# United States Patent

**O'Hara et al.**

[15] **3,699,574**

[45] **Oct. 17, 1972**


[54] **SCANNED CYLINDRICAL ARRAY MONOPULSE ANTENNA**


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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**



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[21] Appl. No.: **867,101**

[52] **U.S. Cl.** ..........**343/16 M,** 343/100 SA, 343/705, 343/768, 343/854

[51] **Int. Cl.** ..............................................**G01s 9/22**

[58] **Field of Search** .....343/16 M, 100 SA, 768, 771, 343/854


[56] **References Cited**

UNITED STATES PATENTS


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|---|---|---|---|
| 3,474,446 | 10/1969 | Shestag et al. | 343/100 SA |
| 3,531,803 | 9/1970 | Rosen et al. | 343/100 SA |



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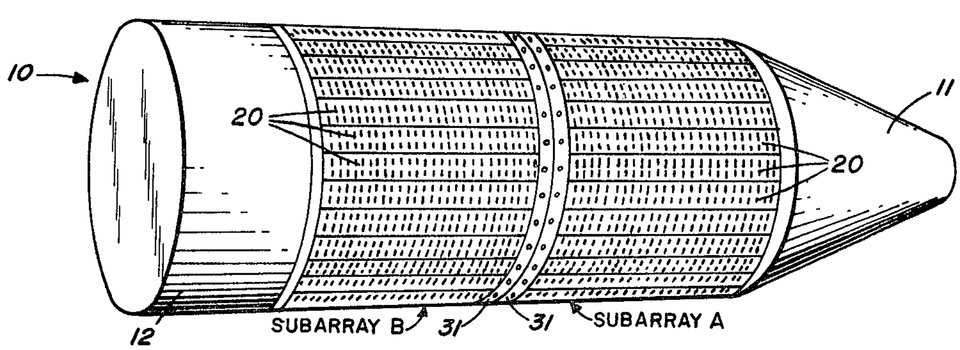
[57] **ABSTRACT**


A cylindrical antenna array system having two cylindrical subarrays flush mounted on a conducting cylinder, each consisting of a plurality of linear phased arrays fed through a pair of feed rings on the conducting cylinder that has a diode switch for each linear phased array coupled through a switching network to switch one-quarter to one-third of the linear phased arrays ON in a rotating manner to scan throughout 360° around the cylinder axis, and each linear phased array having a pair of rotatable dielectric slabs behind the waveguide slots thereof with all dielectric slabs mechanically coupled to rotate in synchronism to phase the radio waves for angular direction with respect to the cylinder axis, the received signals being coupled through a magic-T junction to provide sum and difference monopulse signals of targets in sight of the antenna.


