United States Patent [19]

Coleman

[11] **3,754,258**

[45] **Aug. 21, 1973**

[54] **LINEAR OR PLANAR RETRODIRECTIVE ANTENNA SYSTEM**

[75] Inventor: **H. Paris Coleman,** Alexandria, Va.

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

[22] Filed: **Feb. 25, 1972**

[21] Appl. No.: **229,369**

[52] **U.S. Cl.** ..... **343/100 TD,** 343/850, 343/854

[51] **Int. Cl.** **H01q 15/14**

[58] **Field of Search** ..... 343/100 TD, 854, 343/850; 325/14

[56] **References Cited**

UNITED STATES PATENTS

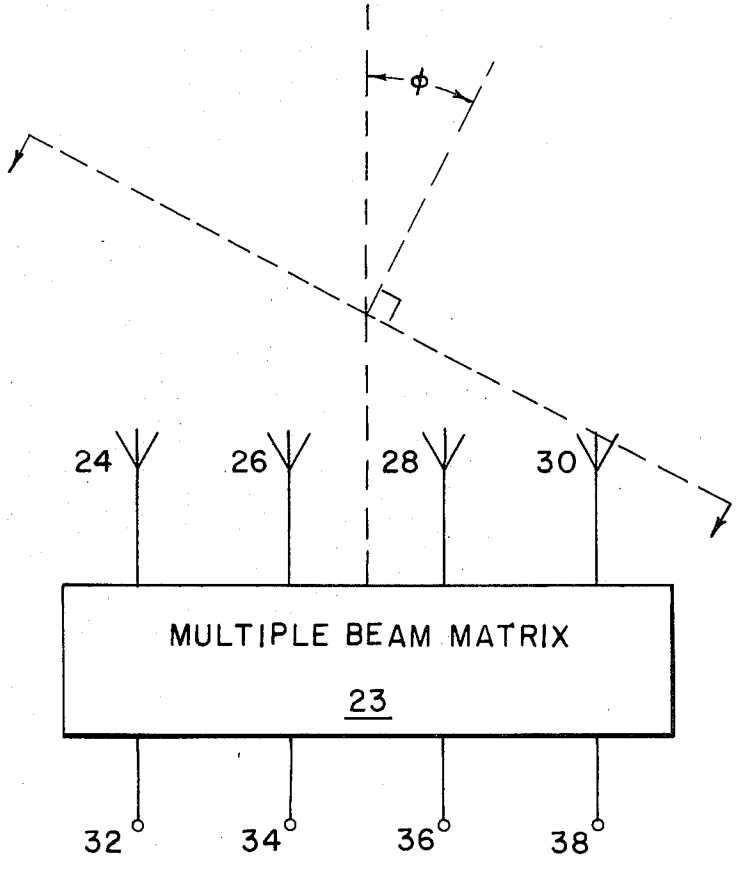
3,255,450 6/1966 Butler ..... 343/100 TD

Primary Examiner—Benajmin A. Borchelt
Assistant Examiner—Richard E. Berger
Attorney—R. S. Sciascia, Arthur L. Branning et al.

[57] **ABSTRACT**

A method and apparatus for obtaining automatic retrodirective performance from a linear or planar electromagnetic antenna array. The system may be employed in an active or passive manner and accomplishes selective retrodirectivity by the manipulation of the beam terminals on a multiple beam matrix. Also, control of the reradiated beam pattern is possible. Furthermore, this retrodirective system can also identify the angle of incidence of any particular transmission, and may therefore be employed as direction finding equipment.

