

[72] Inventors **William Emory Rupp**  
**Glen Arm;**  
**Richard Monroe Cox, Baltimore, Md.;**  
**Robert Alexander Keough, York, Pa.**

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[73] Assignee **The Bendix Corporation**

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*Primary Examiner*—Eli Lieberman  
*Attorneys*—Plante, Arens, Hartz, Smith & Thompson and  
 Bruce L. Lamb and William G. Christoforo

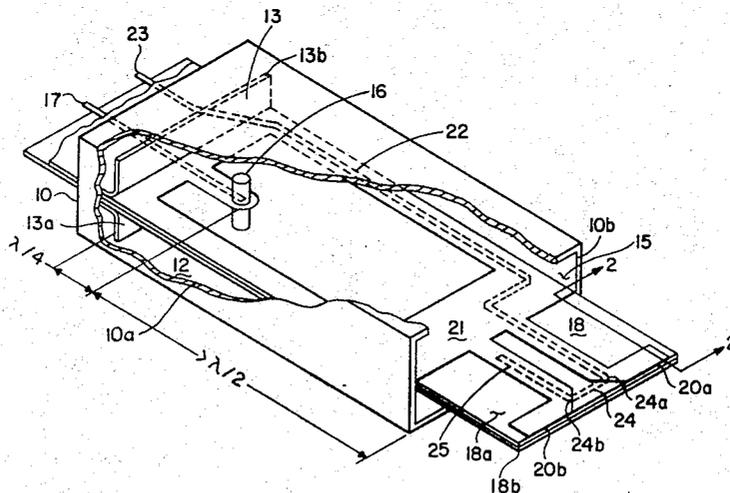
[54] **COMBINED DIPOLE AND WAVEGUIDE  
 RADIATOR FOR PHASED ANTENNA ARRAY**  
 5 Claims, 7 Drawing Figs.

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 343/768, 343/772, 343/821, 343/854, 333/84 M

[51] Int. Cl..... **H01q 3/26,**  
 H01q 21/00

[50] Field of Search..... **343/727,**  
 730, 756, 772, 821, 822, 853, 854; 333/84 M

**ABSTRACT:** An antenna includes a waveguide slot aperture radiator and a dipole radiator centrally located therein and located longitudinally with respect to the waveguide a quarter wavelength from the aperture. Each radiator is separately excited.