**4 Claims, 9 Drawing Figures**



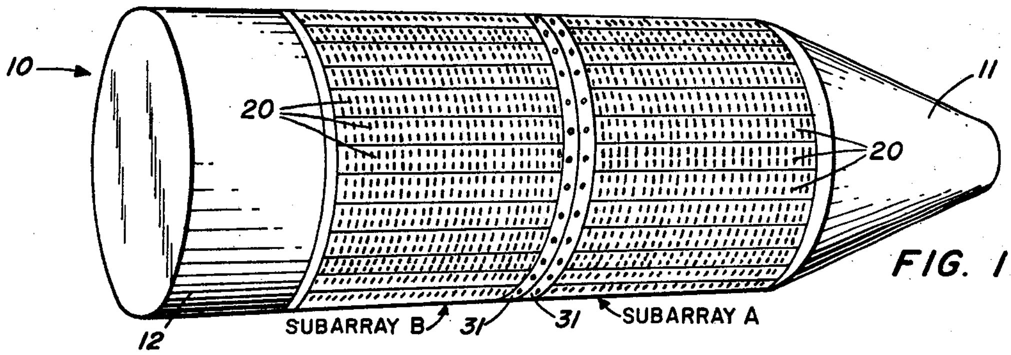



FIG. 1

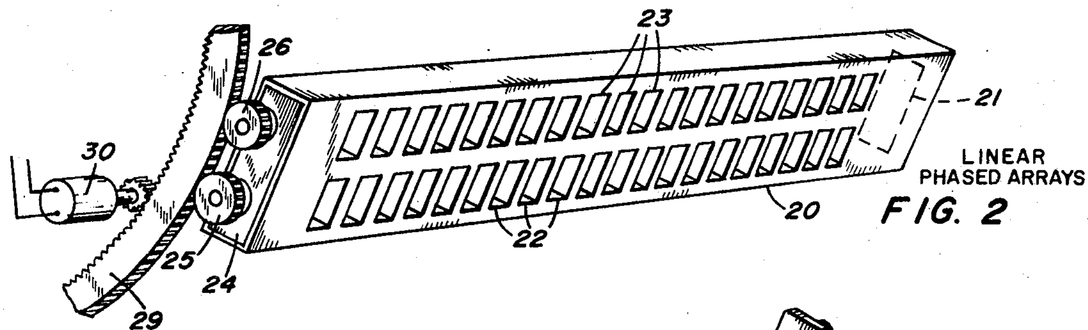



FIG. 2

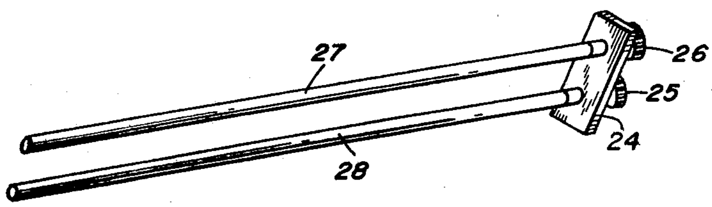



FIG. 3

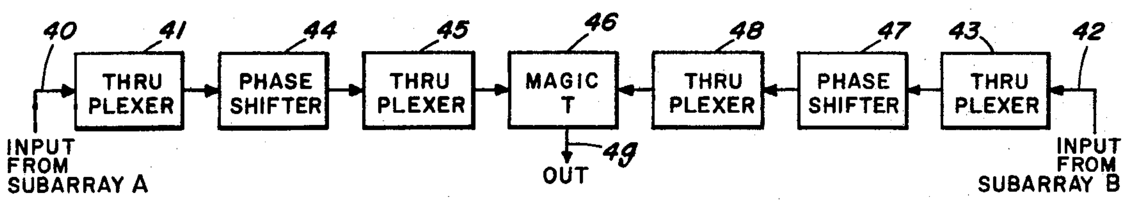



