

Oct. 7, 1969

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3,471,857

PLANAR ARRAY ANTENNA ARRANGEMENTS

Filed May 24, 1967

2 Sheets-Sheet 1

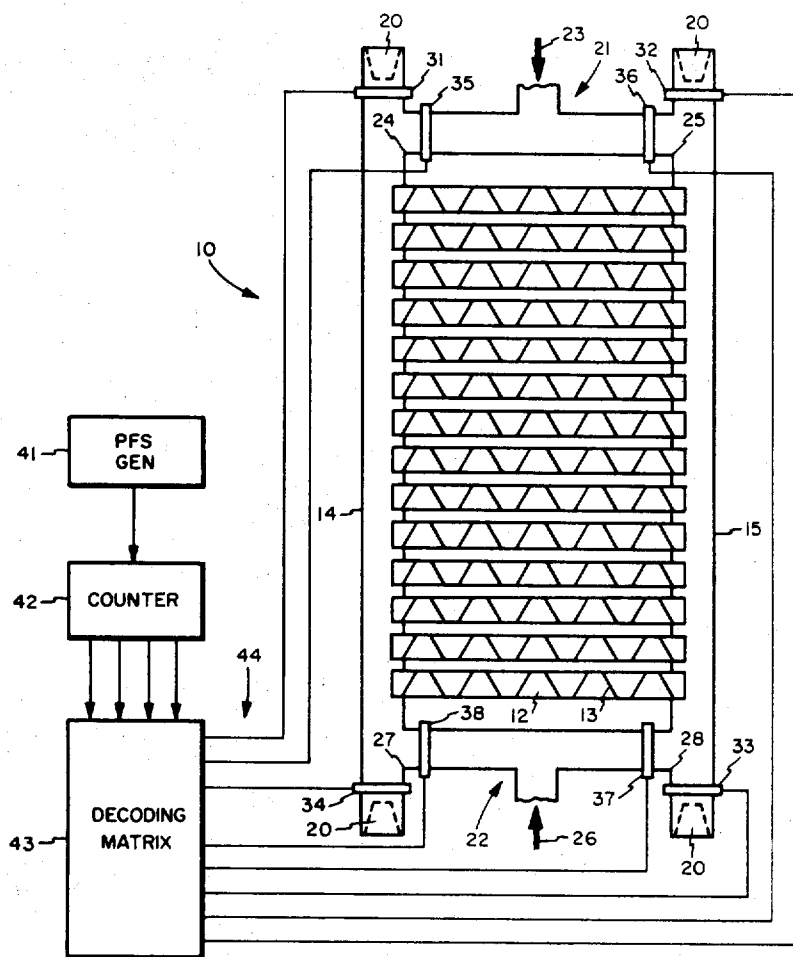


FIG. 1

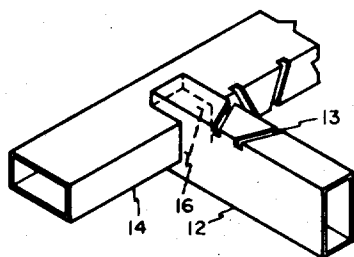


FIG. 2

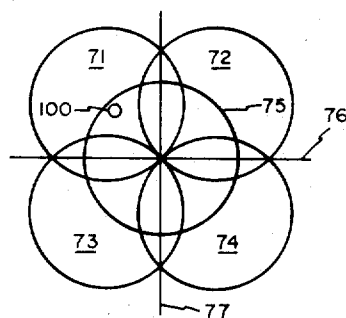


FIG. 4

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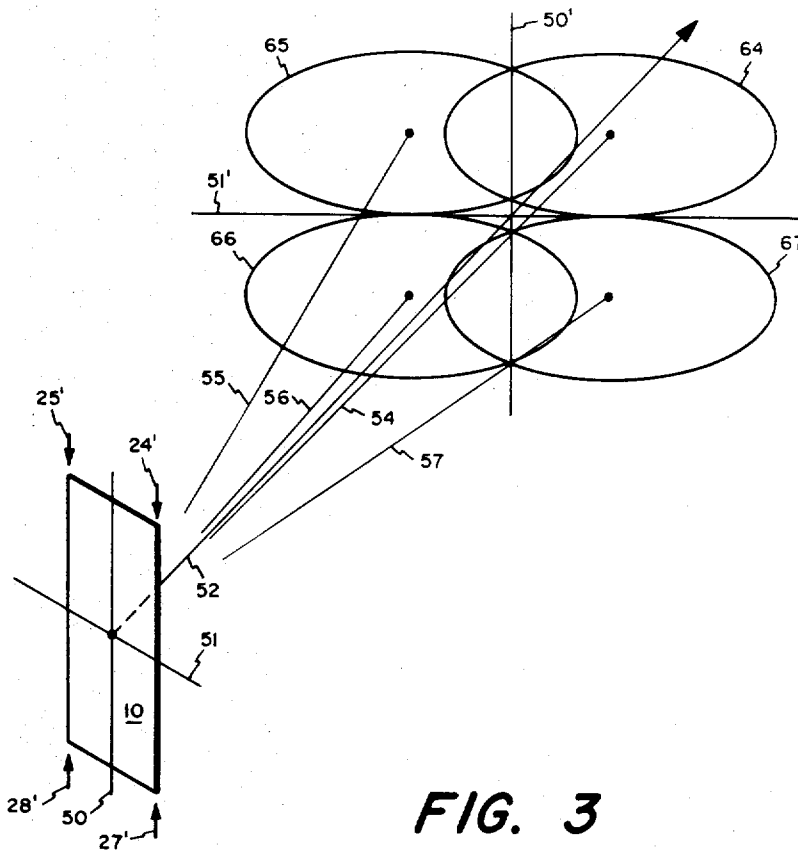


FIG. 3

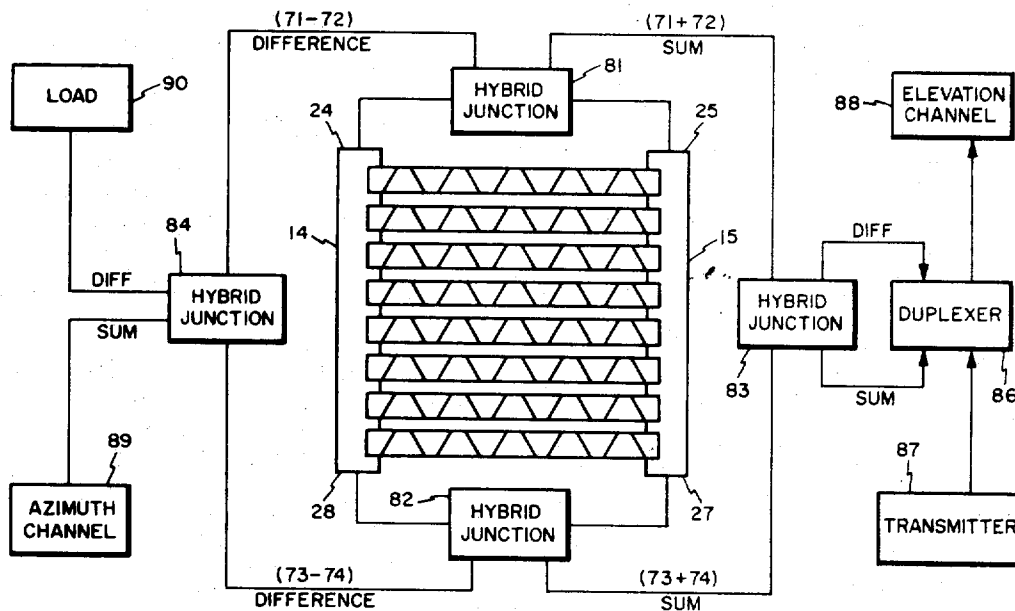


FIG. 5

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PLANAR ARRAY ANTENNA ARRANGEMENTS
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U.S. Cl. 343-16

5 Claims

ABSTRACT OF THE DISCLOSURE

Microwave antenna apparatus for generating a conical scan beam shape and/or for use in two coordinate amplitude comparison monopulse tracking radars. In the first case, a planar array is provided comprising a pair of spaced parallel feed waveguides and a plurality of linear waveguide radiators orthogonally disposed therebetween. The four separate feed ports in the array are periodically coupled in succession to a source of microwave energy with the result that the beam squinted by the array is switched from quadrant to quadrant in space. In the second case, the same planar array is coupled to a microwave comparator comprising four identical four-armed microwave hybrid junctions. Through this arrangement, the array is capable of transmitting a sum beam concentric with boresight which beam is, in reality, composed of four simultaneously squinted overlapping beams. During reception, the comparator functions to add the echoes from two beams, subtract same from the sum of the other two beams and simultaneously subtract the sums of the orthogonal beam pairs.

