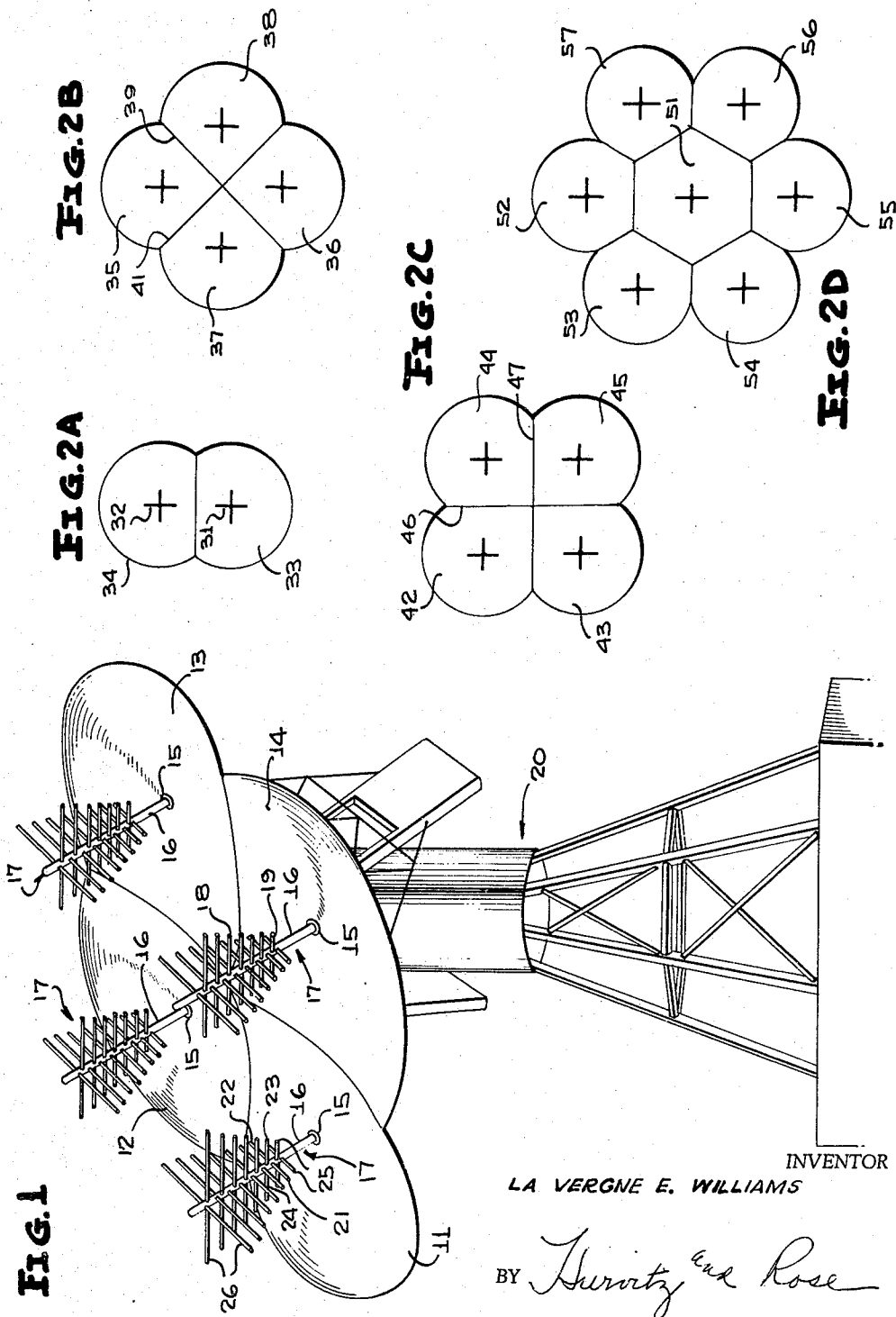


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LA VERGNE E. WILLIAMS  
PLURAL JUXTAPOSED PARABOLIC REFLECTORS WITH  
FREQUENCY INDEPENDENT FEEDS  
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INVENTOR

LA VERGNE E. WILLIAMS

BY *Twinty and Rose*

ATTORNEYS

1

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## PLURAL JUXTAPOSED PARABOLIC REFLECTORS WITH FREQUENCY INDEPENDENT FEEDS

La Vergne E. Williams, Indianalantic, Fla., assignor to  
Radiation, Inc., Melbourne, Fla., a corporation of  
Florida

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The present invention relates generally to antennas and more particularly to an antenna system employing an array of parabolic reflectors with frequency independent feeds which are adapted for use over a wide frequency band. The antenna system may be used for either simultaneous lobing, tracking, as in monopulse type systems, or in sequential lobing systems such as conical scan.

