

[54] **CASSEGRAIN RADAR ANTENNA WITH
SELECTABLE ACQUISITION AND TRACK
MODES**

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343/781, 343/835, 343/837, 343/839**

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[58] Field of Search ... **343/777, 779, 781, 761, 757,
343/758, 835, 837, 839**

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[57] **ABSTRACT**

A Schwarzschild Antenna cooperates with an organ pipe scanner to achieve wide angle sectoral scanning of a high gain pencil beam. A rotatable mirror switches the antenna to conical scanning whereby microwave energy communicates between a nutating horn and reflectors of the Schwarzschild Antenna. During conical scanning, the organ pipe scanner remains unenergized. The mode of operation is selectable by the operator and the system is designed for rapid switching.

[56] **References Cited**

UNITED STATES PATENTS

3,696,432 10/1972 Anderson et al. 343/761

10 Claims, 3 Drawing Figures

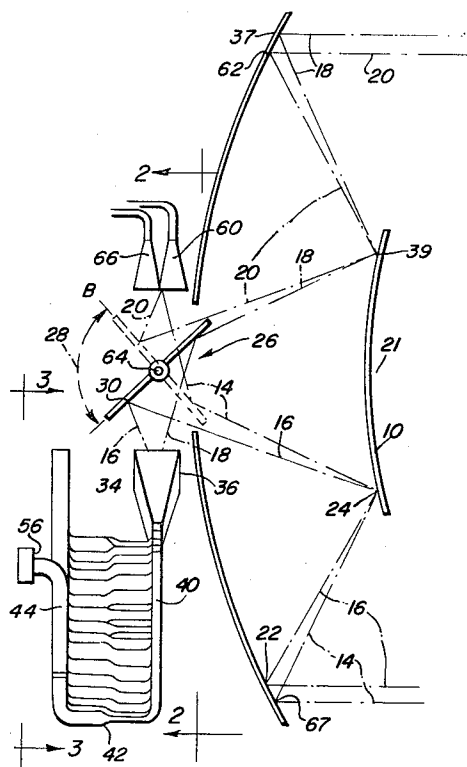


Fig. 1

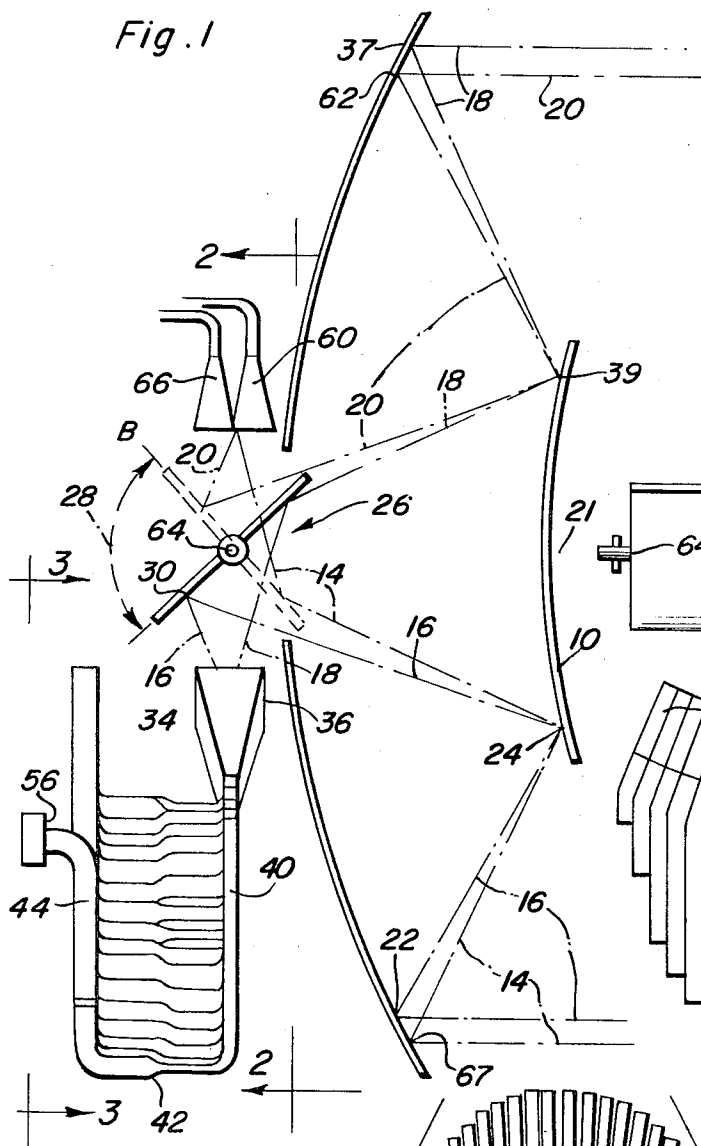


Fig. 2

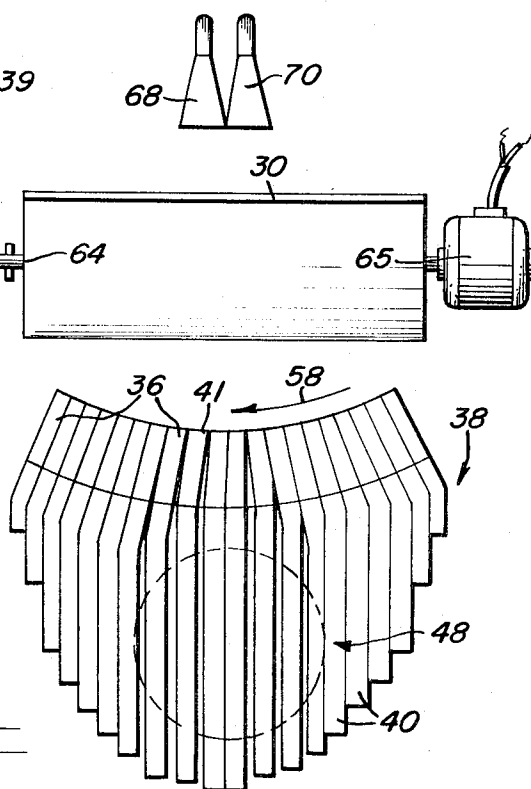
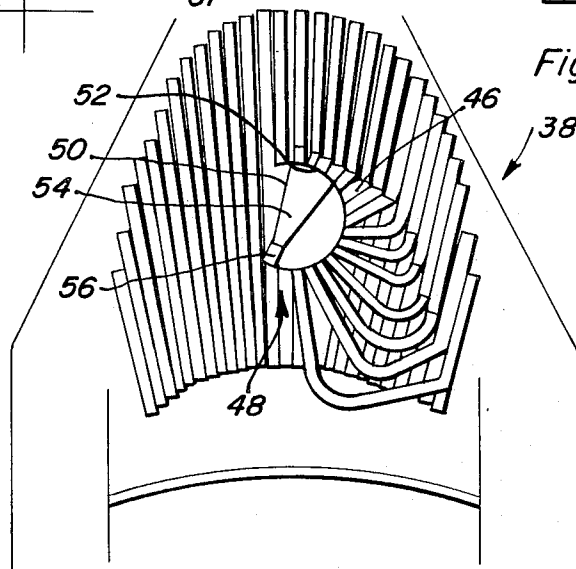


Fig. 3



CASSEGRAIN RADAR ANTENNA WITH SELECTABLE ACQUISITION AND TRACK MODES

The invention described herein may be manufactured, used, and licensed by or for the United States Government for governmental purposes without the payment to us of any royalty thereon.

FIELD OF THE INVENTION

The present invention relates to a Cassegrain Antenna, and more particularly to such an antenna with selectable acquisition and track modes.

