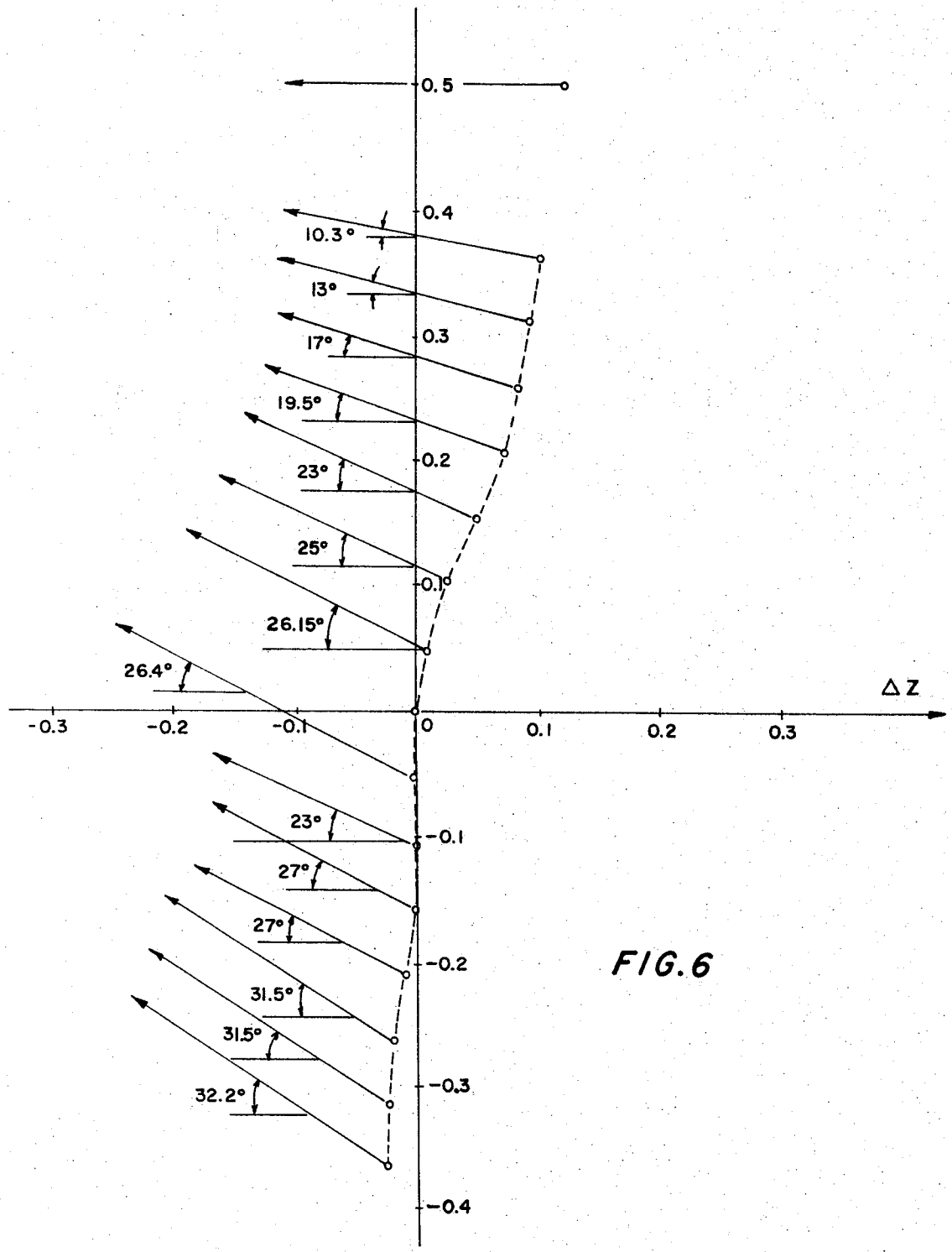

0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
10.3°
13°
17°
19.5°
23°
25°
26.15°
26.4°
23°
27°
27°
31.5°
31.5°
32.2°
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
ΔZ

