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ANTENNA SCANNING SYSTEM

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FIG. 1

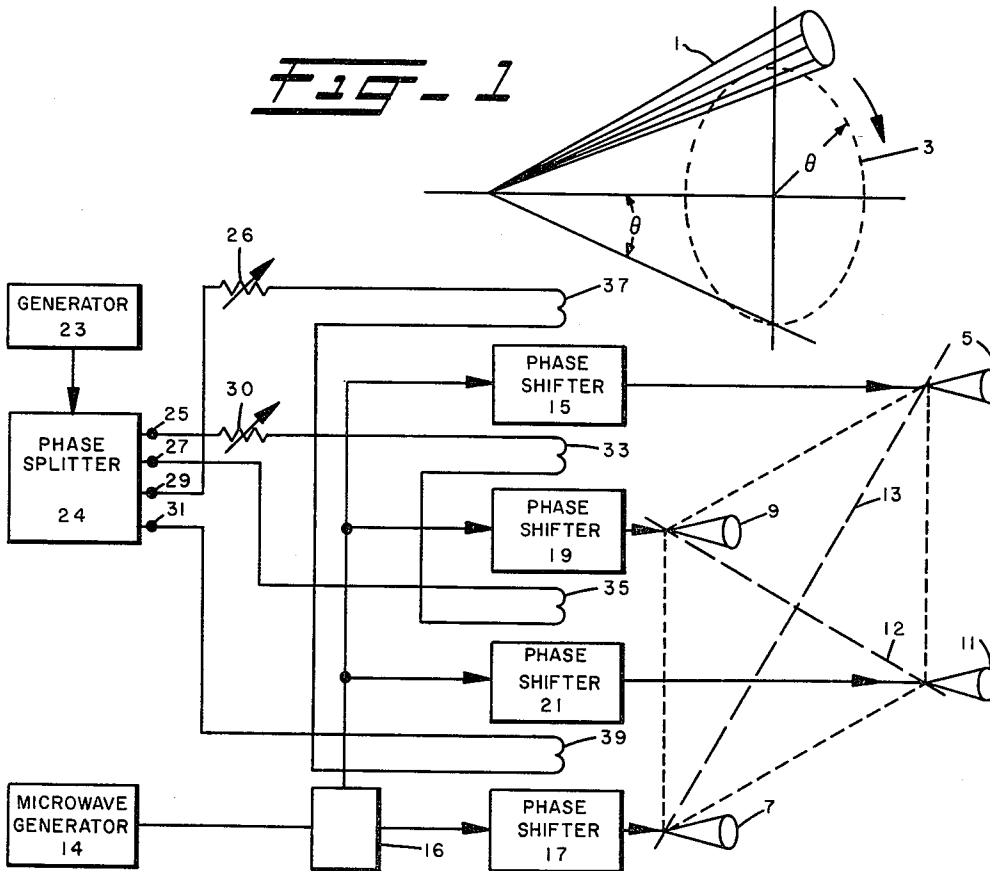


FIG. 2

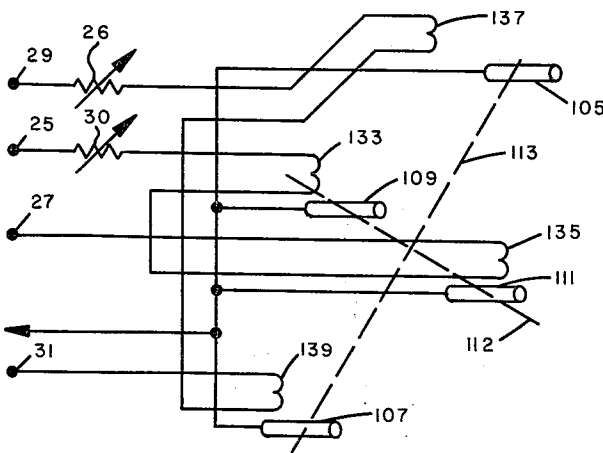


FIG. 3

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ANTENNA SCANNING SYSTEM

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This invention relates to volume scanning antennas suitable for radiating microwaves and more particularly to high speed volume scanning microwave antennas.

Volume scanning microwave antennas in use, heretofore, relied on either mechanical or electro-mechanical means for rotating the radar beam and therefore were limited to relatively low scanning rates. Furthermore, the physical motion imparted to the antenna and its associated feed lines introduced errors and operating limitations which in turn limited the uses to which such antennas might be put and their effectiveness generally.

One object of this invention is to provide a volume scanning antenna which is electronically operated and has no functionally moving parts.

Another object of the invention is to provide a volume scanning antenna having a high scanning rate.

Yet another object of this invention is to provide an electronic volume scanning antenna system which will scan different shaped volumes and may be converted from one to another easily and quickly and without the need for mechanical changes.

A further object of the invention is to provide a high speed conical scan antenna having constant scan rate, scan angle, beam shape and width throughout its entire operating cycle.