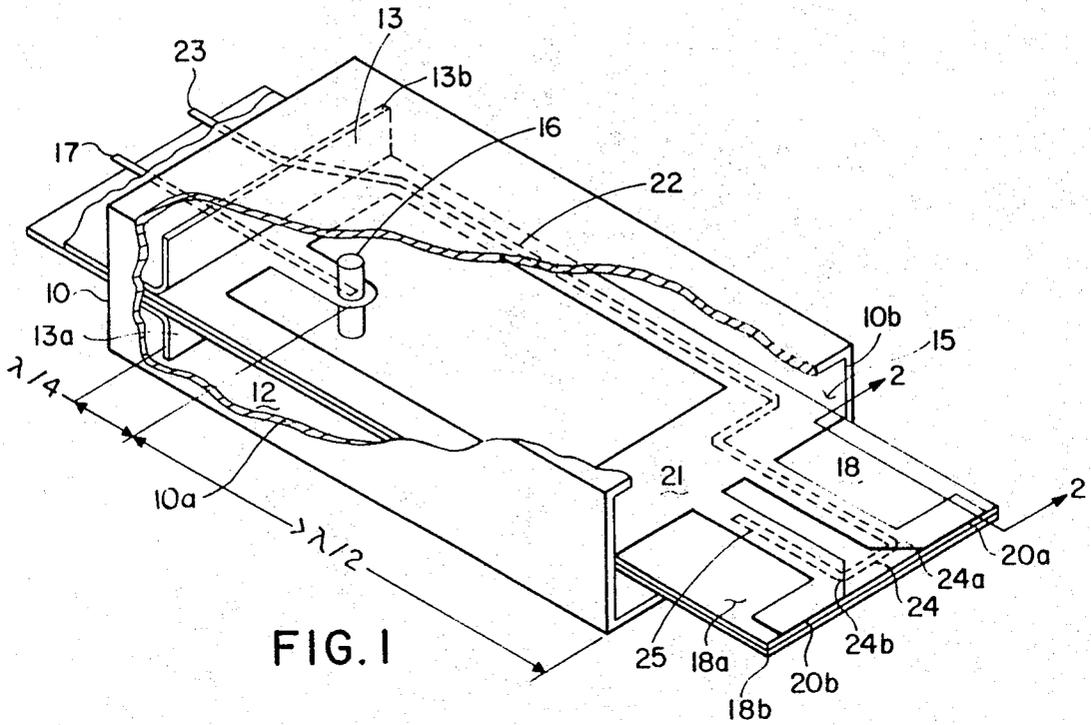


FIG. 1

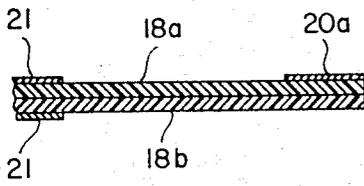


FIG. 2

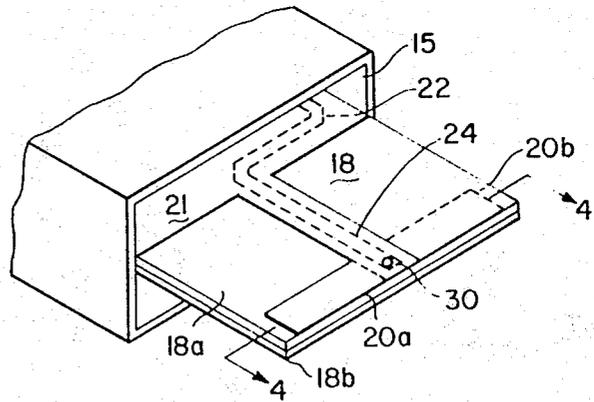


FIG. 3

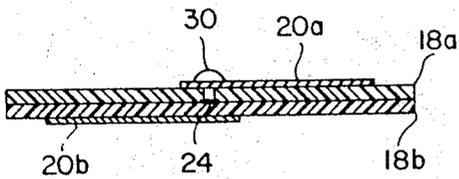


FIG. 4

INVENTORS  
WILLIAM E. RUPP  
RICHARD M. COX  
ROBERT A. KEOUGH

BY  
*William G. Christoforo*  
ATTORNEY

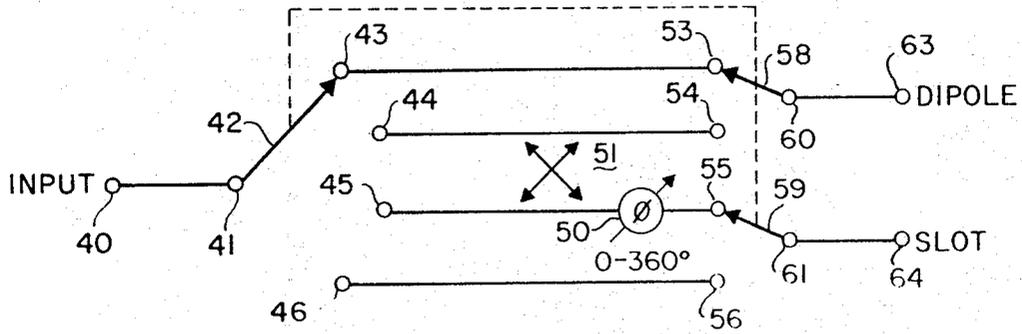


FIG. 5

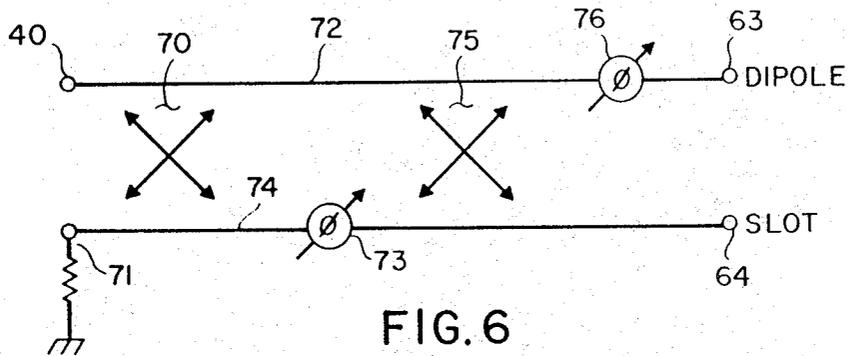


FIG. 6

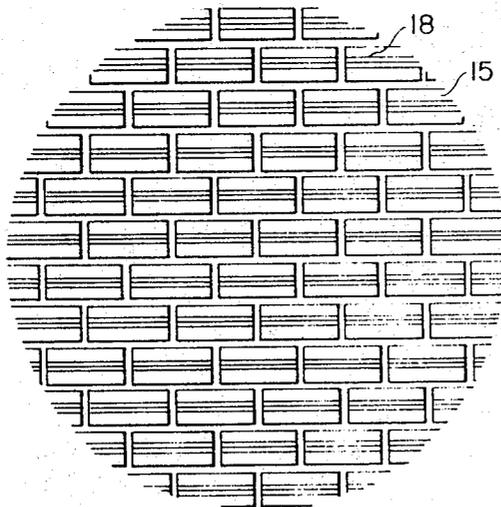


FIG. 7

INVENTORS

WILLIAM E. RUPP  
RICHARD M. COX  
ROBERT A. KEOUGH

BY  
*William J. Christoforo*  
ATTORNEY

# COMBINED DIPOLE AND WAVEGUIDE RADIATOR FOR PHASED ANTENNA ARRAY

## BACKGROUND OF THE INVENTION

This invention relates to radar antennas and more particularly to radar antennas employing a slot radiator and an orthogonally placed dipole excited from a source separate from the slot radiator source.

It is well known that the fields radiated by a slot antenna and a dipole or loop antenna are linearly polarized and that, fortuitously, when the long dimensions of these antennas are aligned their fields are orthogonal and complementary so that the combination can produce elliptical or circularly polarized fields. This phenomenon has been advantageously employed by positioning the dipole or loop radiating element generally in the slot antenna aperture in the neutral plane of the aperture, parasitically feeding the dipole or loop from the slot. Actually, in order for dipole or loop elements to be parasitically fed, they must be tilted with respect to neutral plane of the aperture, thus resulting in some distortion of the combined complementary radiated fields. Additionally, although parasitic excitation will produce good circular polarization along the beam axis of the antenna, when coverage is necessary far from the beam axis, as is the case when an antenna is used as an element in an electronically steered array, controllable polarization can only be produced if the two component antenna elements have superimposed phase centers. The superposition of antenna element phase centers is not generally compatible with the parasitic excitation of one of the elements since efficient parasitic excitation requires the two elements to be closely coupled, that is, the dipole must be located in or very close to the plane of the slot while superimposed phase centers are obtained when the dipole is located approximately a quarter wavelength out of the slot. Thus, it will normally be found to be impossible to obtain both superimposed phase centers and orthogonal fields using a slot antenna in combination with a parasitically fed dipole or loop.

## SUMMARY OF THE INVENTION

It is an object of this invention to provide a simple antenna which will provide a circularly polarized field even when electronically steered off bore sight.

It is another object of this invention to provide an antenna comprised of orthogonally placed slot and dipole antenna elements having a common phase center and capable of radiating a circularly polarized field.

It is another object of this invention to provide an antenna of the type described which is capable of selectively radiating either right- or left-hand circularly or elliptically polarized fields or horizontal or vertical linearly polarized fields.