For varied uses, it is necessary to have a tracking antenna with a wide bandwidth, preferably a 10:1 frequency spread or more. Previously this required switching between arrays of narrow band antennas or changing feed elements. Such switching and changing is undesirable because of expense, duplication of structure, system down time, and personnel hazards.

Certain prior systems employ a multiplicity of narrow band elements in an array to achieve high gain. In general, the element pattern is independent of frequency and the array pattern changes with frequency. This characteristic places inherent limitations on bandwidth even if the elements are broadband. A second approach is the utilization of a broad band amplitude monopulse type feed or a sequentially lobing feed in a single reflector. With these approaches, there are serious electrical and mechanical problems with respect to feed design and optimum electrical performance is not obtained over a wide frequency band.

In the present invention, a broad band antenna system with substantially constant normalized main lobe characteristics is provided by employing an array of parabolic reflectors with frequency independent feeds such as logarithmic periodic structures or conical equi-angular spirals. Each parabolic antenna with associated feed can be considered one element of the array. The beamwidth of the element pattern, therefore, varies inversely with frequency and the principal lobe of the array pattern also varies essentially inversely with frequency. As a result, the normalized secondary pattern shape of the complete antenna remains essentially constant with frequency but the beamwidth varies inversely with frequency. Good aperture efficiency is achieved over a wide band because the full aperture is used at all frequencies.

In the present invention, the elements of the array may be connected to an appropriate hybrid network to produce sum and difference signals from which error signal information may be derived for tracking purposes by use of combining techniques which are well known to the art.

Sequential lobing scan can be used with the present invention by introducing variable phase shifters between the individual elements and the point at which they are connected together to produce a sum. By advancing the phase of the signal transmitted to or received from one side of the array with respect to the opposite side, the secondary pattern can be squinted in one direction. By sequentially changing the relative phase of elements around the perimeter of the array, the secondary beam can be conically scanned and error signal information can be derived by conventional conical scan tracking techniques also well known to the art.

The frequency independent antennas, such as the logarithmic periodic structures and the conical spiral, provide excellent primary feeds for the reflector elements because their pattern is essentially independent of fre-

2

quency. They are capable of providing essentially constant edge taper and aperture elimination for all frequencies within the spectrum.

Orthogonal logarithmic periodic dipole elements may be employed as a feed. For orthogonal linear polarizations, the dipole elements may be used independently. To effect circular polarization, the dipole feeds can be designed such that one set of elements in interleaved 90° electrically with respect to the other orthogonal elements and their combination produces circular polarization. A second approach for achieving circular polarization is to combine the signals from the orthogonal linear elements through an appropriate 90° phase shifter. A third method is the use of conical spirals as feed elements which are circularly-polarized by nature.

For one dimensional tracking, an array consisting of one pair of reflectors have their edges juxtaposition. For two dimensional tracking three, four, or more reflectors are arrayed such that each reflector has its edges juxtapositioned with the reflectors immediately adjacent thereto.

A further advantage of an array of parabolic antennas over a single parabolic structure of equivalent size relates to the overall shape and mounting provisions. The array is essentially a flatter structure with the feeds closer to the reflectors than the single feed in a larger single reflector. This permits the mounting of the center of gravity close to the elevation axis of rotation which in turn reduces counterweight requirements, moment of inertia, wind loading and drive power requirements for a given dynamic performance.

It is an object of the present invention to provide an antenna system having an array of two or more parabolic reflectors with frequency independent feeds, which system is capable of operation over extremely broad frequency ranges without pattern degradation.

Another object is to provide an antenna system comprising an array of two or more parabolic reflectors with frequency independent feed systems that is capable of generating phase monopulse type error signal information by appropriately combining the signals from each element of the array to produce sum and difference signals.

A further object is to provide an antenna system comprising an array of two or more parabolic reflectors which is capable of operation over a wide frequency band and also capable of error signal generation by sequentially lobing or conical scanning of the secondary pattern of the array.