FIG. 5

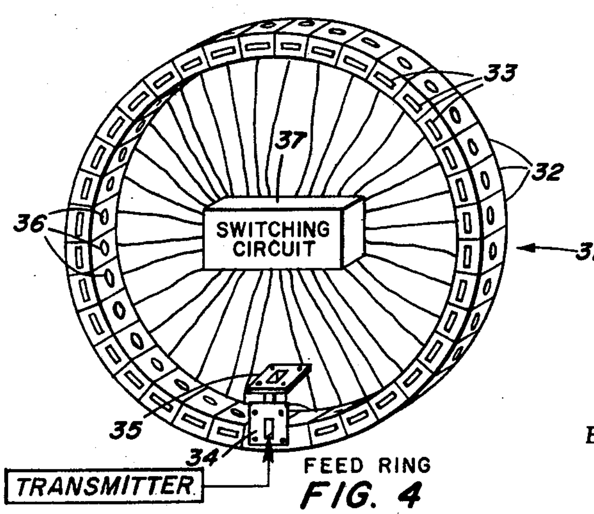



FIG. 4

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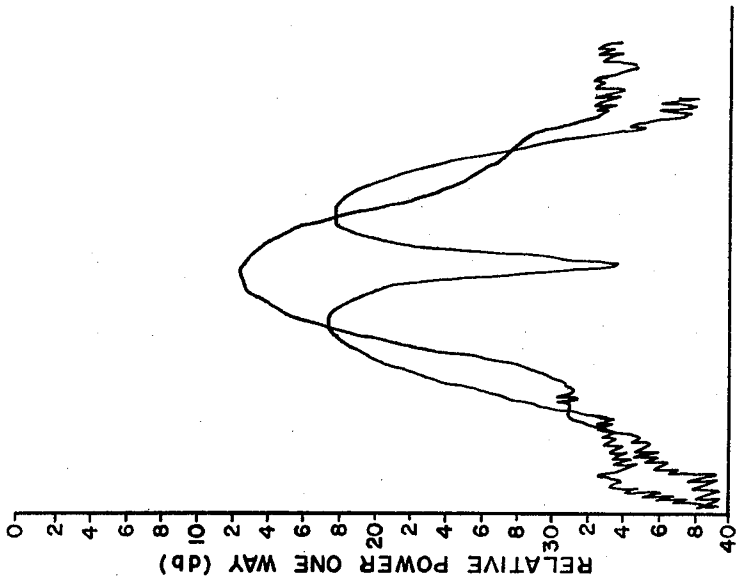
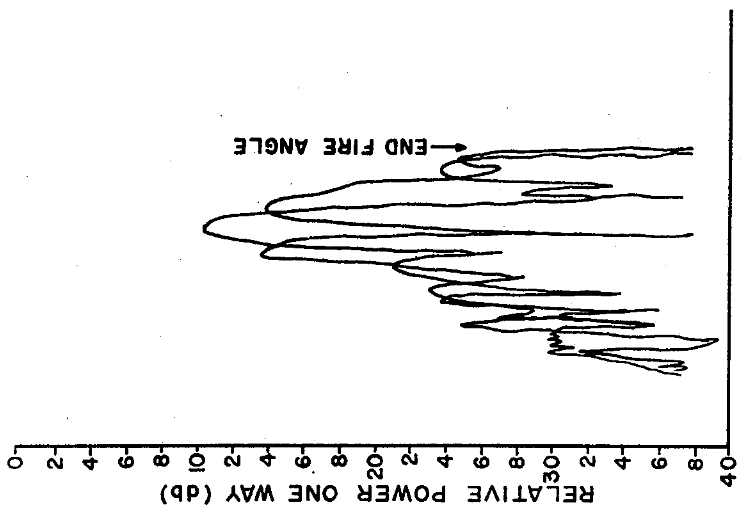