6 Claims, 2 Drawing Figures



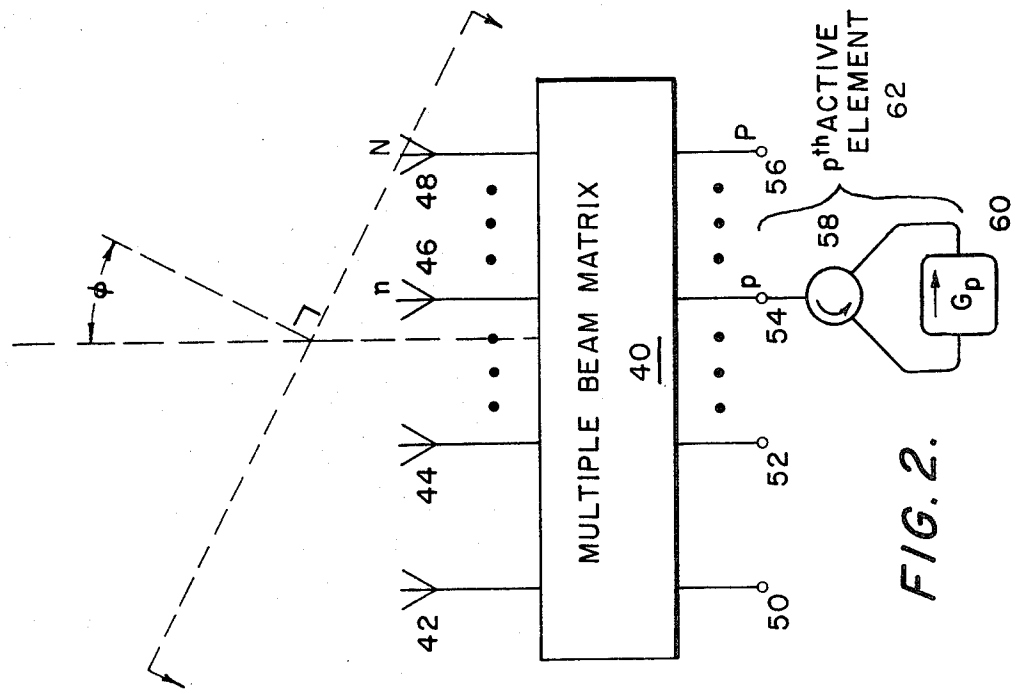

MULTIPLE BEAM MATRIX
40
N
n
P
p
42
44
46
48
50
52
54
56
58
60
62
p^{th} ACTIVE ELEMENT
G_p
φ

FIG. 2.

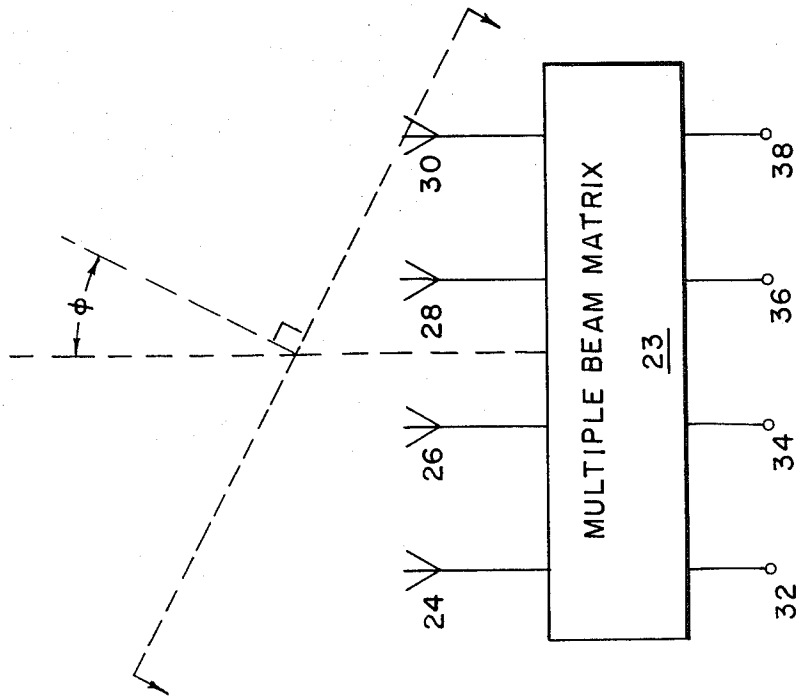

MULTIPLE BEAM MATRIX
23
24
26
28
30
32
34
36
38
φ

FIG. 1.