It is still one more object of this invention to provide an antenna of the type described which is of a physical form readily adaptable for use as a single antenna in an antenna array.

These and other objects of the invention are accomplished by the use of a waveguide slot aperture antenna with a separate dipole antenna element located on the neutral axis of the slot and displaced from the slot approximately one-quarter wavelength. A selectable switching means permits the ratio of slot-radiated power versus dipole-radiated power to be infinitely variable, that is, the antenna selectively can be made to radiate a horizontally polarized field, a circularly polarized field of either right- or left-handed rotation, or an elliptically polarized field of any desired eccentricity and of either right- or left-hand rotation.

The longitudinal axis of the waveguide is disposed in the direction of field propagation with an open end of the waveguide comprising the slot antenna. This configuration permits a plurality of antennas to be arranged adjacent to one another to form an antenna array with minimum interantenna spacing.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cutaway view showing the construction of an antenna made following the teaching of this invention.

FIG. 2 is a sectional view taken along line 2—2 of Fig. 1.

FIG. 3 shows an alternate form of the invention.

FIG. 4 is a sectional view taken along line 4—4 of Fig. 3.

FIG. 5 is a schematic of a switching means used to distribute power to the various elements of the antenna.

FIG. 6 is a schematic of a control means which can be used to distribute power to the various elements of the antenna.

FIG. 7 shows how a plurality of antennas can be stacked to form an antenna array.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings wherein like reference numerals refer to like elements and referring more particularly to Fig. 1, there is shown a section of waveguide 10, cutaway to better show the internal construction of the antenna. The internal volume of the waveguide together with the waveguide-shortening plate 13 which includes plates 13a and 13b comprise a waveguide section 12. The end of the waveguide opposite shorting plate 13 is opened and comprises slot aperture antenna element 15. A waveguide probe feed 16 is connected to a source (not shown) of signal frequency suitable for propagation within waveguide section 12 via conductive stripline track 17 which in this embodiment is conveniently located sandwiched between printed circuit boards 18a and 18b. Probe feed 16 is located a quarter wavelength from waveguide-shortening plate 13 and approximately one-third of the distance along the waveguide transverse axis from waveguide side plate 10a to waveguide side plate 10b to thus excite waveguide section 12 in a manner well known to those skilled in the art. The waveguide length along the waveguide longitudinal axis from slot aperture 15 to waveguide probe feed 16 is at least one-half wavelength. These dimensions permit a well-defined waveguide mode to be established, resulting in the radiation of predictable waves from slot aperture 15.

