

[54] **WIDE SCAN ANGLE ANTENNA UTILIZING
SURFACE WAVE AND MULTIPLE
ELEMENT ARRAY MODES OF OPERATION**

[75] Inventor: **Robert J. Mailloux**, Wayland, Mass.

[73] Assignee: **The United States of America as
represented by the Secretary of the
Air Force**, Washington, D.C.

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343/876**

[51] Int. Cl. **H01q 3/24**

[58] Field of Search **343/833, 730, 777, 876**

[56] **References Cited**

UNITED STATES PATENTS

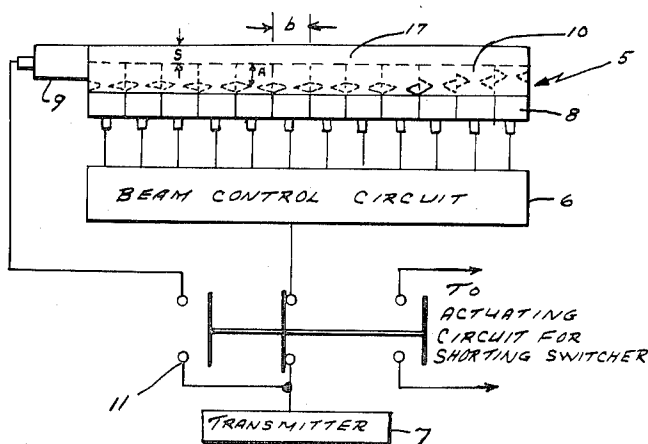
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Primary Examiner—Eli Lieberman
Attorney, Agent, or Firm—Harry A. Herbert, Jr.;
Willard R. Matthews, Jr.

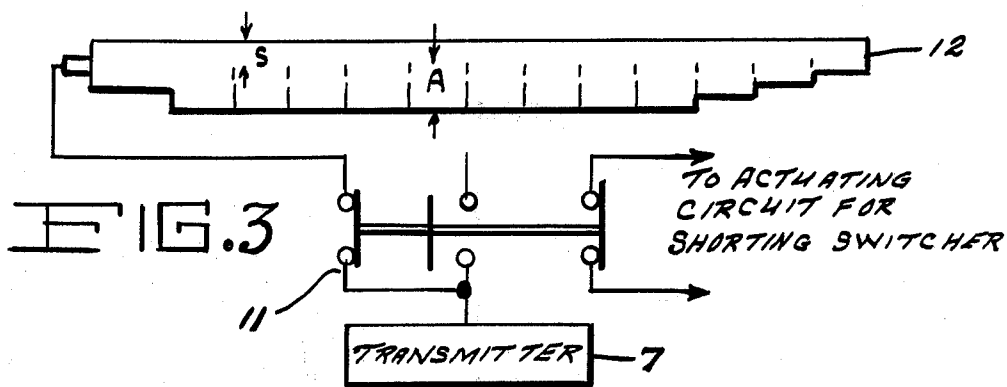
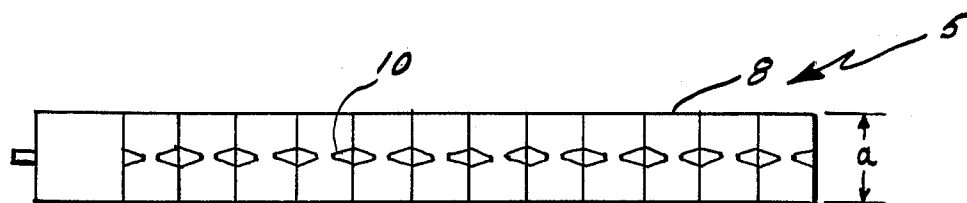
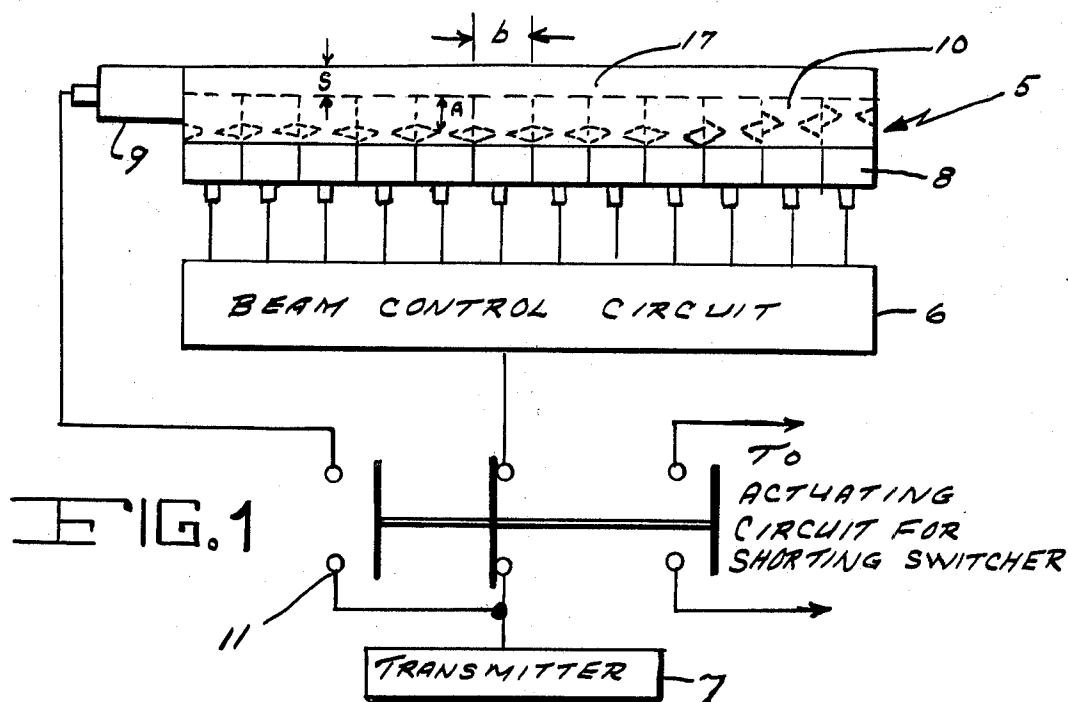
[57] **ABSTRACT**