It is an object of the present invention to provide an antenna system having an array of two or more parabolic reflectors with frequency independent feeds, which system is capable of operation over extremely broad frequency ranges without pattern degradation and is capable of high aperture efficiency over a broad frequency band and will yield patterns of essentially the same normalized shape but with a main beamwidth that will vary inversely with frequency.

It is an object of the present invention to provide an antenna system having an array of two or more parabolic reflectors with frequency independent feeds, which system is capable of operation over extremely broad frequency ranges without pattern degradation, wherein vertical, and horizontal polarizations or circular polarization can be received or transmitted.

Another object is to provide an antenna system comprising an array of two or more parabolic reflectors with frequency independent feed systems that is capable of generating phase monopulse type error signal information by appropriately combining the signals from each element of the array to produce sum and difference sig-

3

nals, wherein vertical and horizontal polarizations or circular polarization can be received or transmitted.

A further object is to provide an antenna system comprising an array of two or more parabolic reflectors which is capable of operation over a wide frequency band and also capable of error signal generation by sequentially lobing or conical scanning of the secondary pattern of the array, wherein vertical and horizontal polarizations or circular polarization can be received or transmitted.

It is an object of the present invention to provide an antenna system having an array of two or more parabolic reflectors with frequency independent feeds, which system is capable of operation over extremely broad frequency ranges without pattern degradation and has normalized patterns essentially independent of frequency, a main beamwidth inversely proportional to frequency and utilizes the entire aperture over a wide frequency band.

Another object is to provide an antenna system comprising an array of two or more parabolic reflectors with frequency independent feed systems that is capable of generating phase monopulse type error signal information by appropriately combining the signals from each element of the array to produce sum and difference signals and has normalized patterns essentially independent of frequency, a main beamwidth inversely proportional to frequency and utilizes the entire aperture over a wide frequency band.

A further object is to provide an antenna system comprising an array of two or more parabolic reflectors which is capable of operation over a wide frequency band and also capable of error signal generation by sequentially lobing or conical scanning of the secondary pattern of the array and has normalized patterns essentially independent of frequency, a main beamwidth inversely proportional to frequency and utilizes the entire aperture over a wide frequency band.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is an illustration of a preferred embodiment of the antenna system of the present invention; and

FIGURES 2a-2d are schematic, plain views of a number of arrays contemplated by the present invention.

Reference is now made to FIGURE 1 of the drawings which discloses four segmented, orthogonally positioned parabolic metal reflectors 11-14. Two edges of each reflector are juxtapositioned with the edges of the two reflectors at right angles thereto. Each of the parabolic reflectors 11-14 is essentially a paraboloid formed by rotating a parabola about an axis of revolution. At the apex 15 and coincident with the axis of revolution of each paraboloids 11-14 is an elongated rod 16 which serves as the axis for log periodic feed 17. The array of reflectors and feeds is mounted at an elevated position relative to the ground by tower 20, having the necessary motors for controlling movement of the reflectors.

Extending at right angles from rod 16 are a plurality of different length dipole pairs 18 which are resonant at different frequencies within and slightly beyond the frequency band of the antenna system. The shortest dipole pair 19 is positioned on rod 16 at a point approximately coincident with the focal point of each of the parabolic reflectors 11-14. The dipole pair lengths progressively increase as the distance between them and the reflector increases. Each of the dipole pairs 18 includes four orthogonally positioned metallic radiating elements, 21 and 22 of equal length. The length of each element within a particular dipole is approximately one quarter of the wavelength of a particular frequency within the band.

4

The dipole elements are connected to appropriate parallel conductor feed lines (not shown) and the feed lines can be connected to balanced transmission line or to a coaxial line by means of a so-called infinite balun, in a manner well known in the art.