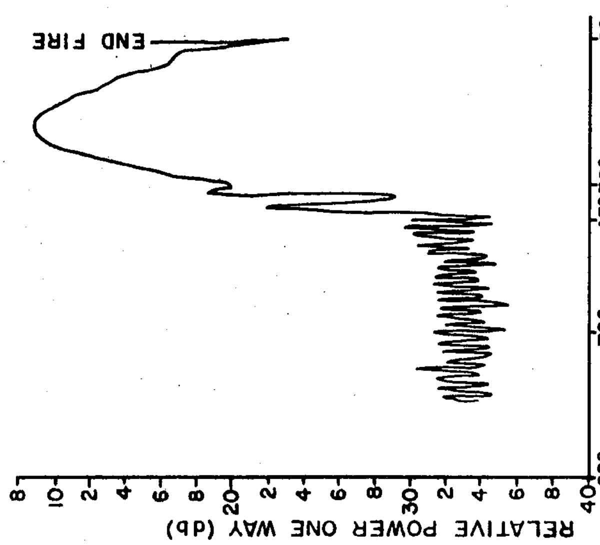

φ PLANE
SUM AND DIFFERENCE
θ SCAN BEAM POSITION 20°

FIG. 9




θ PLANE
SUM AND DIFFERENCE

FIG. 7




θ PLANE

FIG. 6

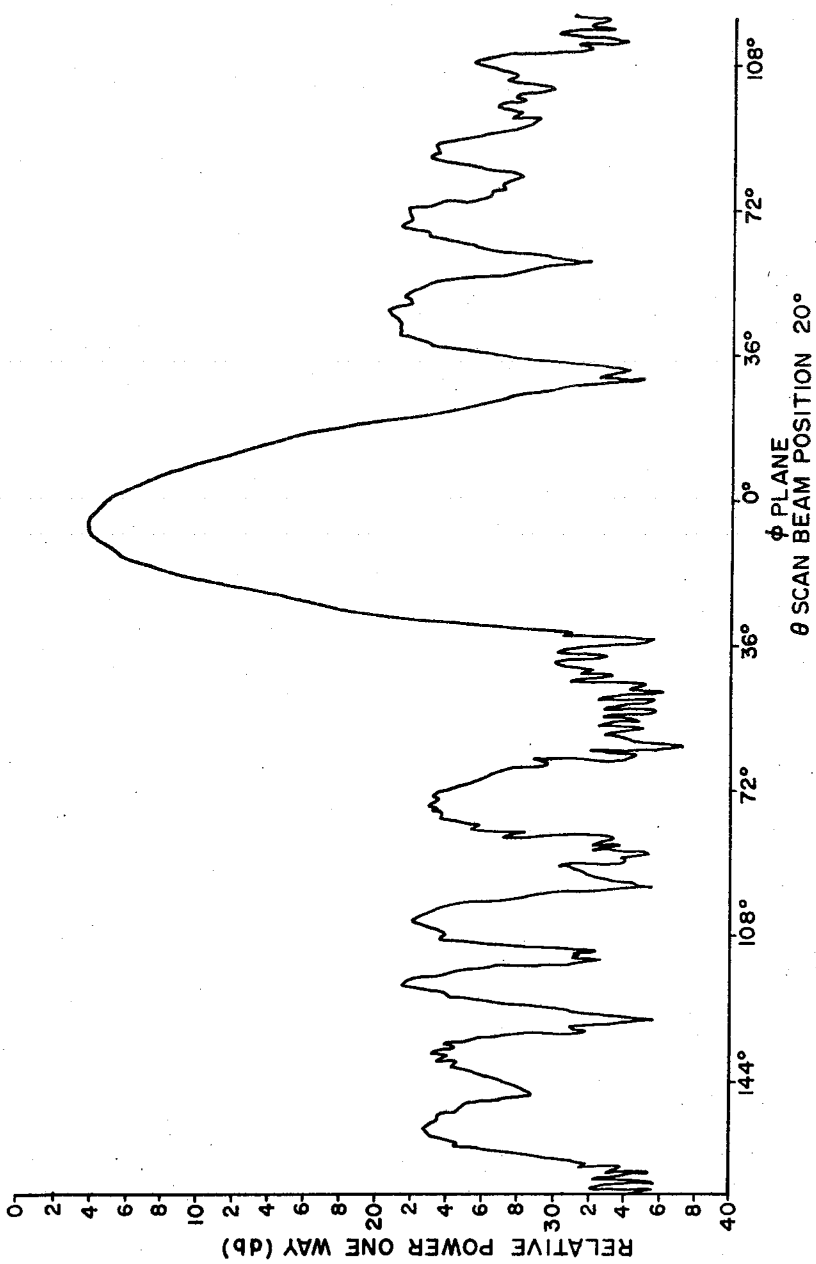

RELATIVE POWER ONE WAY (db)
0 2 4 6 8 10 2 4 6 8 20 2 4 6 8 30 2 4 6 8 40
144° 108° 72° 36° 0° 36° 72° 108°
φ PLANE
θ SCAN BEAM POSITION 20°

FIG. 8

# SCANNED CYLINDRICAL ARRAY MONOPULSE ANTENNA

## BACKGROUND OF THE INVENTION

This invention relates to monopulse antennas and more particularly to monopulse flush mounted cylindrical missile seeker antennas.

Until about 1962 no great need for a flush mounted missile seeker antenna was foreseen, primarily because no antenna scheme could be envisioned which could compete, performance wise, with a conventional flat plate antenna in a missile nose radome. About 1962 jet engine technology had advanced to the point where it was very likely that they could be used in high velocity missiles. In such a missile a flush mounted seeker antenna is imperative. More recent studies indicate that a flush mounted antenna can be used to improve missile kill probabilities in that the warhead can be placed in the missile nose where it is more effective. Considerable interest has been generated also in a flush mounted microwave missile seeker antenna through consideration of dual mode seeker systems. An example of the latter would be an X-band flush mounted antenna which would allow for placement of an infrared seeker in the missile nose.