BRIEF SUMMARY OF THE INVENTION

In conjunction with the tactical landing approach radio system disclosed in Patents Nos. 3,177,777 and 3,309,708, and in copending application Ser. No. 620,974, filed Mar. 6 1967, now Patent No. 3,401,389, each of which is assigned to the assignee of the instant case, there is described an antenna for radiating a beam of electromagnetic energy into space; the beam ultimately functioning to establish glide-slope/localizer references relative to a landing strip. Since the design of this system dictates that the beam be scanned relative to an imaginary fixed glide-slope/localizer axis, a conventional rotating conical scan antenna assembly is cited therein as a suitable example capable of fulfilling this requirement. However, it is well known in the art that such conical scan antennas have several undesirable aspects, chief among which is the fact that they rely essentially upon rotary mechanical switching. This in turn requires expensive motor structures and rather complex and extraneous microwave plumbing fixtures all of which tend to up the cost of these units, lower their reliability, and effectively limit their maximum scanning velocities.

Thus, the present disclosure relates in part to an improved antenna assembly; one which operates upon the principle of electronically switching or lobing a radiated beam of microwave energy about a preselected reference axis to form a new scanned beam envelope, and one which is therefore admirably suited for use in the aforementioned tactical landing approach radio system. Furthermore, as will be made obvious by the ensuing discussion, the antenna according to the present invention is extremely simple in construction, has no moving parts, and is therefore highly reliable and relatively low in cost.

More specifically, the subject antenna system comprises a rectangular planar array consisting of a plurality of parallel related similarly phased linear waveguide radiators. The design is such that each radiator is orthogonally coupled at each of its ends to one of two parallel common feed waveguides thus providing four possible ports through which microwave energy may be fed into the array. As a

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result, each time a different one of the four ports is coupled to an exciting microwave source, the array will squint a beam into a correspondingly different quadrant in space. By utilizing appropriate beam switching rates and port feed sequences a single beam may be made to scan from quadrant to quadrant in pseudo-rotary fashion thus effectively generating a new beam envelope concentrically related to the boresight axis defined by the array's rectangular aperture. It follows that since the new envelope emerges as the product of a periodically scanned beam motion it possesses the same space modulation characteristics produced by a conventional conical scan antenna arrangement.

Although the present antenna system was originally designed for use in the above mentioned instrument landing system, it is by no means limited exclusively to use therein. Rather it is contemplated that the general principles of the invention are broad enough to admit of more extensive application in the microwave arts. For example, in amplitude comparison monopulse tracking radars (or more simply, monopulse) an antenna system is required for generating a lobe sum pattern during transmission and sum and difference lobe patterns simultaneously during reception. Accordingly, prior art two coordinate monopulse antenna installations have heretofore typically included large parabolic reflecting dish assemblies having a matrixed cluster of feed horns centrally mounted thereon. While this antenna system does get the job done, so to speak, it suffers from poor side lobe performance in the difference mode due to the aperture blockage effects introduced by the large feed cluster, and is in general a rather complex and costly affair.

Therefore, an alternative preferred embodiment will be described herein, indicating how the planar array antenna configuration according to the invention may be used with a microwave comparator to produce an antenna system for use in monopulse tracking radars which system will have excellent side lobe performance owing to unrestricted aperture illumination, as well as being simple in construction and low in cost.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a preferred form of antenna in accordance with the invention;

FIG. 2 is a sketch showing in detail the coupling between two waveguide sections;

FIG. 3 is a schematic illustration of the beam shape pattern produced by the antenna of FIG. 1;

FIG. 4 is a sketch of the beam pattern cross-section corresponding to an alternative preferred form of antenna; and

FIG. 5 is a schematic illustration of the alternative preferred form of antenna according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to FIG. 1, a microwave planar antenna is shown comprising a like plurality of parallel contiguously disposed linear arrays. Preferably each array consists of a rectangular waveguide section such as that indicated by reference character 12 and includes a longitudinal series of oblique slot couplings 13 cut into its narrow face. A pair of feed waveguides 14, 15, orthogonally related to the linear arrays at the extremities thereof respectively provide common microwave conduit means to the adjacent ends of the arrays. The feed waveguides are coupled to the arrays through slots in a manner to be explained in more detail below.