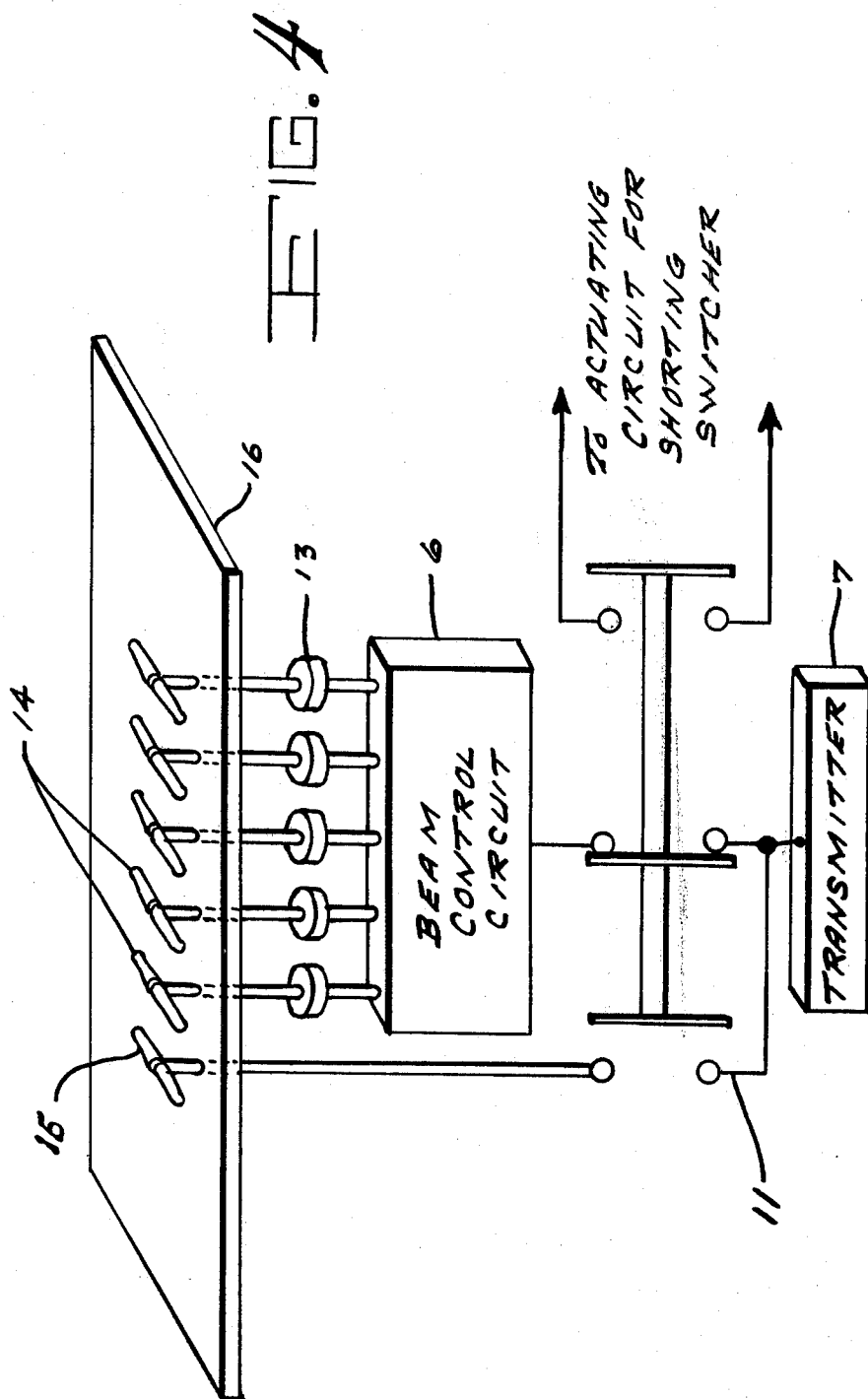
An antenna capable of 180° scan with improved gain characteristics at end-fire is realized by combining multiple element array and surface wave antenna structures. An end-fire feed element is positioned to radiate along a column array of antenna elements. A transmitter is switched to feed either the end-fire feed elements or the column array of antenna elements and the column array antenna elements are short circuited during end-fire operation.