FIG. 6

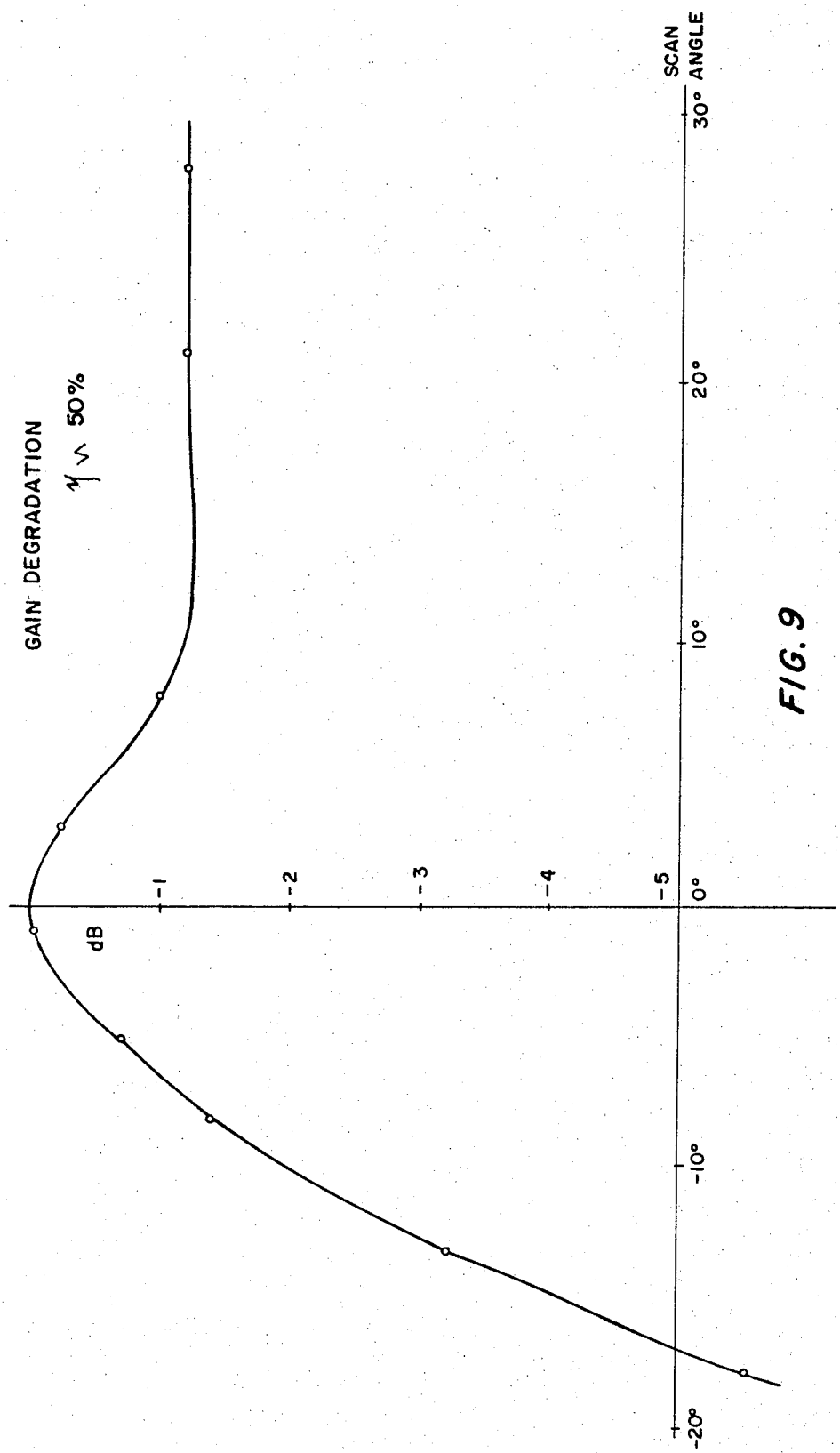


FIG. 9

WIDE ANGLE SCANNING AND MULTIBEAM SINGLE REFLECTOR

FIELD OF THE INVENTION

The present invention relates to antenna reflector systems.

BACKGROUND OF THE INVENTION

A variety of approaches are in present use for tracking of synchronous satellites. These approaches use the whole antenna structure and may be generally classified in three categories, viz., (1) monopulse tracking, (2) so-called "con scan" tracking, and (3) program tracking to pre-computed coordinates. These systems are quite complex and costly and are designed primarily for tracking targets with non-negligible dynamics.

Further problems are encountered in attempting to provide a viable antenna reflector system for tracking and other purposes, which is to be located in severe climate zones. In addition to obvious problems, such as difficulties regarding installation and maintenance, perhaps not as obvious problems such as the accumulation of ice and snow on the reflector are also encountered. The spherical reflector antenna and the Torus reflector antenna are well known devices which yield large scanning performance by moving the feed around the center of curvature of these reflectors. The disadvantages of these devices, however, are the high side-lobe levels of the radiation patterns, as well as the high levels of cross-polarization, and the required large size of the reflector which can handle certain separation of beams. It has been proven that for the same quality of the radiation patterns it is more economic to use a shallow parabola and offset the feed from its focus in order to scan or yield multi-beam operation. Further investigations proved that the offset parabola yields larger scanning performance than a conventional parabola. Moreover, larger aperture availability is also obtained.