Both the coupling slots in the two feed waveguides and the obliquely slotted radiators in the individual linear arrays are designed in accordance with the equation:

$$\sin \theta = \frac{\lambda}{\lambda_g} - \frac{\lambda_g}{2S} \quad (1)$$

where θ is the angle the principal lobe makes with the longitudinal axis of each waveguide, λ is the microwave energy wavelength in space, λ_g is the microwave energy wavelength in each waveguide, and S is the distance between consecutive slot radiators; which is another way of saying that both the feed waveguides and the linear waveguide arrays are all of the antiphase type. Therefore, as is well known in the art, adjacent slot couplings whether in the feed waveguides or in the linear waveguide arrays will be obliquely slanted 180° relative to each other.

Turning briefly to FIG. 2, a detail of the coupling between one of the linear waveguide arrays 12 and one of the feed waveguides 14 is schematically illustrated. As clearly shown the feed waveguide is adapted to couple energy into the linear waveguide array through an oblique slot 16 cut into the former's narrow face. Since there is an oblique slot coupling in the feed waveguide corresponding to each linear waveguide the former feeds energy into the latter in the same fashion the linear waveguide arrays couple the same energy to free space through similar slot couplings 13. Hence, each slot coupling in each feed waveguide is 180° out of phase with its immediately adjacent couplings, or stated differently, has an opposite slant sense in relation thereto.

Returning now to FIG. 1, a nonreflective termination in the form of a tapered block of lossy material say, carbon, for example, is disposed in each end of each feed waveguide as indicated generally by reference character 20. A suitable source of microwave energy such as, by way of illustration, the transmitter channel in the aforementioned copending application Ser. No. 620,974 may then be coupled to the planar array through an upper waveguide T-section 21 and a lower waveguide T-section 22 as viewed in FIG. 1. By this arrangement, microwave energy may be made to flow through the common leg of the upper T as indicated generally by the arrow 23, through either arm of the T, and into the upper ends of each feed waveguide, respectively, entering therethrough via respective feed ports 24, 25. In similar fashion, microwave energy may flow into the lower waveguide T-section as indicated generally by arrow 26 and thence into the bottom ends of each feed waveguide through feed ports 27, 28, respectively. Thus, it will be appreciated that microwave energy may be applied to the planar array through any one of the abovementioned four feed ports, each one of which is located intermediately between the terminal load and first slot coupling corresponding to each end of the respective feed waveguides as shown in FIG. 1.

In the operation of the planar array, microwave energy is sequentially fed through one port at a time at a suitable periodically recurring rate, the sequence beginning, by way of illustration, at port 24, then circulating clockwise around the array through ports 25 and 28 and finally ending with energy being fed through port 27. The whole sequence is then recycled. Now, when energy is being fed through a particular feed port, the nonreflective terminal load adjacent thereto is short-circuited and the remaining three terminal loads are open-circuited while at the same time the remaining three ports corresponding to the three open-circuited terminal loads are closed.

To accomplish the immediately foregoing, including the port feed sequencing, a plurality of conventional microwave switching diodes 31 through 38 are deployed in and among the feed waveguides as schematically depicted in FIG. 1. Inasmuch as the constructional details of a microwave switching diode form no part of this invention, they will not be further described herein. However, as is well known, the behavior of the diode is such that when placed within a waveguide and biased with a suitable voltage it acts as a barrier to the impinging microwave energy. If there is no voltage drop across the diode the microwave energy travelling through the waveguide remains unimpeded as if the diode were not there. Stated simply, the microwave diode may be considered as the analog of a single-pole double-throw switch having stable states corresponding to an open circuit and a closed circuit.

In order to control the energization of the various diodes in the desired manner, a port feeding sequence generator 41 is provided as generally indicated. The latter preferably comprises a standard square wave oscillator which is adapted to constantly emit a pulse train having a frequency equal to a suitable preselected port feeding rate. This pulse train is then applied to a conventional multi-stage binary counter 42 which is designed to respond to each input pulse by periodically coupling one of four different discrete binary coded signals to a diode decoding matrix represented by reference character 43. The matrix includes a plurality of output conductors represented generally by reference character 44, each one of which electrically coupled to each one of the aforementioned microwave switching diodes for energization thereof respectively. Since the matrix may be obviously configured to accommodate each discrete binary coded signal by energizing a different group of output conductors in response thereto, it will be appreciated that the four discrete binary coded signals are all that is actually needed to define the planar array's port feed switching logic.