BRIEF DESCRIPTION OF THE PRIOR ART

The prior art relating to microwave antennas includes a structure known as a Cassegrain Antenna which is comprised of coaxial reflectors. The Cassegrain has met with wide acceptance because its structure eliminates the need for mounting a heavy feed radiator far in front of the main reflector of the antenna. An improvement of the Cassegrain came with the discovery of an antenna structure known as the Schwarzschild Antenna which is basically a modified Cassegrain with reflectors shaped to form an aplanatic system. As those of skill in the art know, the aplanatic Schwarzschild meets the Abbe sine condition and evidences superior off-axis microwave focusing capability, when compared with the older, conventional Cassegrain. Although the Schwarzschild Antenna has been designed to operate in the conical scanning mode, there has not been a satisfactory design heretofore capable of effecting rapid switching between this mode and a sectoral scan mode in one antenna assembly.

Therefore, in conventional radar systems where relatively wide angle sectoral scanning is required along with conical, or steady tracking, a relatively complicated antenna structure becomes necessitated. A result of this complexity is that there is a decrease in performance characteristics and flexibility.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

The present invention is directed to a Schwarzschild Antenna which cooperates with an organ pipe scanner for relatively wide angle unidirectional sectoral scanning. A structurally simple rotatable mirror acts as a microwave energy switch to deactivate the organ pipe scanner, and instead, complete an energy path between nutating horns and the reflectors of the antenna. The switch to the latter described mode effects conical scanning. The combination of the Schwarzschild Antenna with an organ pipe scanner is novel. The further addition of a switching capability to switch the antenna from the sector scan mode to a conical scan mode lends further uniqueness to the present invention.

The resultant structure of the present invention provides an improvement in tracking radar antenna systems related to scanning capabilities, multiple operating modes, and beam pattern optimization.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a side elevational view of the present Schwarzschild Antenna illustrating a pivotally mounted mirror which switches in either an organ pipe scanner or a conical scan horn.

FIG. 2 is a front sectional view taken along a plane passing through section line 2 — 2 of FIG. 1.

FIG. 3 is a rear sectional view taken along a plane passing through section line 3 — 3 of FIG. 1.

This view illustrates the common termination of all pipes in the organ pipe scanner.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the figures and more particularly FIG. 1 thereof, a side elevational view of the present Schwarzschild Antenna and associated scanners are illustrated.

A sub-reflector 10 is shown in radially spaced parallel relation to a main reflector 12. The reflectors constitute a Schwarzschild system. Although the projections of the reflectors 10 and 12 are circular, the contours of the reflectors satisfy the design criterion for aplanatic reflector systems meeting the Abbe sine condition. Parallel rays 14 and 16, for example, are seen to communicate between the lower portion of the main reflector 12 and the far field, while parallel rays 18 and 20, for example, are seen to communicate between the upper portion of the main reflector 12 and the far field. An axis 21 intersects the center of both the sub-reflector 10 and the main reflector 12. A rectangle aperture 26 is formed around the intersection of the axis 21 and the main reflector 12.

When receiving microwave energy in the sectoral scan mode, ray 16 impinges upon the main reflector 12 at point 22. Ray 16 is illustrated to represent the lower limit of impinging microwave energy. Thereafter, the ray is reflected to the sub-reflector 10 where incidence occurs at point 24. Subsequent reflection from point 24 occurs so that the ray passes through the central aperture 26 for formation of a virtual image at focal point 28.

An image at point 28 never develops because of the interceding disposition of a pivotally mounted flat mirror 30. While operating in a relatively wide angle sectoral scan mode, the mirror, which may be rectangularly shaped, assumes the solid position indicated by A. The mirror 30 is positioned to reflect the microwave energy after it passes through the aperture 26. Therefore, ray 16 is reflected from the lower part of the mirror 30 until it is focused at focal point 34. A pyramid-shaped horn (flare) 36 surrounds the focal point 34 so that the horn 36 can feed microwave energy to (or from) connected waveguides. Upper ray 18 travels a similar route. After reflection from the main reflector at point 37, the ray impinges upon the sub-reflector 10 where it is further reflected at point 39 through the aperture 26. After passing through the aperture 26, the ray 18 impinges upon the upper portion of mirror 30 and is reflected therefrom to the focal point 34. Thus, the energy associated with the upper beam 18 is likewise fed to the horn 36.