LINEAR OR PLANAR RETRODIRECTIVE ANTENNA SYSTEM

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

The most well known method of obtaining retrodirective beam radiation is disclosed by Van Atta, in U. S. Pat. No. 2,908,002. Van Atta discloses a linear array of elements, interconnected in a manner such that an electromagnetic beam is redirected at substantially the same angle from which it came. It has become possible to construct an active Van Atta Array but a primary disadvantage of such an array is the need for an expensive bidirectional circuit disposed in each line connecting a pair of elements. Thus, since each pair requires an individual circuit, no reduction in the number of active components are possible even when a reduced angular sector of coverage may be acceptable. Also, with the active Van Atta system no shaping of the beam in the form of beam response vs. angle of incidence is possible; and more importantly, there is no direct means which are presently available for including information regarding the angle of incidence in the return signal.

Considering such drawbacks, I have developed a linear and planar array which displays none of the disadvantageous conditions set forth above and is capable of active or passive retrodirectivity and may include information relating to the angle of incidence upon retransmission. Also, retrodirectivity may be specifically limited to a reduced angular sector if such a reduction is desirable.

SUMMARY

A number of antenna elements are arranged in the form of a linear or planar array in the usual well known manner. Each element is connected to a terminal of a multiple beam matrix. The matrix which typically may be a Butler matrix or a Blass-Lopez has the characteristics of propagating a wavefront at a particular angle depending upon the selection of that angle respective beam terminal. I have found that by open or short circuiting all of the respective beam terminals, passive retrodirectivity results, and that by open or short circuiting selected terminals, the reradiated beam may be limited to a particular angular sector. Furthermore, I have also found that active retrodirectivity may be obtained by the use of the multiple beam matrix, and that angular information can be included in the reradiated beam.

OBJECTS

It is an object of the present invention to provide a linear or planar array having automatic retrodirective properties.

Another object of the invention is to provide retrodirective performance by the use of a multiple beam matrix.

A further object of the invention is to eliminate the need for providing an active circuit for every pair of elements when retrodirectivity is limited to a reduced angular sector.

A further object of the invention is to provide information regarding the signal angle of incidence in the retransmitted beam.

Other objects of the invention will become readily apparent to those skilled in the art by referring to the following detailed description in connection with the accompanying drawings wherein like parts are similarly labeled throughout.

DRAWING

FIG. 1 shows a multiple beam matrix in conjunction with a linear array employed in the passive retrodirective array;

FIG. 2 is a diagram of the structure which provides active retrodirective performance.

DETAILED DESCRIPTION

Referring to FIG. 1, four antenna elements are shown for the purpose of illustration. The elements **24, 26 28** and **30** are arranged in a linear manner, and may be dipoles, horns, or even an array of dipoles or horns. Although the elements are shown in the form of a linear array, a planar array may also be employed to obtain retrodirectivity.

The purpose of the structure shown in FIG. 1 is to receive a wave front from a particular direction, for example ϕ, and to passively reradiate the plane wave back in the direction from which it came. To accomplish this purpose, each antenna element in the array is connected to the NXN multiple beam matrix **23** in a left to right, sequential manner. Beam terminals **32, 34, 36** and **38** are usually either all open or all short circuited and of the same electrical length so as to provide retrodirective properties. The multiple beam matrix **23** may typically be a Butler matrix or a Blass-Lopez.