A board assembly 18 comprised of printed circuit boards 18a and 18b arranged in a sandwiched configuration, is located on the neutral axis of the waveguide. Printed circuit board 18a has deposited thereon by stripline techniques the dipole antenna comprised of elements 20a and 20b connected at their bases to ground plane 21. Printed circuit board 18b also includes a ground plane 21 on its exterior face, but does not include the dipole elements 20a and 20b, these elements being only present on printed circuit board 18a. Referring now also to Fig. 2 it can be more clearly seen that the dipole elements, for example, element 20a, appear only on the exterior face of printed circuit board 18a while ground planes 21 appear on the exterior faces of both printed circuit boards 18a and 18b. Returning to Fig. 1 it should be noted that the ground planes 21 terminate at and are in electrical contact with the waveguide walls 10a and 10b at the slot aperture 15. A dipole feed line 22 having an input end 23 is sandwiched between printed circuit boards 18a and 18b and includes a balun 24, similarly sandwiched between boards 18a and 18b and which, in superposition, bridges dipole elements 20a and 20b but is separated therefrom by the thickness of printed circuit board 18a. The opposite end of balun 24 is connected to the quarter wavelength stripline section 25 which terminates in an open circuit. This short circuits one end 24a of the balun to dipole element 20a and the other end 24b of the balun to dipole elements 20b and additionally balances the currents flowing in the dipole elements. The dipole, as previously mentioned, is located on the neutral axis of the slot aperture and displaced from the face of slot aperture 15 so that the phase center of the dipole coincides with the phase center of the slot aperture. This will be found to be approximately one-quarter wavelength. Additionally, since the dipole is located directly on the neutral axis of the waveguide the fields within waveguide section 12 and radiated by slot aperture 15 cannot excite the dipole.

Referring now to Fig. 3, there is seen an alternate embodiment of the invention. That portion of the antenna not shown, that is, the portion of the antenna on the waveguide side of slot aperture 15, is identical to that shown in Fig. 1. In Fig. 3 dipole

element 20a is laid on the outer surface of printed circuit board 18a while dipole element 20b is laid on the outer surface of printed circuit board 18b. It should be obvious that with this arrangement, printed circuit board 18a is identical to printed circuit board 18b thus permitting substantial production savings, especially if a large number of antennas is to be fabricated. The dipole feed line 22, as before, is sandwiched between ground planes 21 and includes as a termination balun 24 which is connected by conductive pin 30 to dipole element 20a. Referring now also to Fig. 4, there is seen in cross section how the end of balun 24 is connected by pin 30 to dipole element 20a but not connected to dipole element 20b. As before, the dipole is spaced approximately a quarter wavelength away from the slot aperture so that the phase centers of the dipole element and the slot aperture antenna element coincide.

Referring now to Fig. 5, there is seen a switching means which can advantageously be used with the above-described antennas. The switching means is comprised of input terminal 40 which is connected to a source of radar signals (not shown), and output terminal 63 which is connected to the dipole feed input 23 of Fig. 1 and an output terminal 64 which is connected to the waveguide input feed terminal 17 of Fig. 1. The switching means also comprises switch arm 42 which selectively connects terminal 41 to terminal 43, 44, 45 or 46, and switch arm 58 which connects terminal 60 to terminals 53 and 54 and switch arm 59 which selectively connects terminal 61 to terminals 55 or 56. The switching means also comprises adjustable phase-shifter 50 and quadrature hybrid 51. The switch arms 42, 58 and 59 are ganged together in such a manner that when switch arm 42 is in the position shown, switch arm 58 is also in the position shown, and when switch arm 42 is connected to either terminal 44 or 45, switch arm 59 is in the position shown and switch arm 58 connects with terminal 54, and when switch arm 42 connects to terminal 46 switch arm 59 connects to terminal 56.