As clearly shown in FIG. 2, a plurality of adjacently-spaced pyramid horns 36 and their connected pipes 40 form an assembly of pipes 38 that is conventionally referred to as an organ pipe scanner. The horn portions 36 of the organ pipe scanner 38 have outward ends referred to as output flares. These flares lie along a circular arc 41. The edges of the horns 36 are positioned as shown, perpendicular to the arc 41.

Each horn 36 has a rectangular cross section and pyramidal or tapered interior shape.

The inward end of each horn communicates with its own pipe such as 40. The lower end portion of all pipes such as 40 may be twisted 90° as shown by the rear-

wardly extending section 42 so as to provide the desired direction of linear polarization in the far field. The latter mentioned section 42 articulates to a further perpendicularly disposed pipe section 44 that has its outer end 46 (FIG. 3) communicating with a circular chamber generally indicated by reference numeral 48 in FIG. 3. As indicated by FIG. 3, the openings 46 of the various pipes perpendicularly intersect the circumference of the circular chamber 48 and are arranged so that the microwave E planes coincide (coplanar). Otherwise stated, the pipes are radially positioned with respect to the center of the circular chamber 48.

A single horn 50 flared in the microwave E plane is mounted about an axis 54 that is perpendicular to the plane of the circular chamber 48. The axis intersects the center of the circular chamber 48. The outer, outwardly flared end of the horn 50 communicates with several pipe openings 46 (stacked in the narrow E plane dimension as stated) at a given instant of time as the horn 50 rotates either clockwise or counterclockwise. This is due to the relatively large opening 52 of the horn 50 as compared with a much smaller opening in the end 46 of the radially positioned pipes. As illustrated in FIG. 3, the axis about which the feed horn 50 rotates is indicated by reference numeral 54. The inward end of horn 50 communicates with a waveguide fitting 56 that is connected to waveguides (not shown) which deliver microwave energy from the antenna to a remote transmitter-receiver.

As the horn 50 rotates in a circular manner, energy is sequentially collected from the ends 46 of the pipes. At some point along the circumference of the circular chamber 46, one of the pipes will represent the left most horn 36 in FIG. 2, while an adjacent pipe along the circumference 48 in FIG. 3 represents the right most horn in FIG. 2. Accordingly, as the horn 50 rotates circularly, an arcuate scan is produced in a unitary directional manner at the horns 36. This unidirectional scan is indicated by the direction arrow 58 in FIG. 2. The result of this unidirectional scan is a wide angle unidirectional sector scan by the radar.

Proper illumination of the sub-reflector is accomplished to a large extent by providing a primary beam width corresponding to the circular extent of the sub-reflector. Generally, a narrower flare (36) transverse to the direction of scan provides a broader beam and vice versa. In the direction of scan, the total width of the several horns illuminated at a given instant is essentially the governing factor. The phasing of output waves at these horns should preferably be controlled by adjusting waveguide electrical path lengths between feed and output, so that the output wave is directed toward the center of the subreflector at all scan angles.

It should be understood that the antenna is a reciprocal device and the ray paths illustrated apply for both transmission and reception.

As previously mentioned, the central object of the present invention is to be able to selectably switch from the organ pipe sector scan to a steady monopulse or conical scan. This is done by rotating shaft 64 that mounts mirror 30. This rotation is achieved by a mirror drive torquer (motor) 65 shown in FIG. 2. The torquer 65 achieves rapid 90° rotation of the mirror 30 to position B shown in FIG. 1. As the mirror is shifted to this new position, the microwave channel to the pipe organ scanner is disconnected and becomes inoperative. For precise mirror positioning, a zero-backlash, motor

driven cam mechanism may be employed in lieu of the torquer mentioned above.