Referring to FIG. 2 an active retrodirective system is shown and may be considered an extension of the structure shown in FIG. 1. Active circuits **62** are connected to selected beam terminals. Although P beam terminals are shown in FIG. 2, it is not necessary to connect an active element to each terminal. Also if there are N elements connected to the multiple beam matrix, less than N beam terminals can be employed. The active network **62** comprises any well known directional transfer device such as a circulator **58**, and an amplifier and/or frequency shifting equipment **60**, having a gain G_p. It is possible to provide individual modulation of the individual circuits **60** which is indicative of the angular information. Thus, information regarding the angle of incidence of the plane wave may be incorporated into the return signal. This arrangement results in signal amplification before reradiation takes place. Therefore, the reradiated signal in the direction of the far field source is strengthened, and the far field beam pattern may be controlled by the adjustment of the individual gain G_p.

The operation of the active circuit **62** is well known in the art, and FIG. 2 would appear to be self-explanatory. However, when a signal from a beam terminal of multiple beam matrix **40** or **23** is applied to the active circuit **62**, a circulator **58** transfers the signal to an amplifier **60**. The output of the amplifier is applied to the circulator **58**, and the resultant amplified signal is transferred to beam terminal **54** of multiple beam matrix **40**.

The retrodirective nature of the passive system can be easily realized by considering a plane wave incident

upon the antenna from a source in the direction $\phi = \phi_o$. This plane wave results in voltages appearing across the set of beam terminals such as 32, 34, 36 and 38. The voltages across the beam terminals will be proportional in amplitude and display the same relative phase that would have been required to produce a beam in the direction $\phi = \phi_o$. Since, in most cases, beam terminals are of equal electrical length and all are either open or short circuited, in the passive case, the beam terminals can be considered a set of unity reflection coefficient terminals. The set of unity reflection coefficient terminations permit incident energy to be reradiated toward the source $\phi = \phi_o$ in the retrodirective manner because of the correct amplitude and phase relationships established as a result of the original incident signal. In the active case the circuits 62 preserve the same phase relationships as the unity reflection coefficients as described above. However, the relative gain of the individual circuits may be adjusted to favor response in selectable directions. The above description applies to both linear and planar arrays.

The description so far has been limited to linear array. However, in the case of a planar array where a multiplicity of matrices are employed to provide a two dimensional "grid" of beam terminals, the retrodirective principles discussed herein equally apply. Specifically most planar arrays which provide three dimensional retrodirectivity employ two sets of multiple beam matrices. The first set of matrices is coupled to the rows of elements in the planar array, i.e., one matrix for each row. The second set of matrices is connected to the columns of beam terminals of the first set of matrices. Thus in the "grid" of beam terminals created by the second set of matrices, an individual beam terminal controls a particular beam; manipulation of the beam terminals as discussed herein will provide three-dimensional retrodirectivity for this type of planar array. Also, an inhibited response may be provided by the retrodirective system as shown in FIG. 1 or FIG. 2. For example, if it is desirable to inhibit the retrodirective response in a particular sector bounded by ϕ_1 to ϕ_2 the beam terminals which correspond to this sector may be terminated in a matched load. Under this condition a retrodirective response will be inhibited in the sector bounded by ϕ_1 and ϕ_2.

Obviously many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. A passive retrodirective antenna system comprising:
   - a plurality of linear or planar arrangement of antenna elements;
   - multiple beam matrix means having a plurality of beam terminals;
   - coupling means for coupling said antenna elements to said multiple beam matrix;
   - individual open circuits of equal electrical length connected to said plurality of beam terminals such that retrodirective performance results.

2. The system as claimed in claim 1 wherein said multiple beam matrix is a Butler matrix.

3. The system as claimed in claim 1 wherein said multiple beam matrix is a Blass-Lopez.

4. A passive retrodirective antenna system comprising:
   - a plurality of linear or planar arrangement of antenna elements;
   - multiple beam matrix means having a plurality of beam terminals;
   - coupling means for coupling said antenna elements to said multiple beam matrix;
   - individual short circuits of equal electrical length connected to said plurality of beam terminals such that retrodirective performance results.

5. The system as claimed in claim 4 wherein said multiple beam matrix is a Butler matrix.

6. The system as claimed in claim 4 wherein said multiple beam matrix is a Blass-Lopez.

* * * * *