SUMMARY OF THE INVENTION

In accordance with the invention, an antenna reflector system is provided which overcomes many of the problems discussed above. Generally speaking, according to the invention, a reflector is provided which remains fixed during scanning operations, scanning being performed by a variable position feed which is installed within a main equipment shelter remote from the reflector.

The reflector assembly is preferably comprised of a shallow offset parabolic reflecting surface, or a shaped modification, and a reflector back-up structure and offers a number of advantages including the facts that the reflector is fixed under operating conditions and there is no blockage of the active reflecting surface. The simple, shallow curvature of the reflector enables high surface accuracy and the reflector assembly is substantially maintenance free and is easy to install. The reflector, preferably by proper choice of design, has a more vertical direction than, and has less curvature than, a conventional antenna thus preventing to a large extent the accumulation of ice and snow, a serious problem in severe climates. The advantages of using the shallow reflector are explained in co-pending application Ser. No. 855,570 now Pat. No. 3,633,209.

The position of the feed is varied within the housing or in combined motion with a supporting tower by a device which provides calibrated movement in the *x*-, *y*- and *z*- directions. The device preferably comprises a movable carriage which rides on tracks and supports a platform which may be raised or lowered.

The antenna system of the invention is readily adapted to multi-beam operations merely by adding a further feeding device in proper location with respect to the common reflector. With such an arrangement provisions may be made to instantaneously switch to alternate beams in the event of a failure of a particular link so as to increase the reliability of service. Further, by switching between beams, adding or re-routing traffic to handle peak loads may be achieved.

By locating the feed device in a separate enclosure, the feed horn, as well as antenna associated equipment such as polarizers, duplexers, low noise and power amplifiers, transmission lines and the like, can be located indoors where rapid and effective maintenance is possible.

The antenna system of the invention permits wider scan angles or beam separations so that many of the operations previously possible only with phased array antennas can now be performed at lower cost by the instant antenna. Further, space tracking of a satellite in the equatorial plane, or simultaneous communication links with these satellites, from a point on the earth's surface using multiple beams can be greatly simplified.

Other features and advantages of the invention will be set forth in or be apparent from the detailed description of a presently preferred embodiment described hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic representation, in perspective, of an antenna tracking system in accordance with the invention;

FIG. **2A** is a perspective view of a feed device in accordance with a presently preferred embodiment of the invention;

FIG. **2B** is an end view of the feed device of FIG. **2A** illustrating the feed opening and corresponding field configuration;

FIG. **3** is a perspective view of a feed positioning device in accordance with a presently preferred embodiment of the invention;

FIG. **4** is a perspective view of a detail of the positioner of FIG. **3** drawn to an enlarged scale;

FIG. **5** is a perspective view of a further detail of the positioner of FIG. **3**, drawn to yet a larger scale;

FIG. **6** is a diagram illustrating the displacement of the feed from the focal point of the reflector during a typical test operation;

FIGS. **7A** and **7B** illustrate schematically the antenna arrangement used for the test operation associated with FIG. **6**;

FIG. **8** is a diagram of the radiation patterns of the main beam region for different scan angles in the plane of symmetry of the offset reflector; and

FIG. **9** is a diagram illustrating the beam degradation decibels of the main beam of the antenna arrangement of FIG. **7A** and **7B** as a function of the scan angle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, an antenna system in accordance with the invention includes a fixed reflector **10** and an

equipment shelter or housing **12** which houses a movable feed **14.** As discussed hereinabove, an important feature of the invention is the provision of a movable feed entirely separate from the antenna reflector and located within a housing or enclosure which is protected from the elements. Housing **12** is constructed to provide space for the necessary controls for controlling movement of the feed, indicated generally at **16** and described hereinbelow with reference to FIGS. **3** and **5,** as well as the necessary tracking equipment indicated at **18.** In contrast to conventional systems, tracking is effected by moving the feed **14,** the reflector **10** remaining fixed during tracking operations.

The wall of shelter **12** which faces the antenna reflector **10** is built as a radome. The shelter frame is covered on the outside by Hypalon and from inside the shelter **12,** a lens cover **12***a*, necessary for weather protection of the feed **14,** is provided and the radome is plugged with panels **12***b* of various sizes and constructed of plastic structural foam encased in fiberglass cloth.