To illustrate, assume the binary coded signal corresponding to the feeding of microwave energy through port 24 appears at the output of counter 42. This signal enters the matrix 43 where it is decoded by the energization of the output conductors leading to diodes 31, 36, 37 and 38. The remaining output conductors leading to diodes 32, 33, 34, 35 remain unenergized. As a result, the microwave energy flows through the left most arm of upper waveguide T-section 21, through port 24, and down feed waveguide 14 where it is coupled through slots 16 to each of the individual linear waveguide arrays which in turn couple the energy to free space. It will be apparent that the energy can only flow through port 24 because the diode in the other arm of the T-section 21 and both diodes in the T-section 22 are being energized thereby effectively short-circuiting these waveguide sections. At the same time, the absorptive load immediately adjacent port 24 is isolated therefrom by reason of its associated diode being energized, while the remaining three nonreflective terminations load the array since their associated diodes are unenergized.

Counter 42 then counts the next pulse in the train emitted by PFS generator 41 thus changing the character of the binary coded signal in its output. Accordingly, a different plurality in the group of conductors 44 is now energized corresponding to the new binary coded signal input to the decoding matrix 43. Since this different binary coded signal now corresponds to the feeding of microwave energy through port 25 diodes 35, 38, 37 and 32 are energized and diodes 31, 34, 33 and 36 will become deenergized. It follows that the microwave energy will now travel through upper waveguide T-section 21, through the latter's right most arm, port 25, and down feed waveguide 15 into the individual linear waveguide arrays.

In similar fashion counter 42 will count the third and fourth pulses in the train emitted by generator 41 whereupon in each instance a different plurality or set of conductors in the group 44 will be energized corresponding to the feeding of microwave energy through ports 28 and 27 respectively. Finally, upon the appearance of the fifth pulse counter 42 will be automatically reset and the first-mentioned binary coded signal corresponding to the feeding of microwave energy through port 24 will again be fed into decoding matrix 43 and the port feeding sequence cycle repeated.

Thus, it can now be appreciated that each time the planar array's switching logic circuitry is clocked by a pulse from the port feeding sequence generator a different preselected discrete plurality of switching diodes will be energized in the manner required to sequentially feed microwave energy through a different port in a repetitive cycle having a rotative sense running clockwise around the array as viewed in FIG. 1. For convenience the diode

switching logic associated with one complete array feeding sequence is set forth in the following table.

Feed Ports:	Diodes Energized	Diodes Unenergized
24-----	31, 36, 37, 38	35, 34, 32, 33
25-----	35, 38, 37, 32	31, 34, 33, 36
28-----	38, 35, 36, 33	37, 34, 31, 32
27-----	34, 37, 35, 36	31, 32, 33, 38

Referring now to FIG. 3, the planar array antenna is shown having a longitudinal axis 50 and a transverse axis 51. The axis 52 extends normal to the planar array at the intersection point of the aforementioned axes and thus defines the antenna system's boresight axis. In use, therefore, the rectangular planar array antenna will be positioned on or near a landing strip (not shown) in a generally upright condition; however, it will be tilted rearwardly slightly such that the boresight axis 52 is in colinear alignment with an imaginary glide-slope/localizer axis prepositioned in space.

When, for example, microwave energy is fed through port 24 (FIG. 1) as generally indicated by arrow 24' the planar array will squint a beam 54 into space whose three db contour shape is represented generally by the ellipse 64. The squint angle, as it is termed in the art, is equal to the angle between the beam center 54 and the planar array's boresight axis 52.

In order to understand this squinted beam formation, it will be helpful to recall that the rectangular array comprises feed waveguides and linear waveguide arrays having similar antiphase propagatory characteristics. Thus, as microwave energy travels down the feed waveguide 14 from port 24 the array will actually radiate two orthogonally related beams each assuming the shape of a conical shell. Owing to the transverse direction of the coupling slots 13 in the individual linear arrays one beam will be radiated in coaxial relation to the transverse axis 51 forming a half-angle with respect thereto and will extend toward the feed waveguide 14. Since the slot couplings 13 may also be considered to form a plurality of antiphase arrays parallel to the longitudinal axis 50 of the array, the second beam will be radiated in coaxial relation to the last-mentioned axis, and will extend toward the feed port 24. Phase coincidence of these two beams then occurs in space to form a new beam shape represented by the illumination contour 64. When microwave energy is switched from port 24 to port 25 the identical beam formation process takes place. In this case, however, the transverse beam will now extend toward feed waveguide 15 and accordingly the composite beam 55 will be squinted into a new quadrant in space and illuminate an area therein indicated by the ellipse 65. Likewise, when microwave energy is switched from port 25 to port 28 the longitudinal beam component generated by the array will extend in the direction of the latter port thereby forming beam 56 which is shown being squinted into a third quadrant in space to illuminate the area 66. Finally, when the energy is switched from port 28 to port 27 to complete the port feeding cycle, a fourth beam 57 is squinted into a fourth quadrant in space having an illumination area therein designated generally by the ellipse 67.