The dipole of the log periodic feed which is resonant to the signal frequency transmitted or received by the system is the driven element which propagates most of the signal energy into the air or receives most of the signal. The adjacent dipole which is larger than the driven element reflects the energy from the driven element towards the reflector with which the feed is associated while the smaller adjacent dipole pair directs the signal towards the reflector in the transmitting case. In response to the received signal, the smaller element adjacent the resonant dipole pair directs the signal reflected from the paraboloid towards the resonant element while the larger adjacent element reflects energy which may have passed the resonant element towards it. By selecting a sufficient number of dipole pairs within the expected frequency band, great uniformity of patterns throughout the band is achieved. As the frequency of the propagated and received energy varies in the band, different dipole pairs are rendered resonant and accordingly different dipole pairs serve as the directors and reflectors. To obtain the same propagation from the extreme ends of the spectrum as from the mid range, dipole pairs 25 and 26, respectively, resonant at frequencies slightly greater and slightly less than the spectrum limits which are provided at opposite ends of rods 16. The dipole pair 25 serves as the director for its adjacent dipole pair, resonant at the upper frequency of the spectrum, while dipole pair 26 serves as a reflector for its adjacent dipole pair, resonant at the lowest frequency within the band.

In the preferred embodiment of the antenna system shown in FIGURE 1 four antennas with their feed systems are used to provide two dimension, azimuth and elevation angle, information in a phase monopulse system. In a single dimension phase monopulse, it is necessary to employ only two such antennas. To provide the necessary phase shift in the received signals to obtain azimuth and elevation angle information the apices 15 of reflectors 11-14 must be separated by at least one half the longest wavelength (and typically much more) to be propagated or received.

Several possible array configurations for deriving monopulse information are shown in FIGURE 2. FIGURE 2a is a one dimensional array which is capable of providing monopulse sum and error signal information by adding and subtracting the signals received by feed elements 31 and 32 in the juxtapositioned reflectors 33 and 34, respectively. FIGURE 2b is a preferred configuration for two-dimensional tracking in which the signals from the top and bottom reflectors 35 and 36 can be subtracted for vertical (or elevation) error and the signals from the right and left reflectors 37 and 38 can be subtracted for horizontal (or azimuth) error. All four signals may be added together for a sum channel. Parabolic reflectors 35-38 are juxtapositioned and located relative to the surface of the earth so that their common intersecting lines 39 and 41 form a 45° angle with the vertical. In the configuration shown in FIGURE 2c, the signal from the two left reflectors 42 and 43 can be added and their sum subtracted from the signal received by the two right reflectors 44 and 45 for horizontal or azimuth error. Similarly, the signals received by the two top reflectors 42 and 44 can be added together and subtracted from the signal received from the two bottom reflectors 43 and 45 for vertical or elevation error. Parabolic reflectors 42-45 are juxtapositioned and the array is located so the common intersecting lines 46 and 47 are vertically and horizontally orientated, respectively.

FIGURE 2d discloses an array of seven parabolic, juxtapositioned, respectively.

5

positioned reflectors as comprising reflectors 52-57 equally spaced about center reflector 51. One advantage of a large array of this type is that the relative signal received by each reflector can be weighted when adding the signals together to effectively produce an aperture taper which, in turn, permits a design with low side lobes in the sum channel. A second advantage is that it is possible to utilize a lesser number of elements than the total for broadening the secondary antenna pattern. This capability is very useful when one is attempting to acquire a target at an unknown location. All of the configurations shown in FIGURES 2a-d are capable of sequential lobing for error signal generation and more elements or different configurations from those shown can be used.

In the preferred configurations illustrated the axes of the feed elements are co-incident with the axes of the revolution of the parabolas. This co-incidence is not a necessity, however, and in some configurations it may be desirable to steer the primary illumination pattern by changing the axis of the primary feed with respect to the axis of revolution. In some configurations, this will result in better over-all primary illumination and if all feeds are mounted symmetrically the operation of the array will not be impaired.

The embodiments of the invention shown in FIGURES 2a-2d are capable of receiving vertical polarization and horizontal polarization simultaneously, or the orthogonal signals can be connected so as to yield circular polarization.

While I have described an illustrated once specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the dependent claims.

I claim:

1. An antenna system for use in monopulse radar having wavelength propagations between  $\lambda_1$  and  $\lambda_2$ , where  $\lambda_1$  and  $\lambda_2$  are the shortest and longest wavelengths, respectively of said radar, comprising four orthogonally positioned, substantially co-planar parabolic reflectors, each of said reflectors having juxtapositioned edges with two of said other reflectors, each of said reflectors having an axis of revolution, the axes of revolutions of adjacent ones of said reflectors being separated by at least

$$\frac{\lambda_2}{2}$$

and a separate log periodic feed positioned in energy exchanging relationship with each of said reflectors, said log periodic feeds having longitudinal axes coincident with the respective reflector axes, said feeds having a plurality of driven elements resonant between  $\lambda_1$  and  $\lambda_2$ .