Reflector **10** is preferably in the form of a shallow offset parabola with its axis of symmetry inclined to the vertical plane by an angle which realizes a specific vertical travel of the used feed (this is determined by the design consideration at the location of the station) in combination with yielding good electrical performance characteristics. The vertex of the offset parabola is below the lower edge of the reflector by an amount which yields clearance of the main beam of the antenna from the structure of the feed building in the worst location of this beam. At the same time, the choice of this offset factor is influenced by the required quality of the radiation pattern of the antenna. This construction provides improved tracking performance as compared with conventional parabolic and other reflectors whereas the relatively shallow configuration aids in preventing icing of the reflector, a serious problem in Arctic and other Northern sites. Further, the reflector **10** is oriented more vertically then conventional antennas which also aids in preventing the accumulation of ice and snow. Reflector **10** is mounted on a concrete pedestal **10***a* and supported by a galvanized structural steel back-up structure denoted **10***b*. The reflector may also include a limited motion hour angle-declination (not shown) to provide adjustment of the orientation of the reflector **10,** the declination axis being preset and fixed for a particular tracking station. As stated, the reflector remains fixed during operation.

The feed **14** for reflector **10** can be a ridged waveguide of the form illustrated in FIGS. **2**A and **2**B. This construction enables matching with the predominant modes in the circular wave guide **22** which is shown in FIG. **2**A, and which includes orthogonal receive and transmit posts **22***a* and **22***b* as well as rectangle wave guides, by transition to a convenient field configuration in the feed opening **20***a* such as shown in FIG. **2**B. In a typical construction, the resulting beam widths for the radiation patterns in the E and H-planes at different operating frequencies, extending between 4 and 12 GHZ. The feed horn illustrated is merely exemplary and because the details of the particular feed used forms no part of the present invention, further description thereof is thought unnecessary.

Referring to FIGS. **3, 4** and **5,** a three coordinate axis positioning system for feed **14** is shown. The positioning system, which is generally denoted **24,** includes a carriage **26** mounted on wheels **28** and longitudinally movable in the *x*-direction along a pair of spaced tracks **30**; as illustrated in FIG. **5,** each track **30** is formed by an I-beam **30***a* which rests on the floor of the shelter **12** and the upper flange of which supports an upward extending wedge or V-shaped surface **30**b along which wheels **28** roll. Wheels **28** include suitable peripheral grooves **28**a which ride on the knife-edge surface presented by tracks **30.** A pointer **32** attached to the carriage **26** cooperates with scale **34** which parallels track **30** to provide an indication of the position of the feed **14** along the *x*-axis.

Referring particularly to FIGS. **3** and **4,** carriage **26** includes an open framework **36** in which feed **14** is supported. As shown in FIG. **4,** feed **14,** which is represented schematically by box **14** and an outwardly extending feed horn **20,** both of which are shown in chain lines, is mounted on a movable platform **38** which can be raised or lowered. Platform **38** rides on a pair of spaced screw tracks **40** located within framework **36** and secured to opposite walls thereof. Platform **38** is supported on a traveling nut arrangement (not shown) such that utilizing a control handle (not shown) to rotate screws **40,** platform **38** can be raised and lowered as desired. A vertically extending scale **42** mounted on frame **36** cooperates with a pointer **44** to provide an indication of the position of the feed **14** in the *y*-direction.

As can best be seen in FIG. **4,** platform **38** includes first and second spaced parallel runners or tracks **46** mounted thereon which extend parallel to the *z*-axis and permit movement of feed **14** along that axis. As shown in FIG. **4,** a base support **48** for feed **14** rides on tracks **46** which are graduated to provide an indication of the position of feed **14** along the *z*-axis. Hence, by virtue of the construction described hereinabove, calibrated movement of feed **14** along the *x*-, *y*- and *z*- axes is provided.

In accordance with a further important feature of the invention different feeds, of equal or different designs, may be utilized so as to provide multibeam operation. For example, a separate carriage, corresponding to that indicated in phantom lines and denoted **26′** in FIG. **3** and mounted for movement along tracks **30** may be used to mount a further feed. This is, of course, merely an exemplary arrangement, the point being that simultaneous operation with more than one beam is made feasible simply by adding a feeding device at the proper location with respect to common reflector **10.** The use of different feeds depends on the desired beam separation and the quality of the beam. The coupling between different beams (cross-talk) depends on the locations of the feeds around the focal point of the reflector **10** and the configuration of the reflector. It should be noted that obtaining minimal beam degradation normally conflict with high isolation between the beams at different locations. However, it has been found possible to provide both high beam insulation (minimum cross talk) in combination with low gain-degradation with design approaches which include the reflector and feed designs discussed above. The multi-beam mode of operation of the antenna of the invention can be used in many types of communications systems such as in satellite repeaters, satellite earth terminals, and interrestial microwave communication links. Further, the wide scanning performance of the antenna is ideally suited to applications such as aircraft instrument land-

ing systems and in three-dimensional or volume search radar applications.