Referring once again to FIG. 1, reference numeral 60 denotes a nutating pyramid horn that is positioned above the mirror reflector which is now assumed to be in the dotted position B. Reference numeral 20 is seen to denote the geometric upper limit of received microwave energy which impinges upon the main reflector at point 62. From there, the beam 20 is reflected at point 39 on the sub-reflector 10. Thereafter, the beam passes through the opening 26 where it impinges upon the front surface of mirror 30. Reflection from the mirror takes place and the beam 20 intersects the focal point 65. In a similar manner, the geometric opposite ray 14 reflects off the main reflector 12 at point 67 for subsequent impingement upon the sub-reflector 10 at point 24. Thereafter, the ray 14 is directed through the aperture 26 until it impinges upon a lower portion of the mirror 30. The ray 14 is reflected from this lower portion so that it intersects the focal point 65. The nutating horn 60 centered at the focus collects these rays, as well as the rays that are present in between the edge rays 20 and 14. By virtue of the nutating motion, conical scanning is achieved.

During transmit operation of the antenna, the microwave signal flow is oppositely directed as compared to during receive operation.

Thus far, sectoral scan and conical scan have been described. The beam is a high gain pencil or fan beam. The present invention is equally applicable to steady tracking or monopulse radar operation. To achieve this monopulse operation, four or more ports are employed. For example, the ports are characterized by pyramid horns including the aforementioned horn 60, horns 66 (FIG. 1), 68 and 70 (FIG. 2). These four fixed horns form approximately a square pattern and transmit and receive microwave energy in the conventional manner.

Thus described, the present Schwarzschild Antenna is seen to operate with selectable acquisition and track modes. These modes include unidirectional organ pipe; wide-angle-sector scan; monopulse steady track; and conical scan. The beam may be generally described as either pencil beam or oval (fan) beam.

Although the present invention has been discussed in a manner indicating only two extreme positions of mirror 30 (position A and B), it should be appreciated that the mirror 30 can be varied in position about these extreme mirror locations to achieve within certain angular limitations bi-level or raster scanning patterns of the far-field pencil beam. This is achieved, for example, by adjusting the mirror 30 so that it steps to a new scanning plane at the termination of a unidirectional sector scan. This is easily accomplished with state of the art techniques. Instead of a two-position torquer, a stepping motor or Geneva movement can be employed, for example.

An additional design consideration for the present invention is directed to the utilization of a twistreflector for the main reflector, and a transreflector for the sub-reflector. As those of ordinary skill in the art know, the twistreflector has a grating for changing linear polarization (90°) during reflection. The transreflector allows energy to be propagated or reflected depending on the polarization of incident energy. In considering the microwave energy path between the reflectors, the twistreflector changes the polarization of the energy imping-

ing thereupon and effects reflection to the sub-reflector on receive. The sub-reflector then directs the microwave energy through the aperture 26. As is well known in the art, the use of a twistreflector-transflector combination has the advantages of minimizing side lobes, maximizing gain, and generally producing an improved pattern due to decreased blockage.

When designing the antenna of the present invention, certain parameters are specified. Thus, for a particular application one must choose or specify for example frequency of operation, antenna size, scan angle, gain, beam width, and maximum side lobe level.

In order to convert these given parameters to the antenna component measurements, ray tracings are performed. This is a conventional technique which gives shapes of Schwarzschild reflectors. After the tracings have been made, a computer program is employed to determine beam pattern parameters for design optimization. That is, the best compromise must be made between the desired radiation characteristics and physical size limitation of antenna geometry. The ray tracing-beam pattern parameters may include:

Specification of a Schwarzschild or a regular Cassegrain antenna design.

Antenna diameter to operating wavelength ratio.

Antenna/feed aperture illumination functions.

Sector scan angle.

Focal length.

Magnification factor.

Diameter of sub-reflector for opaque reflectors (blockage).

Size of aperture in main reflector when using twist-transflector (blockage).

The desired scanner is designed by laying out, as scale drawings, various configurations of waveguide convolutions, fitting scanner feed arc to reflector focal arc (from ray tracings). Also feed apertures are inserted in the design drawings and test models to give proper feed beam width and directivity to illuminate the sub-reflector.