## SUMMARY OF THE INVENTION

In the present invention two subassemblies of linear phased arrays placed longitudinally around a conduction cylinder produce a flush mounted cylindrical antenna. Each subarray has a ring feed with waveguide feed openings corresponding to openings in each linear phased array to feed same and each ring feed opening is controlled by a diode coupler that is in circuit with a switching network to control the bias on selected diode couplers to commutate a rotating group of linear phased arrays thereby producing a 360° rotation of transmitted and reflected beams of radio frequency. Each linear phased array has a pair of eccentrically rotatable dielectric slabs therein that have mechanical connections, as by gear means to a ring gear, to drive all slabs alike to phase the transmitted and reflected signals for angular direction with respect to the centerline of the cylinder. The rotatable dielectric slabs and the diode coupler switches provide a 360° beam rotation of 45° fan for both antenna arrays. The reflected signal outputs from both subarrays are coupled to a magic-T junction from which the signals are processed for sum and difference for target identification and angle tracking. It is therefore a general object of this invention to provide a flush mounted monopulse cylindrical antenna array consisting of two subarrays for missiles or other aircraft vehicles for use in enemy missile detection and destruction.

## BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and the attendant advantages, features, and uses will become more apparent to those skilled in the art as the description proceeds when considered along with the accompanying drawings in which,

FIG. 1 is an isometric view of a missile or other aircraft device illustrating the subarray items of this invention,



FIG. 2 illustrates one of the linear phased array elements making up the composite subarray items disclosing the waveguide phasing slab adjustment means,

FIG. 3 illustrates an isometric view of the phasing slabs used in the linear array of FIG. 2,

FIG. 4 shows an isometric view of the waveguide feeder ring for the subarray antenna of FIG. 1,

FIG. 5 is a block circuit schematic in the receiver component of the antenna system, and

FIGS. 6, 7, 8, and 9, illustrate the $\theta$ plane, the $\Phi$ plane, and the sum and difference graphs produced by the received signals of a target in space.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to FIG. 1 with occasional reference to FIGS. 2 and 3, there is illustrated an isometric view of a device, such as a missile 10, having a nose cone 11 and a propulsion section 12 with flush mounted subarray antenna means. A and B circumferentially about the middle portion. The subarrays A and B may be placed on any aircraft device for detecting and angle tracking a target by monopulse radar means. Each subarray A and B consists of a plurality of linear phased array sections 20 more particularly shown in FIG. 2 arranged circumferentially about the central body portion of the missile device.

The linear phased array shown in FIG. 2, and identified by the reference character 20, generally consists of a rectangular waveguide section having an inlet port 21 on one end and two rows of radiating or outlet ports 22 and 23 along one face thereof. The opposite end of the linear phased array waveguide section 20 to the inlet port 21 includes an enclosed end 24 with two gear driven eccentric slabs shown by the exterior gears 25 and 26. The waveguide slabs which extend into the linear phased array waveguide 20 are more particularly shown in FIG. 3, in the reverse direction, to more particularly illustrate the two eccentric slabs 27 and 28 extending outwardly from the end plate 24. The two gears 25 and 26, together with like gears on all other linear phased array waveguide elements 20 constituting the subarray A or the subarray B, are driven in unison by a ring gear 29. The ring gear 29 is preset with the gears 25 and 26 of all the linear phased array elements 20 to cause the radar beam to radiate at the same angle with respect to the longitudinal axis of the missile device 10 for all array elements 20. One extreme of the radar beam would be approximately in the end-fire direction which produces a beam parallel to the longitudinal axis of the missile 10. The other limit of phasing the radar beam out of the linear phased array ports 22 and 23 would be about 45° from the longitudinal center line of the missile 10, the purpose of which will be more readily understood as the description proceeds. The ring gear 29 may be driven by some motor means, herein illustrated as being an electric motor 30, which may be computer controlled or otherwise automatically controlled to phase all the linear phased arrays 20 for the same angle of transmission and reception between the limits of near end-fire and about 45°. One ring gear 29 and motor means 30 are required for each subarray A and subarray B for the purpose and in the manner to be described.