As discussed above, by instantaneously switching between beams in the event of failure of a particular link, the reliability of the system can be increased. Further, such a switching system (not shown) could be used in re-routing traffic during peak loads by switching between beams.

Considering the operation of the system described, the feed **14** (or feeds) are moved along predetermined paths or trajectories in different focusing regions of reflectors **10.** The actual trajectory will be a function of (a) the shape and configuration of reflector **10** and (b) the configuration of the feed **14** and the relationship thereof to field distribution generated in different focal locations off the focus of the reflector **10.** The gain degradation of the main beam of the antenna, as the beam is scanned off the main focused beam well, when the feed is moved through the proper trajectory, also depends on the same factors.

The ideal trajectory for feed **14** is that which is determined from the movement of the phase center of the focal field distributions.

These focal region distributions correspond to different scanned beams and represent the required excitation of the reflector which yield the ideal, identical beams on and around the main focused beam of the reflector, the focused beam being that generated by positioning the feed at the reference focal point of the reflector. Although these remarks apply to any reflector, as mentioned hereinabove, a shallow offset parabolic reflector is preferred. Referring to FIG. **6,** a trajectory path of the feed corresponding to a conventional diagonal horn feed, from the focal point, is shown. These measurements were taken utilizing a reflector such as shown in FIGS. 7A and 7B. An outset parabola was formed by covering a major portion of a conventional parabolic reflector **50** with absorbent material indicated at **52.** The exposed portion of reflector **50,** denoted **54,** the feed trajectory shown in FIG. **6,** is generally indicated by line **56** in FIG. 7B. In the experiment in question the diameter D of reflector **50** was 7 feet whereas the diameter of offset parabola **54** was 48 inches. The focal distance F was 47.5 inches. FIG. **8** shows the scanning performance, i.e., the radiation patterns of the main beam region for different scan angles for the offset parabola system of FIGS. 7A and 7B in the plane of symmetry. FIG. **9** shows the degradation in decibels as a function of the scan angle with the feed following the proper trajectory.

Tracking techniques utilizing the antenna system of the invention may involve basically the same procedure as used by a human operator in manually tracking a satellite. The antenna beam is moved a slight amount in each direction to determine the direction of the v.f. signal. The antenna beam is then moved until a maximum signal is received.

Although the present invention has been described relative to an exemplary embodiment thereof, those skilled in the art will understand that variations and modifications may be effected in this exemplary embodiment without departing from the scope and spirit of the invention.

We claim:

1. An antenna scanning system comprising a reflector which is fixed in position during scanning, a feed means separate from and spaced from said reflector for transmitting electromagnetic energy to or receiving electromagnetic energy from said reflector, an enclosure remote from said reflector for housing said feed means at a location remote from said reflector, and positioning means for varying the position of said feed means within said enclosure relative to said reflector to provide scanning of the reflector.

2. A system as claimed in claim **1** wherein said antenna comprises an offset parabola.

3. A system as claimed in claim **1** wherein said antenna comprises a shaped offset parabola.

4. A system as claimed in claim **2** wherein said positioning means comprises means for varying the position of the feed means along the *x*-, *y*- and *z*-axes.

5. A system as claimed in claim **4** wherein said positioning means includes a carriage for mounting said feed means and track means along which said carriage is movable.

6. A system as claimed in claim **5** wherein said positioning means includes means for indicating the position of the feed means.

7. A system as claimed in claim **2** wherein said feed means comprises a ridged wave guide.

8. A system as claimed in claim **1** wherein said enclosure comprises a shelter which includes space for tracking equipment and wherein said reflector is separately mounted by support means spaced from said shelter.

9. A system as claimed in claim **6** wherein said positioning means includes a platform and means for raising and lowering said platform within said carriage and means for providing movement of said feed means on said platform in a direction perpendicular both to the direction of movement of said feed means on said platform in a direction perpendicular both to the direction of movement of said carriage and to said direction of movement of said platform.

10. A system as claimed in claim **1** wherein said enclosure houses a plurality of said feed means for providing multi-beam operation, said reflector comprising a shallow, offset parabola.

* * * * *