

[54] REFLECTOR ANTENNA WITH IMPROVED SCANNING

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[58] Field of Search **343/777, 778, 779, 854**

[56]

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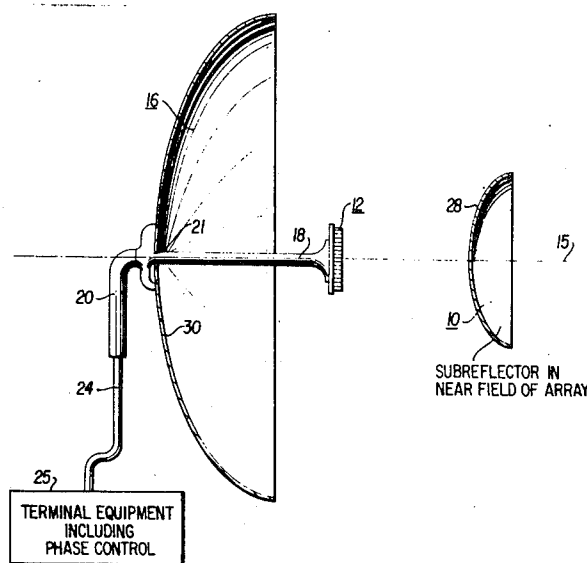
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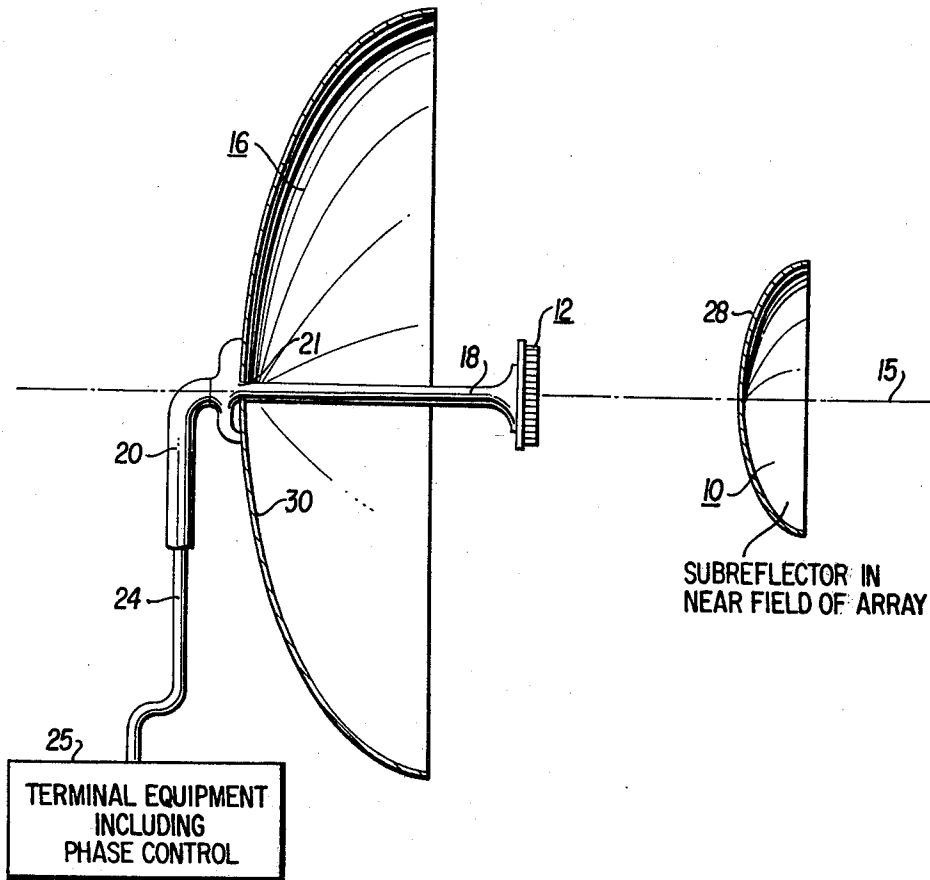
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ABSTRACT

A Cassegrainian antenna system has a planar array as the feed. An intermediate reflector is positioned in the near field of the array for substantially collimated illumination with all array elements operating in phase. Accordingly, an on-axis main beam is radiated from the main reflector upon illumination by energy from the intermediate reflector. By impressing a linear phase gradient across the array, the main beam is controllably tilted off-axis.