Thus, by squinting a shaped beam into space and then switching this beam from quadrant to quadrant in pseudorotary fashion, the planar array according to the present invention will effectively synthesize the same beam pattern produced heretofore by conical scan antenna systems.

In connection with the actual design of the planar array, it is to be noted the shape of the squinted beam may be varied within rather wide limits by merely changing the relative dimensions of the array's rectangular aperture. For example, if it is desired to increase the beam width in the direction of axis 50' it is only necessary to reduce the dimensions of the rectangular array along axis

50. This can be done by simply removing a selected number of linear waveguide radiators. Similarly, if the beam width in the direction of axis 51' is to be made narrower, then the array's dimension in the direction of axis 51' will have to be extended accordingly. This may be accomplished by merely extending the length of the individual linear waveguide arrays in the rectangular configuration. Reference to Equation 1 will indicate that the squint angle of the radiated beam may be changed by merely adjusting the coupling slot spacing and/or the waveguide wavelength design parameters. In addition, it may be considered desirable from a design standpoint to increase the coupling slot angles progressively and symmetrically in both the feed waveguides and the linear arrays starting with a minimum slot angle at each end of the waveguide in question and reaching a maximum slot angle at the center. This technique, called amplitude contouring in the art, is quite effective in improving the side lobe level performance of the planar array, although at the expense of increasing beam width somewhat. Hence, in view of the foregoing, it will be appreciated that the instant planar array antenna is completely flexible in design aside from being simple in construction and efficient in operation.

And, although the use of anti-phase feed waveguides and linear arrays was cited in the description of the planar antenna, this was done only by way of illustrating the preferred embodiment thereof. It will be apparent to those skilled in the art that so-called inphase waveguides and linear arrays may be used instead, allowance being made for the mirror image reversal of the beam squint angle when the same port feeding sequence is used.

Reference will now be made to FIGS. 4 and 5 in describing the alternative preferred embodiment of the invention.

Utilizing the conception of the previously described planar array, it has been found possible to design a novel antenna system suitable for use in amplitude monopulse tracking radars and possessing excellent pattern characteristics.

As is well-known, a monopulse radar system for extracting error signals in both elevation and azimuth requires the generation of four overlapping antenna beams. During transmission the four overlapping beams combine to form a sum pattern coaxially related to the boresight axis defined by the antenna's aperture. When functioning in the receiving mode a difference pattern in one plane is formed by taking the sum of two adjacent beams and subtracting this from the sum of the other two adjacent beams. The difference pattern in the orthogonal plane is obtained in a similar manner by adding the differences of the orthogonal adjacent pairs. Thus as indicated schematically in FIG. 4, beams 71, 72, 73 and 74 are radiated in overlapping fashion during transmission to form composite beam 75 concentrically and coaxially related to the boresight axis of the system as defined by the intersection of the azimuth plane 77 with the elevation plane 76. Then, simultaneously and during reception, the system looks at the sum of beams 71 and 72 and subtracts from this the sum of beams 73 and 74 to derive the error signal in elevation. To derive the azimuth error signal, the system simultaneously looks at the sum of beams 71 and 73 and subtracts therefrom the sum of beams 72 and 74.

Turning now to FIG. 5, the antenna system for producing the aforementioned beam pattern is shown comprising essentially the same planar array configuration disclosed relative to the first preferred embodiment of the invention. That is, a plurality of rectangular linear waveguide arrays 12 are contiguously disposed in parallel coplanar relation to each other and respectively include a longitudinal series of oblique coupling slots 13 cut into their narrow faces. Commonly coupling the adjacent ends of the linear arrays are two orthogonally disposed parallel rectangular feed waveguides 14 and 15. The coupling slots in each feed waveguide and the cou-

pling slots in the individual rectangular linear arrays are all designed in accordance with Equation 1 therefore producing a pure antiphase array.