Referring more particularly to FIG. 4 there is illustrated an isometric view of a rectangular waveguide feeder ring 31 which is illustrated in FIG. 1 as the circular rings 31 between subarrays A and B. While both feeder rings 31 are shown centrally in FIG. 1, it is to be understood that these feeder rings could be on opposite ends of the subarrays A and B or on the same end of each subarray A and B, as desired. Each feeder ring is made of a plurality of rectangular feeder input sections 32 having rectangular ports 33 which are connected by bolting or otherwise affixed to the inlet end of the linear phase arrays 20 so that the rectangular ports 33 of the feeder rings are each in alignment with the rectangular inlet ports 21 of the linear phased array elements 20. Each waveguide feeder ring 31 has waveguide coupling members 34 and 35 for coupling inlet and outlet waveguide sections for the radar system, as is well understood by those skilled in the radar art. Each waveguide feeder ring 31 has a crystal 36 for each ring section 32. Each crystal 36 is coupled to a switching circuit, herein illustrated in block form by the reference character 37, to switch the radio frequency as from the inlet 34 to the port 33 in a manner to activate about one-fourth to one-third of the linear phased arrays 20 at any one time. The switching circuit 37 may be any switchable electronic switch designed, such as a commutating device, to cause the one-fourth to one-third linear phase arrays to be activated in a circularly rotating manner. As may be understood from the description in FIG. 1, each phased array A and B will be made to produce a transmitted radar beam to travel radially outwardly from the longitudinal center line of the missile at an angle set by the phased arrays shown in FIG. 2 from near end-fire to about 45° to produce a cone scan about the missile 10 forwardly through the 45° angle. Such transmitted radar signals will be reflected by any targets in the area illuminated by the transmitting signals and reflected back through the subarrays A and B to the radar system in a monopulse mode readily understood by those skilled in the radar art.

Referring more particularly to FIG. 5, a block diagram illustrates the components in the receiver section of the radar system in which the outlet, such as 35 from the subarray A, is applied as an input 40 to a thruplexer 41 while the output 35 of subarray B conducts as an input 42 to a thruplexer 43. The thruplexer 41 is coupled through a waveguide phase shifting means 44 through a second thruplexer 45 to a magic-T junction 46 while the thruplexer 43 is coupled through a waveguide phase shifter 47 and a second thruplexer to the magic-T 46. The output of the magic-T junction 46 is the waveguide output 49 to the receiving equipment of the monopulse radar system in the well known manner to produce sum and difference radar signals for use in angle target tracking of any radar target illuminated by the antenna. The thruplexers 41 and 43 are each waveguide adapters to convert rectangular mode waveguide inputs 40 and 42 into circular waveguide sections for the phase shifters 44 and 47. The thruplexers 45 and 48 are also waveguide adapters to reconvert the circular mode of the waveguide back to the rectangular mode for coupling to the magic-T junction 46. For the purpose of definition, the phasing of the radio frequency at an angle with respect to the longitudinal axis of the missile device by the slab means 27 and 28 may be referred to as the $\theta$ position, while the rotation of the radio frequency circumferentially about the missile axis may be referred to as the $\Phi$ position. The radio frequency (rf) outputs (or inputs on transmit) can be added in a conventional monopulse network to produce monopulse information in the $\theta$ direction. In antenna terminology this is a phase monopulse system in the $\theta$ plane since the monopulse beams are formed as a result of the physical space of the two cylindrical areas in this plane. The rf beams from the two subarrays A and B can be scanned together with $\theta$ direction by identically controlling the linear array scanning within each subarray by the motor control 30. To complete effective $\theta$ direction scan of the sum and difference monopulse beams, it is necessary to maintain proper phase control versus scan angle $\theta$ between the two subarrays. This is accomplished by the two phase shifters 44 and 47 although only one phase shifter may be used in either of the rf outputs from the subarrays A or B. In this way the sum and difference array factors formed by the addition or subtraction of the two subarrays A and B can be scanned in the $\theta$ direction thus completing the phase requirements for $\theta$ scan of the monopulse beam. The phase shifters 44 and 47 are preferably of a type to change the phase while in the circular mode since this is a more practical method.