9 Claims, 1 Drawing Figure





REFLECTOR ANTENNA WITH IMPROVED SCANNING

This is a continuation, of application Ser. No. 190,777, filed Oct. 20, 1971, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to antenna systems, and more particularly to a reflector-type antenna system which is adapted for efficient electronic scanning through moderate angles.

2. Discussion of Prior Art:

It is frequently necessary to install a Cassegrainian antenna in an environment which may be subject to slow variations or to perturbations in orientation relative to an independent system, such as a target (e.g., a remote tracking station or receiving station). Moreover, these slight changes in orientation may occur along with a desired relatively rapid movement between the two systems. A typical example is the use of a Cassegrainian antenna aboard ship where, quite obviously, the antenna experiences undesirable movement as a consequence of ship roll, along with a more rapid change in relative distance between ship and target. Another example is found in a satellite- or space vehicle-borne antenna system, whose orientation relative to the target or to a baseline is adjusted to some extent by conventional coarse control of major vehicle movement, but for which other more complex techniques are required for fine adjustments necessitated by slight changes in orientation.

It is desirable to provide a simple means for varying the orientation (i.e., direction of the main beam) of the antenna under such circumstances, or in related situations where scanning of the beam through moderate angles may be necessary or desirable. Heretofore no truly simple means has been devised.

SUMMARY OF THE INVENTION:

It is a principal object of the present invention to provide a technique for moderate adjustment of the direction of the main beam of the reflector-type antenna by purely electronic means.

Another object of the invention is to provide a Cassegrainian antenna system utilizing improved techniques for efficient scanning of the main beam over limited scan angles.

Briefly, the above and other objects of the invention are achieved in part by locating the intermediate reflector (or subreflector) of the Cassegrainian antenna in the near field of a scanning array which is utilized as the feed for the antenna. A definition of the term "near field" is provided in a book entitled "Reference Data For Radio Engineers," written and published by International Telephone and Telegraph Corporation, New York, N.Y., 5th edition, 3rd printing, March, 1970, Chapter 25, page 47. That definition states that the near field region may be considered to extend out from an antenna to a distance of $A/(2\lambda)$ where A is the area of the antenna aperture and λ is the wavelength. It has been observed that the nearly-collimated near field of the array promotes uniform illumination of the subreflector with all array elements operating in phase, i.e., an on-axis beam. More importantly, we have discovered that the high illumination efficiency can be maintained with a phase gradient impressed across the ar-

ray, which causes a controlled off-axis beam to be radiated. Appropriate control of the phase gradient may be used to achieve a desired rotation of the "tilted" beam about the axis, through moderate scan angles. A linear phase gradient scans the beam to the greatest extent in the far field, and to a much lesser extent (but with far higher illumination efficiency) in the near field.

It is generally known to place a subreflector of a Cassegrainian antenna system in the near field of a single feed to improve illumination efficiency (as exemplified by the disclosure of U.S. Pat. No. 3,231,893 issued Jan. 25, 1966 to D. C. Hogg). However, we are not aware of any prior art in which a phased array of elements was used as the feed in such a system, nor in which such a system was utilized to achieve beam tilt or scanning over limited scan angles.

BRIEF DESCRIPTION OF THE DRAWINGS:

The attainment of the objects of the present invention will be better understood from the following detailed description of a preferred embodiment, which refers to the accompanying drawing, wherein:

The sole FIGURE is a sectional side elevation of an antenna system according to the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT:

Before proceeding with a description of the preferred embodiment, it is to be emphasized that all of the components of the antenna system to be described are purely conventional. The invention resides not in these components themselves, but in their cooperative relationship, both structurally and functionally, within the antenna system.