With the long axis of the antenna horizontal and the switching means in the position shown, that is, switch arm 42 connected between terminals 41 and 43 and switch arm 58 connected between terminals 53 and 60, input terminal 40 is connected directly to output terminal 63 so that only the dipole radiating elements are energized and the antenna will radiate only a horizontal linearly polarized field. If switch arm 42 is moved so that terminal 41 is connected to terminal 46 and terminal 56 is connected to 61 all the input power will go through the slot aperture so that the antenna will radiate a vertical linearly polarized field. With terminal 41 connected to either terminal 44 or 45, the input power will be split between the dipole- and slot-radiating elements in accordance with the setting of phase-shifter 50. If zero phase shift is introduced, power will be split evenly between the dipole and slot aperture resulting in a circularly polarized radiated field. As the phase shift introduced by phase-shifter 50 is increased, the field will become elliptical with increasing eccentricity. Of course, the sense of circular polarization, that is either right- or left-hand circular polarization, depends upon whether terminal 41 is connected to terminal 44 or 45.

Referring to Fig. 6 there is seen the schematic of control means which can be used in place of the switching means of Fig. 5 to distribute power to the antenna elements. As before, a source of radar signals (not shown) is connected to input terminal 40, and output terminal 63 is connected to the dipole feed input 23 of Fig. 1 and output terminal 64 is connected to the waveguide input feed terminal 17 of Fig. 1. The control means additionally comprises hybrids 70 and 75, adjustable phase-shifters 73 and 76 and termination impedance 71. Signal power applied to terminal 40 is split equally by hybrid 70 onto lines 72 and 74. If no phase shift is introduced by phase-shifter 73, signal power will be recombined by hybrid 75 so that all the signal power will appear at terminal 64. In this case, since only the slot antenna is excited, the resultant radiated field will be linearly polarized. If a 180° phase shift is introduced by phase-shifter 73, hybrid 75 will recombine the signal power so that it all appears on terminal 63. In this case,

only the dipole antenna is excited with the resultant radiated field being rotated 90° with respect to the slot radiated field. If no phase shift is introduced by phase-shifter 76, a linear field whose orientation varies in accordance with the phase shift introduced by phase-shifter 73 will be radiated by the antenna. If phase shift is now introduced by phase-shifter 76 the radiated field will become elliptical with an eccentricity dependent upon the setting of phase-shifter 76 and a major axis orientation generally dependent upon the setting of phase-shifter 73. In the limiting case a circularly polarized field of either rotation can be radiated.

Referring now to Fig. 7 there is seen a portion of an antenna array comprised of the aforementioned antennas. In particular, a slot aperture 15 and the card assembly 18 on which is laid the dipole are indicated for one of the antennas. The close spacing of the antennas can readily be seen and it should be obvious that in addition to the staggered array as shown the antennas can also be stacked in other configurations, for example, in regular rows and columns. The means for phase steering an array of the type shown would be identical to the means used to steer a conventional array and should be obvious to one skilled in the art.

The invention claimed is:

1. An antenna for radiating a predetermined frequency comprising:

a rectangular waveguide having one closed end and an open end comprising a slot aperture;

a printed circuit board sandwich assembly having top and bottom exterior surfaces, said assembly being disposed on the neutral axis of said waveguide and having a first end on which is disposed a strip line dipole antenna element, said first end being displaced out of said waveguide from said slot aperture so that the phase centers of said slot aperture and said dipole coincide, said assembly additionally including first and second ground planes disposed on said top and bottom exterior surfaces respectively within said waveguide and stripline means connecting said dipole element to said ground planes;

waveguide end plate means for closing the end of said waveguide opposite said slot aperture, said end plate means having an opening coinciding with the neutral axis of said waveguide through which said printed circuit board assembly is disposed;

first means located within said waveguide for exciting said waveguide;

first conductor means extending from said first means along a path between said ground planes and through said end plate opening;

second means for exciting said dipole antenna element located in close proximity to said dipole antenna element, and,

second conductor means extending from said second means along a path between said ground planes and through said end plate opening.

2. An antenna as recited in claim 1 wherein said dipole antenna element is displaced approximately one-quarter wavelength out of said waveguide.

3. An antenna as recited in claim 1 with additionally:

a source of predetermined frequency;

an input terminal connected to said source;

first and second output terminals;

means for splitting said predetermined frequency into first and second signals and applying said signals to said first and second output terminals respectively;

means connected between said first output terminal and said first conductor means; and,

means connected between said second output terminal and said second conductor means.

4. An antenna as recited in claims 3 with additionally:

means for selectively and exclusively connecting said input terminal to said first output terminal; and,

means for selectively and exclusively connecting said input terminal to said second output terminal.

5. An antenna as recited in claim 3 with additionally phase-shifter means for shifting the phase of one of said first and second signals.

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