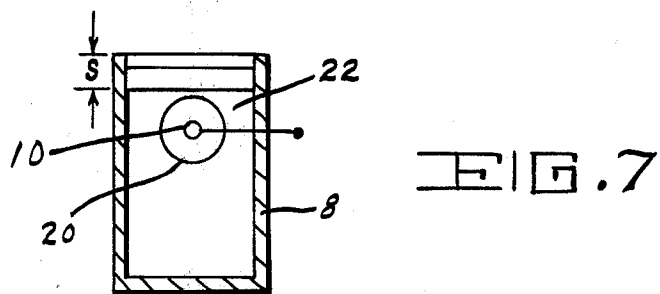
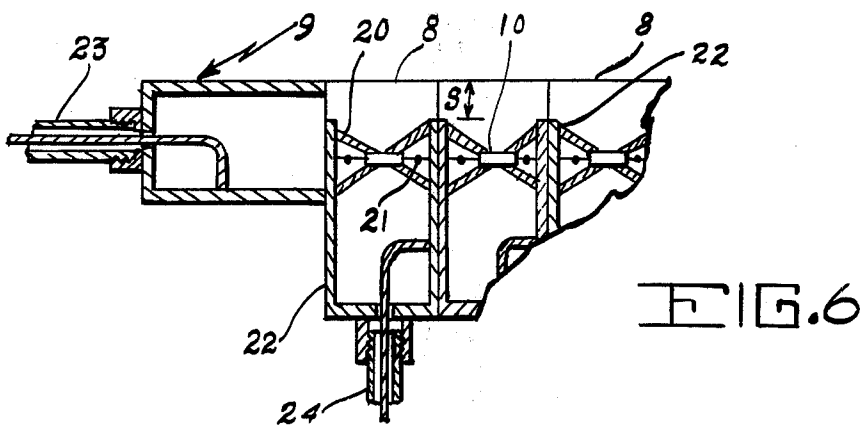
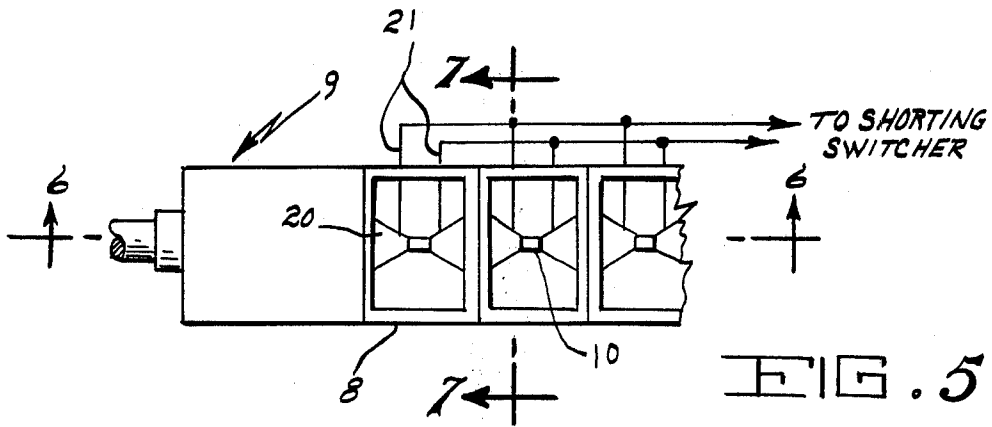
1 Claim, 7 Drawing Figures