Referring now to FIG. 1, a reflector-type antenna system is generally arranged in a Cassegrainian configuration in which an intermediate reflector (sometimes hereinafter referred to as a subreflector) 10, of hyperboloidal shape for example, is positioned for illumination by energy radiated from a feed 12. Typically, the feed 12 and intermediate reflector 10 share a common axis 15 with main reflector 16, although this is not essential since the principles of the present invention are equally applicable to known off-axis illumination techniques for reflector-type antennas. The main reflector is usually of paraboloidal shape.

In many instances, the Cassegrainian antenna is constructed with the feed placed behind the main reflector, with exposure to the intermediate reflector being had via a central hole in the main reflector. As will become apparent from the ensuing description, the arrangement shown in FIG. 1 in which the feed 12 is physically positioned between the main reflector 16 and the intermediate reflector 10 is preferred for purposes of the present invention, but again, is not essential to the invention. Feed 12 is supported at its location by a support arm 18 which may be an extension of, or may be coupled to, the central support 20 for main reflector 16. In any event, support arm 18 and support 20 are conveniently connected via a central hole 21 in the main reflector, and each of these support elements may be hollow to house the necessary feed lines 24 from the terminal equipment 25 to feed 12. Such details as supports, guys, and the like are well known and readily implemented in the antenna art, and, since they have no direct bearing on the invention, will not be discussed further.

In the usual operation of the Cassegrainian antenna system, the energy impinging on the convex face 28 of intermediate reflector 10 from feed 12 is reflected onto the concave face 30 of main reflector 16 thus creating a highly directional beam of energy from the main aperture of the antenna, in a direction parallel to axis 15. In essence, the intermediate reflector is shaped to concentrate its reflected energy upon the surface 30 of the main reflector with as little spillover radiation as is practicable, and the main reflector is shaped to collimate this received energy into the aforementioned main beam.

According to a preferred embodiment of the present invention, the feed 12 is a planar array of feed elements, such as waveguide horns, themselves fed via suitable lines from terminal equipment 25 which, also according to the invention, includes suitable conventional means for controlling the phase excitation of the elements of the array for selectively impressing a phase gradient across the array, and to permit selective variation of the phase gradient. According to a further important feature of the invention, the intermediate reflector 10 is positioned in the near field of array 12. That is to say, the geometry of the antenna system is arranged such that the intermediate reflector is in the near field of the radiation pattern of array 12. In this field region the radiated feed energy is highly collimated, thereby providing high illumination efficiency, when all of the elements of the array are excited in phase. For an array aperture size of 20λ by 20λ (where λ is the wavelength or center of the band of wavelengths of RF energy transmitted by the antenna) with one hundred equally sized array elements (i.e., 2λ by 2λ , each) excited in phase, the field distributions at distances up to approximately 80λ from the array displayed near-uniformity of illumination and near-uniformity of phase distribution over a radius of almost 20λ . An aperture whose dimensions are 20λ by 20λ has an aperture area of approximately $400\lambda^2$. This aperture area, when divided by a distance 80λ , produces a quotient 5λ . This quotient represents the ratio of the aperture area (of the feed array) to the distance D between the feed array and the intermediate reflector. When $A/D = 5\lambda$, then $D = A/(5\lambda)$. Thus, a subreflector 10 within that dimension and distance from the array 12 is substantially uniformly illuminated and enjoys a substantially uniform phase distribution across a plane tangent to the center of its convex face 28 at the axis 15 of the system. This results in a high aperture efficiency for the main aperture, with an on-axis main beam.