As mentioned previously in connection with the initially described embodiment of the planar array, the latter's aperture may be so designed as to produce practically any desired beam shape. Accordingly, in this case, the aperture of the planar array is chosen to be essentially square so that the beams developed thereby will be for the most part generally circular in cross-section as shown in FIG. 4. In addition, by choosing suitable values for the waveguide wavelength and slot spacing in both the waveguides and the individual arrays the squint angle of each beam is designed to produce the generally overlapping relationship shown in FIG. 4. This is necessary to generate a composite beam concentrically related to the boresight axis of the array as will be discussed in more detail below.

As already explained, the planar array shown in FIGS. 1 through 3 squints a single beam into space which is then regularly switched among a plurality of positions on a time shared basis by feeding microwave energy from one port to the other. When, substantially the same array, however, is used in conjunction with a monopulse system it is necessary to generate four beams simultaneously. Generally speaking, this requirement is met by providing a microwave comparator consisting of four hybrid junctions between the planar array per se and the transmitter-receiver channel of the monopulse system.

More specifically, and as schematically shown in FIG. 5, ports 24 and 25 of the array are respectively coupled through suitable waveguide fixtures to hybrid junction 81 while ports 28, 27 are respectively coupled in similar fashion to hybrid junction 82. Since microwave hybrid junctions are conventional their structural details need not be described here in any great detail. Suffice it to say, that a hybrid whether of the "magic T," "rat race," or "short-slot-coupler" type is usually a device having four arms, namely, two input arms, a sum arm and a difference arm. Accordingly, the microwave energy being coupled through two of the arms will be subtracted in the third arm and added in the fourth arm. Hence in the comparator, the difference outputs of hybrids 81, 82 are respectively coupled to hybrid junction 84 while the sum outputs of hybrids 81, 82, respectively, are coupled to hybrid junction 83 as shown. As respects hybrid junction 83 its sum port is connected through duplexer 86 and thence to the transmitter channel of the monopulse system which latter is indicated generally by block 87. The duplexer functions also to couple the difference output arm of hybrid 83 to the elevation receiver channel 88. Finally the difference port of hybrid 84 is coupled to the azimuth channel in the receiver as indicated generally by block 89 while its sum output port is connected to an appropriate terminal load indicated generally by reference character 90.

In describing the operation of this system, let it be assumed that the duplexer has just switched on transmitter channel 86 and has isolated the receiver section from the antenna. Microwave energy thus flows from the transmitter channel through the duplexer into the sum arm of hybrid 83 wherein it divides and travels through the hybrid's input arms to the respective sum arms of hybrids 81, 82, respectively. The last mentioned hybrids again divide the incoming microwave energy and respectively feed same to ports 24, 25 on one hand and ports 28, 27 on the other hand. Since each port is being fed simultaneously, the planar array radiates the four beams 71, 72, 73 and 74 simultaneously, which latter then combine in space to form the sum pattern 75 as previously described.

The duplexer 86 then shuts down the transmitter and enables the receiver which, in turn, looks through the antenna system at the corresponding areas in space illuminated by beams 71 through 74.

Now, by way of example, let it be further assumed that the antenna system is tracking a target in the upper left quadrant as viewed in FIG. 4, the target being represented therein by reference character 100. The antenna detects the echo signal reflected by the target and passes same through port 24 to hybrid junction 81 wherein it is summed with the return obtained from port 25, that is corresponding to illuminated area 72. This sum signal (71 plus 72) is then fed through the hybrid's sum output arm to hybrid 83. The returns from illuminated areas 73, 74 are passed through ports 28, 27, respectively, into hybrid 82, wherein they are added together and applied through the latter's sum output to the other input arm of hybrid 83. Accordingly, in the last mentioned hybrid the signal corresponding to (71 plus 72) minus (73 plus 74) is obtained and fed via its difference arm to the elevation channel in the receiver which in response thereto drives at error voltage portional in magnitude to the lateral distance between the target 90 and the elevation plane 76'.

Simultaneously, and in similar fashion, the difference signals (71 minus 72) and (73 minus 74) developed in hybrid junctions 81, 82 respectively, are fed from the latter's difference arms to hybrid 84 wherein they are summed to yield (71 plus 73) minus (72 plus 74). This signal is then applied to the azimuth channel 89 in the receiver which emits an error signal whose voltage magnitude represents the lateral departure of target 100 from the azimuth plane 77.