2. An antenna system comprising a plurality of substantially co-planar juxtapositioned parabolic reflectors, each of said reflectors being a segmented paraboloid of revolution, each of said reflectors having a substantial portion of its rim common with a substantial portion of a rim of each adjacent reflector, a separate frequency independent feed being positioned in energy exchanging relationship with each of said reflectors, each of said feeds being frequency independent between a minimum wavelength  $\lambda_1$  and a maximum wavelength  $\lambda_2$ , the shortest wave-length resonant point of each feed being positioned approximately at the focus of its respective reflector, the apices of adjacent ones of all of said reflectors being separated by at least

$$\frac{\lambda_2}{2}$$

6

3. The system of claim 2 wherein said plurality equals four, and said reflectors have a common point of intersection.

4. The system of claim 3 wherein said four reflectors are orthogonally arranged.

5. The system of claim 2 wherein a multiplicity of said reflectors are symmetrically positioned about a central one of said reflectors.

6. The system of claim 5 wherein said multiplicity equals six.

7. The system of claim 2 wherein said reflectors and the common edges thereof are arranged so that a reflecting surface is everywhere present via any path from one edge of said plural reflectors to the other edge thereof.

8. The antenna system of claim 2 wherein each of said feeds is a log-periodic feed.

9. The antenna system of claim 8 wherein the longitudinal axis of each feed is coincident with the longitudinal axis of its respective reflector.

10. The antenna system of claim 2 wherein the longitudinal axis of each feed is coincident with the longitudinal axis of its respective reflector.

11. An antenna system having operating wavelength between  $\lambda_1$  and  $\lambda_2$ , where  $\lambda_1$  and  $\lambda_2$  are the shortest and longest wavelengths, respectively of said system, comprising at least four orthogonally positioned, substantially co-planar segmented paraboloidal reflectors, each of said reflectors having a substantial portion of its rim juxtapositioned with a substantial portion of the rim of at least two others of said reflectors, each of said reflectors having an axis of revolution, the axes of revolutions of adjacent ones of said reflectors being separated by at least

$$\frac{\lambda_2}{2}$$

and a separate frequency independent feed positioned in energy exchanging relationship with each of said reflectors, said feeds having longitudinal axes approximately coincident with the respective axes, each of said feeds being frequency independent between  $\lambda_1$  and  $\lambda_2$ , where

$$\frac{\lambda_2}{\lambda_1}$$

is at least 5, the shortest resonant point of each feed being positioned approximately at the focus of its respective reflector.

12. An antenna system having operating wavelengths between  $\lambda_1$  and  $\lambda_2$ , where  $\lambda_1$  and  $\lambda_2$  are the shortest and longest wavelengths, respectively, of said system, comprising at least three operating symmetrically arranged, substantially co-planar paraboloidal reflectors, each of said reflectors having a rim juxtapositioned with at least two of said other reflectors, each of said reflectors having an axis of revolution, the axes of revolutions of adjacent ones of said reflectors being separated by at least

$$\frac{\lambda_2}{2}$$

and a separate feed positioned in energy exchange relationship with each of said reflectors, said feeds having longitudinal axes at least approximately coincident with the respective reflector axes, respectively, said feeds having a plurality of driven elements resonant between  $\lambda_1$  and  $\lambda_2$ , each reflector having an adjacent rim portion coinciding over a substantial portion of its rim length with the rim of each juxtaposed reflector.

13. The combination in accordance with claim 12 in which said at least three symmetrically arranged substantially co-planar paraboloidal reflectors are at least four of said reflectors and wherein said feeds are of the log-periodic type.

14. An antenna system comprising two substantially co-planar juxtapositioned parabolic reflectors, each of said reflectors being a segmented paraboloid of revolution, said reflectors having a substantial portion of their adjacent

7

rims common, a separate frequency independent feed being positioned in energy exchange relationship with each of said reflectors, both of said feeds being frequency independent between a minimum wavelength  $\lambda_1$  and a maximum wavelength  $\lambda_2$ , the shortest wavelength resonant point of each feed being positioned approximately at the focus of its respective reflector, the apieces of said reflectors being separated by at least

$$\frac{\lambda_2}{2}$$

8

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