FIG. 6 shows a graph of the subarray resulting radar signal from near end-fire in the $\theta$ plane starting at near 0° to about 45° giving the amplitude of the signal in decibels and the abscissa co-ordinate in degrees.

FIG. 7 illustrates the sum and difference output from the end-fire angle in the $\theta$ plane while FIG. 9 illustrates the sum and difference pattern in the $\Phi$ plane.

FIG. 8 shows the $\theta$ scan signal for the decibel output when the scan beam is 20° from end-fire in the $\Phi$ plane.

## OPERATION

In the operation of the antenna means illustrated in FIGS. 1 through 5, let it be assumed that the antenna means of FIG. 1 is coupled to a conventional monopulse radar system with the received signal coupled through a circuit as shown in FIG. 5. Either by computer means of other automatic driving means the two motors 30 and the switching circuit 37 can be made operative to cause the rf beam to traverse the angle from near end-fire of the missile to approximately 45° to the longitudinal centerline of the missile for subarrays A and B while at the same time the switch circuit 37 is energizing one-third to a one-fourth of the linear phased arrays 20 to cause antenna illumination in two full circle cones of scan by both subarray antennas A and B. The returned or reflected signals from any targets in the cones of illumination will be received through the circuit of FIG. 5 to produce sum and difference signals of the target for angle tracking of that target. The output signal on the waveguide output 49 may be used for automatically piloting the missile 10, which may include a warhead element in the nose cone 11, to seek out, track, and collide with the enemy target missile to destroy same. If the missile 10 is of the ramjet engine type, for which this invention would be particularly adaptable, it would make this missile a high velocity missile which would improve the missile kill probability in that the warhead could be placed in the missile nose where it is more effective. This flush mounting type of missile microwave seeker antenna could be used for dual mode seeker systems in which X-band frequencies could be used which would allow for the placement of an infrared or optical type seeker in the missile nose, where desired.

While many modifications may be made in rearrangement of parts as described herein to produce the same results and functions, we desire to be limited in the scope of our invention only as limited by the accompanying claims.

I claim:

1. A flush mounted cylindrical array monopulse scanning antenna comprising:

a conducting cylinder with two subsystems of linear phased waveguide arrays arranged longitudinally around said cylinder to produce a flush cylindrical monopulse antenna;

a waveguide feeder ring on one end of each subarray to feed radio frequency into and out of said array, said feeder ring having a crystal coupler for each linear phased array with all crystal couplers coupled to a switching network to activate one-fourth to one-third of adjacent linear phased arrays in a rotating manner to scan 360° around said cylinder axis;

a pair of rotatable dielectric slabs extending through each linear phased array with rotation means thereon to rotate same to vary the phase angle and the scan beam over an angle with respect to said cylinder axis;

master means in coupled co-operation with all said rotation means of said dielectric slabs to rotate same in synchronism; and

transmitting means and receiving means coupled to said waveguide feeder rings, said receiver means having means therein to obtain sum and difference of all target signals scanned by said antenna whereby said antenna is aerodynamically constructed for high speed and capable of scanning a spherical section forward thereof to identify targets for destruction.

2. A flush mounted cylindrical array monopulse scanning antenna as set forth in claim 1 wherein

said linear phased waveguide arrays each have a double row of slots with one each pair of dielectric slabs therein and one said crystal coupler for each double row of slots of the linear phased array.

3. A flush mounted cylindrical array monopulse scanning antenna as set forth in claim 2 wherein

said master means coupled in co-operation with all said rotation means of said dielectric slabs is a positive mechanical reversible driving means.

4. A flush mounted cylindrical array monopulse scanning antenna as set forth in claim 3 wherein

said receiving means includes two inputs, one coupled to each of said feeder rings, each input coupled through a first thruplexer, a phase shifter, and a second thruplexer in common to the inputs of a magic-T, the output of which provides sum and difference signals of a target.

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