In actual use the planar antenna may be mounted on a suitable gimbal structure and driven by appropriate servo motor circuitry. The error signals produced in either azimuth or elevation channels may then be utilized to slew the antenna until the latter's boresight axis coincides substantially with the target at which point the error signals will be nulled. By this arrangement the antenna system can be made to track the target. Of course it will be obvious to those skilled in the art that the antenna system may be used in conjunction with airborne systems as well as with monopulse systems on the ground.

In view of the foregoing it should now be apparent that the alternative embodiment in the present disclosure relates to a greatly improved planar array antenna configuration adaptable for use in two coordinate monopulse tracking radar systems. The great advantage of this antenna configuration over prior art monopulse antennas is that both the squinted beams and sum beam are produced from an unrestricted fully illuminated aperture and therefore it is possible to achieve equally good sidelobe performance in both the sum and difference channels. Multiple horn-fed parabolic antennas heretofore used in monopulse environments are incapable of producing adequate sidelobe performance in the difference mode because of the blockage problem produced by the feed-horn cluster in front of the dish. This plaguing problem has been completely overcome by the present invention.

Thus, although two preferred embodiments of the invention have been described in considerable detail for illustrative purposes, many modifications will occur to those skilled in the art. It is therefore desired that the protection afforded by Letters Patent be limited only by the true scope of the appended claims.

What is claimed is:

1. In a two coordinate amplitude comparison monopulse radar system having a transmitter and a receiver, said receiver including an azimuth error channel and an elevation error channel, the combination comprising, planar array antenna means having a substantially square aperture and including four microwave feed ports each one of which being disposed at a respective corner thereof, said antenna means being adapted to squint four overlapping beams into free space each one of which corresponding to microwave energy being fed from said

transmitter through a different one of said ports respectively, whereby said beams combine in free space to form a single beam having a generally circular cross-section concentrically related to the boresight axis defined by said aperture, and
 means coupled between said four microwave feed ports and said receiver for deriving a first microwave signal equal to the sum of the echoes from two of said beams minus the sum of the echoes corresponding to the other two beams and for deriving a second microwave signal equal to the difference between the sums of pairs of beams orthogonally related to the pairs of beams subtracted to obtain said first microwave signal, said first and second microwave signals being separately applied to the azimuth error channel and elevation error channel in said receiver respectively.

2. The apparatus of claim 1 wherein said means coupled between said four microwave feed ports and said receiver comprises four microwaves hybrid junctions, a first one of which is connected to two of said feed ports, a second one of which is connected to the remaining two feed ports, a third one of which is connected between said first and second junctions and said azimuth channel, and the fourth one of which is connected between said first and second junctions and a double-pole double-throw microwave switch, said switch being coupled to said elevation channel and said transmitter.

3. The apparatus of claim 2 wherein each of said hybrid junctions comprises four arms including two input arms, a sum arm and a difference arm respectively.

4. The apparatus of claim 1 wherein said planar array antenna means comprises,

- a pair of spaced parallel liner feed waveguides each having a plurality of coupling slots longitudinally disposed therein, and
- a plurality of linear waveguide radiators orthogonally disposed between said feed waveguides in individual cooperative relation with a particular coupling slot in each respective feed waveguide whereby microwave energy may be simultaneously fed in either direction through each end of each feed waveguide radiator, each of said waveguide radiators having a plurality of elements for coupling microwave energy to and from free space, the phase coupling characteristics of

said radiator elements and said feed waveguide slots being substantially identical.

5. An antenna system for use in amplitude comparison monopulse radars comprising,

a pair of spaced parallel identical rectangular feed waveguides each one of which includes a feed end at either extremity and a series of coupling slots longitudinally disposed therebetween,

a plurality of separate rectangular linear waveguides parallel and coplanar in relation to each other orthogonally disposed between said spaced feed waveguides in intimate cooperative association with a respective coupling slot in each feed waveguide thereby forming a planar array having four feeding ports, first, second, third and fourth microwave hybrid junctions each of which include two input arms, a sum output arm, and a difference output arm,

the input arms of said first junction being connected to two of said feeding ports respectively,

the input arms of said second junction being connected to the remaining two of said feeding ports respectively,

the input arms of said third junction being connected to said sum arms respectively corresponding to said first and second junctions, and

the input arms of said fourth junction being coupled respectively to said difference arms associated with said first and second junctions.

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