SHEET 1 OF 3







WIDE SCAN ANGLE ANTENNA UTILIZING SURFACE WAVE AND MULTIPLE ELEMENT ARRAY MODES OF OPERATION

BACKGROUND OF THE INVENTION

This invention relates to electronically scanned antenna arrays and end-fire antennas, and in particular to the combination of such arrays with means for changing between multiple element array and end-fire modes of operation.

It is often desirable to achieve hemispherical coverage with electronically scanned antenna arrays. The communication system between an aircraft and a satellite requires this type of coverage. Conventional phased arrays, however, suffer seriously decreased efficiency when scanned to regions near end-fire. For example, typical results for arrays on cylinders show gain reductions of 5 to 7 db at end-fire compared with broadside radiation for arrays with between 20 and 30 db broadside gain. Although selectively switching to an end-fire mode of operation as the scan approaches horizontal theoretically improves the situation, simply adding the necessary surface wave structure to the phased array will not provide a practical solution. This is because integrating the two structures results in excessive amounts of energy being transmitted in a large side lobe at end-fire. There currently exists, therefore, the need for a low-cost, efficient electronically scanned antenna having good gain characteristics throughout a 180° scan range. The present invention is directed toward achieving this end.

SUMMARY OF THE INVENTION

The present invention comprehends the use of a dual mode radiating structure consisting of a conventional waveguide phased array and the added feature that each waveguide can be short circuited to form a corrugated surface for end-fire radiation. The phased array is therefore used over a wide angle scanning range, but is not required to provide radiation at end-fire. End-fire radiation is provided by exciting the short circuited corrugated structure with a separate waveguide feed. A second major embodiment of the invention comprises an array of dipole antenna elements which are short circuited and switched to a conventional yagi array for end-fire mode operation.

It is a principal object of the invention to provide a new and improved wide scan angle phased array antenna system.

It is another object of the invention to provide an electronically scanned antenna that is capable of hemispherical coverage with improved gain characteristics at end-fire.

It is another object of the invention to provide a composite multiple element array and surface wave antenna structure that transmits efficiently in both phased array and end-fire modes of operation.

These, together with other objects, features and advantages of the invention will become more readily apparent from the following detailed description when taken in conjunction with the illustrated embodiments in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of an embodiment of the invention utilizing waveguide type antenna radiating elements;

FIG. 2 is a top view of the structure illustrated in FIG. 1;

FIG. 3 illustrates the equivalent structure for the surface wave mode of operation of the embodiment of FIG. 1;

FIG. 4 is an isometric illustration of an embodiment of the invention utilizing dipole type antenna radiating elements;

FIG. 5 is a detailed partial top view of the embodiment of FIG. 1;

FIG. 6 is a sectional view of FIG. 5 taken at 6—6; and

FIG. 7 is a sectional view of FIG. 5 taken at 7—7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