We have further found that when the elements of array 12 are excited such that a linear phase gradient is impressed across the array, a similar situation to that described above is encountered with respect to illumination of the subreflector 10. However, the phase distribution across face 28 of the subreflector attributable to the linear phase gradient impressed across the array causes an off-axis tilt of the main beam. In particular, a 5.4 radian phase gradient across the array produced results comparing quite closely in illumination of the subreflector at distances up to 80λ , to those results obtained with in-phase excitation of the array elements, but caused an approximately 1° off-axis tilt of the main beam. Moreover, by varying the phase gradient across the array the tilted main beam may be rotated about the axis. A change in the degree of the phase gradient

correspondingly changes the angle of tilt, although this procedure has its limitations and it is expected that it is effective up to angles of about 10 to 15 beamwidths of the main antenna beam.

Thus, the invention provides an efficient transferral of both aperture illumination and array phase tilt (i.e., phase gradient) to the main aperture, thereby permitting efficient scanning of the main beam over limited scan angles. This is in sharp contrast to the complex phase control required in previous types of scanning antenna systems.

The maximum allowable separation between the array and the subreflector is defined by a point at which the array beam collimation begins to undergo appreciable beam deflection. The minimum separation between array and subreflector is governed by aperture blockage considerations.

While the invention has been described with specific reference to a Cassegrainian antenna system it will be apparent that the principles of the invention are applicable to other reflector antenna schemes. Similarly, other variations and modifications of the embodiment described herein are within the skill of the art, without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A reflector-type antenna system, comprising a feed including a planar array of antenna elements, said array having an aperture area A , a main reflector having a boresight axis, an intermediate reflector to couple energy from said feed to said main reflector, and means for exciting said feed so as to radiate energy having wavelength λ toward said intermediate reflector such that the radiated energy, when the array elements are all excited in phase is substantially a collimated energy beam extending along said axis, said intermediate reflector being spaced along said axis a distance D from said array to receive a substantially collimated feed beam of energy from said array when all of the array elements are excited in phase, whereby to effect the radiation of an on-axis main beam from said main reflector, said distance D being less than about A divided by 5λ , said exciting means including means for exciting said array elements with a linear phase gradient across said array to selectively tilt said main beam off-axis.
2. An antenna system, comprising a planar array of feed elements, said array having an aperture area A , means for exciting said array to radiate energy of wavelength λ such that when said elements are all excited in phase the radiated energy is a first beam that is essentially collimated for a near field distance along an axis of said array, an intermediate reflector spaced along said array axis from said array a distance D and positioned relative to said array for illumination by energy radiated from said array in said first beam, where $D < A/(5\lambda)$, and a main reflector having a main axis coincident with the array axis and responsive to energy coupled thereto by said intermediate reflector upon illumination of said intermediate reflector by said array

to form a highly directional main beam of said energy.

said exciting means including means for exciting all of said feed elements to produce a phase gradient across said array for selectively tilting said main beam relative to said main axis.

3. An antenna system comprising a planar array of antenna elements, said array having an aperture area A and an array axis; a main reflector; an intermediate reflector for receiving energy from said feed array and reflecting said energy to said main reflector; and means for exciting said feed array so as to radiate energy having wavelength λ such that said radiated energy, when the feed array elements are substantially all excited in phase, is a substantially collimated energy beam extending along said array axis to said intermediate reflector, said intermediate reflector being spaced a distance D from said feed array, said distance D being less than about A divided by 5λ , thereby to effect the radiation of a main beam in a first direction from said main reflector; said exciting means including means for exciting said array elements with a phase gradient across said array to selectively direct said main beam to a different direction.

4. An antenna system as defined in claim 3 and wherein said main reflector has a main axis of geometric symmetry coinciding with said array axis, and said intermediate reflector is located on both of said axes.

5. The system of claim 1, wherein said reflector-type antenna is a Cassegrainian antenna.

6. The reflector-type antenna system of claim 1, wherein

said exciting means includes means for producing rotation of the tilted beam about the axis of the main reflector by varying the phasing of the array elements.

7. The antenna system of claim 2, wherein said array, said intermediate reflector, and said main reflector are in a Cassegrainian configuration.

8. The antenna system of claim 2, wherein said phase gradient is linear.

9. The antenna system of claim 2, wherein said exciting means includes means for varying said phase gradient across the array to rotate the tilted beam about said axis.

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