The following will provide references, in the literature, to the above-discussed design considerations.

BEAM PATTERN PROGRAM

One may use a computer program developed by the Rome Air Development Center (Griffiss Air Force Base New York) and TRG Company (Nihen and Kay). Reference RADC TR-66-582, November 1966, authored by Hildebrand. The reference is entitled "Design and Evaluation of Two-Reflector Antenna Systems." This program is modified to permit the use of quasi-parabolic primary illumination functions and for patterns in scan direction and orthogonal thereto.

RAY TRACING PROGRAM

Ray tracing equations may be derived from the basic Schwarzschild reflector equations given in an Airborne Instrument Laboratory report found in the records of the IRE Convention of 3-20-62, Topics in Electronics, Volume IV, 1963, authors W. White and L. DeSize. The title is "Scanning Characteristics of Two-Reflector Antenna Systems." Also reference Radio Engineering and Electronics Physics, USSR, Volume VI, 1961, authored by N. G. Ponomarev. The title is "Graphical Methods of Designing Aplanatic Antennas."

OPTIMIZATION OF TWIST-TRANSFLECTOR (GRATING) SYSTEM

Wheeler Labs (Great Neck, New York), Hazeltine Corporation, Greenlawn, New York. The report is denoted as 666 and is entitled "Design of Twistreflector Having Wideband and Wideangle Performance." The report is dated 4-7-55 and authored by Peter W. Hannan.

ANTENNA APERTURE BLOCKAGE

IRE Transactions on Antennas and Propagation, 3-12-60. The report is entitled "Microwave Antennas Derived from the Cassegrain Telescope." The article was authored by Peter. W. Hannan.

ORGAN PIPE SCANNERS

Naval Research Lab Report 3842, dated Aug. 1, 1951. The authors were K. Kelleher and H. Hibbs. The report is entitled "An Organ Pipe Scanner."

RING FEED SCANNERS

Georgia Tech Research Institute Report 212-168; AB No. 17816; 1953. The report is entitled "Two Beam Scanning Antenna."

We wish it to be understood that we do not desire to be limited to the exact details of construction shown and described for obvious modifications can be made by a person skilled in the art.

Wherefore we claim the following:

1. A Schwarzschild antenna system comprising:

reflector means for reflecting microwave energy that impinges thereon;

scanner means adjacent the reflector means and communicating with the reflector means for producing a wide angle unidirectional sectoral scan; horn means disposed in adjacent spaced relationship to the reflector means and communicating with the reflector means for producing a narrow angle scan; and

microwave switching means mounted adjacent to the reflector means to selectively complete microwave communication between the reflector means and either the scanner means or the horn means; whereby the switching means enables rapid selection of the sectoral scan or the narrow angle scan.

2. The structure of claim 1 wherein the scanner means comprises a plurality of adjacently spaced feed horns communicating with respective waveguide pipes to form an organ pipe scanner which produces a unidirectional scan across the outlet ends of the feedhorns.

3. The structure of claim 1 wherein the horn means comprises at least a single nutating horn for conical scan tracking.

4. The subject matter of claim 1 wherein the horn means is a multi-port assembly comprising a plurality of adjacently positioned stationary horns for operating in a steady track mode.

5. The structure of claim 2 wherein the switching means comprises a movably mounted flat mirror reflector positioned in intermediate relation between the scanner means and the horn means for selectably communicating microwave energy between the reflector means and either the scanner means or the horn means.

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6. The subject matter of claim 2 wherein each of the feed horns has a pyramidal shape.

7. The structure of claim 3 wherein each of the horn means has a pyramidal shape.

8. The subject matter of claim 2 and further wherein the horn means comprises at least a single nutating horn for conical scan tracking.

9. The subject matter of claim 5 wherein the mirror

is longitudinally mounted to a shaft to permit selectable rapid rotation of the mirror between two angular positions.

10. The subject matter of claim 9 wherein the shaft is connected to a torquer that selectably drives the shaft between the two angular positions in response to electrical energization of the torquer.

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