One presently preferred embodiment of the invention is illustrated by FIGS. 1 and 2. Having reference thereto, electromagnetic wave power from transmitter 7 is coupled by means of switch 11 to antenna structure 5 through either beam control circuit 6 or end-fire feed element 9. Antenna structure 5 comprises a column array of waveguide antenna radiating elements 8 that are inserted through the bottom wall of waveguide member 17. The top wall of waveguide member 17 is removed to provide a channel type corrugated radiating structure. Alternatively, contiguously arrayed waveguide antenna radiating elements 8 could be provided with appropriate sheet metal side walls to effect an equivalent structure. Each waveguide antenna radiating element 8 is provided with a short circuiting device 10 positioned to short circuit the waveguides at the same point a distance A from the end of each waveguide. Short circuiting device 10 can be waveguide shutters, diodes, or other conventional means. They are put in a closed or short circuiting condition by means of an actuating circuit (not shown) and switch 11 when end-fire feed element 9 is coupled to transmitter 7. Beam control circuit 6 can be a multiple beam forming network or, if electronic scanning is desired, it can comprise the power dividers and phase shifters of a conventional phased array antenna. FIGS. 5, 6 and 7 illustrate the details of a structural arrangement that gives effect to the embodiment of the invention illustrated in FIG. 1. The waveguide antenna radiating elements 8 are contiguously aligned to form a row of elements as shown. The sidewalls 22 of each of these antenna radiating elements can be cut down an appropriate amount S as hereinafter indicated. The short circuiting device 10 in this particular example can be diodes that are connected across each radiating element 8 and affixed thereto by means of holding members 20. Bias voltage for the diode is supplied from the shorting switcher via leads 21. Each antenna radiating element 8 is fed by a coaxial cable 24. End fire element 9 can be a conventional waveguide feed of the type illustrated. It is fed by coaxial cable 23. Coupling of coaxial cables 23 and 24 to their respective waveguide elements is accomplished in the conventional manner.

In the end-fire mode of operation all waveguides of the array are shorted by their short circuitry devices and switch 11 is positioned to divert all the power into the single waveguide end-fire feed element to excite the corrugated structure. The entire antenna is now equivalent to the equivalent structure 12 shown in FIG. 3 and comprises only a single excited element and a set of corrugated plates mounted across the waveguide channel antenna. The propagation constant of the sur-

face wave antenna can be fixed by adjusting the channel width a , the corrugation spacing b , and the distances A and S . The structure can be tapered at its end to improve the radiation characteristics by modifying the short circuiting device positions in the manner shown in FIG. 1.

Alternatively, the antenna radiates in a scanned mode when the switch 11 is positioned to pass all the power through the beam control circuit and the short circuiting device in the waveguide are deactivated. In this mode of operation the structure behaves as a column array and can be used as a scanned array or a multiple beam array depending upon the beam forming technique. One important feature of this mode of operation is that when used with the shutters open, the structure does not support an end-fire surface wave. Consequently, the radiation pattern for each element of the array will be a smooth function of the elevation angle. Furthermore, the spacing b must be less than a half wavelength in order for the surface wave antenna to work. This spacing also leads to smooth element patterns for the scanned array mode of operation.

A second embodiment of the invention is illustrated by FIG. 4. This embodiment comprehends an array of dipole radiating elements 14 and a dipole end-fire feed element 15 protruding through ground plane 16. Dipole radiating elements 14 are provided with shorting switches 13. Operation is identical with that described

above with the dipoles becoming a conventional yagi array in the end-fire mode of operation.

While the invention has been described in presently preferred embodiments, it is understood that the words which have been used are words of description rather than words of limitation and that changes within the purview of the appended claims may be made without departing from the scope and spirit of the invention in its broader aspects.

What is claimed is:

1. A wide scan angle antenna comprising a multiplicity of antenna radiating elements arranged in a column array, an end-fire antenna feed element positioned adjacent to one end of said column array and directed to transmit electromagnetic wave energy therealong, a source of electromagnetic wave energy, short circuit means for short circuiting each antenna radiating element of said column array, and a switching circuit for engaging said source of electromagnetic wave energy either to said column array radiating elements or to said end-fire antenna feed element, said switching circuit being adapted to actuate said short circuit means only when said source of electromagnetic wave energy is engaged to said end-fire antenna feed element.

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