Another object of the invention is to provide a conical scan antenna, the scan rate of which may be varied quickly and easily.

The invention contemplates a volume scanning microwave antenna comprising a predetermined array of microwave radiators, means connected to said radiators for coupling the radiators to a microwave generator and arranged to continuously vary, in a predetermined manner, the phase between the radiators to provide a beam scanning a predetermined volume.

The foregoing and other objects and advantages of the invention will appear more clearly from a consideration of the specification and drawings wherein several embodiments of the invention are described and shown for illustration purposes only.

In the drawings:

FIGURE 1 is a representation of one desired beam pattern;

FIGURE 2 is a schematic diagram of a volume scanning antenna constructed in accordance with the invention; and

FIGURE 3 is a schematic diagram of a modification of the system shown in FIG. 2.

In FIG. 1 a conical pattern is shown. A beam 1 of constant shape and width in any given transverse plane, revolves around a circular path 3 and defines a cone having a half angle θ . Angle θ remains constant and the beam rotates at a constant velocity to provide a constant scan rate.

The circuit shown in FIG. 2 has four identical horn radiators 5, 7, 9 and 11 in a square array and mounted on a plane which contains intersecting dashed lines 12 and 13. Radiators 5, 7, 9 and 11 are connected to a microwave generator 14 through ferrite phase shifters 15, 17, 19 and 21, respectively, which may be similar to that shown in U.S. Patent No. 2,787,765 to Fox issued April 2, 1957. A power divider circuit 16 is inserted between the generator 14 and the radiators to provide uniform distribution of the power.

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A generator 23 is connected to a variable phase splitter 24, which supplies two outputs of the same amplitude and frequency but displaced from each other in phase by 0-180° on terminal pairs 25, 27 and 29, 31. Generator 23 is of the variable frequency type and the beam scanning rate may be varied by varying the frequency of generator 23 as will be pointed out in detail later.

A control coil 33 associated with ferrite shifter 19 is connected in series with a control coil 35 associated with ferrite shifter 21 and both are connected across terminals 25, 27. Coils 33 and 35 are so wound and connected that the magnetic fields, induced by the current there-through, are 180° out of phase with each other and therefore cause the phase difference between the signals through ferrite shifters 19 and 21 to vary continuously. In a similar manner a control coil 37 associated with ferrite shifter 15 is connected in series with a control coil 39 associated with ferrite shifter 17 and both are connected across terminals 29, 31 of phase splitter 24. Coils 37 and 39 are so wound and connected that the magnetic fields, induced by the current there-through, are 180° out of phase with each other and cause the phase difference between the signals through ferrite shifters 15 and 17 to vary continuously. Variable attenuators 26 and 30 are connected in series with windings 37, 39 and windings 33, 35, respectively, and may be adjusted to control the peak value of the excitation currents through windings 37, 39 and 33, 35 respectively. Windings 33, 35, 37 and 39 are identically wound and the 180° field phase reversal is secured by connecting the windings of each pair oppositely as shown in the drawings.

In order to illustrate the operation of the device for a conical volume scan, attenuators 26 and 30 must be set to provide identical peak currents through control windings 33, 35, 37 and 39 and phase splitter 24 is adjusted to provide outputs which are displaced from each other in phase by 90°. Furthermore, assuming that radiators 5 and 7 only are radiating and that the phase difference between the radiated signals is continuously varying, when both beams are in phase, or have zero phase difference, a single beam will be observed which is normal to the plane containing intersecting lines 12 and 13. As the phase difference increases the beam will deviate an increasing amount from the normal. The direction of deviation will depend on which beam leads or lags in phase and a normal projection of the beam on the plane will coincide with line 13 which connects radiators 5 and 7. Should these conditions prevail the beam would scan between radiators 5 and 7 and its projection on line 13 would vary sinusoidally.

The above analysis also applies for radiators 9 and 11 except that the beam projection would coincide with line 12 and would vary cosinusoidally with respect to the projection on line 13. Therefore, the combination of the four beams when controlled as described above would produce a single beam displaced by some angle θ , as shown in FIG. 1 from a line normal to the intersection of lines 12 and 13 of FIG. 2. The beam will rotate about the normal at a frequency equal to the frequency of generator 23 since one complete cycle of variation in phase difference is produced in each cycle of generator 23. Furthermore, generator 23 is of the variable frequency type and thus permits an easy and inexpensive means for varying the scanning rate. In order to assure constant beam width in any given plane, such as 3 of FIG. 1, radiators 5, 7, 9 and 13, are of a type having circular symmetry in their radiation patterns.

The embodiment shown in FIG. 3 is similar to that shown in FIG. 2 with the exception of the radiators used. In FIG. 3 ferrite rod radiators 105, 107, 109 and 111 are used in place of horn radiators 5, 7, 9 and 11 of FIG. 2. This permits the associated control coils 133, 135, 137

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and 139 to be positioned in close proximity to the radiators and results in a considerable saving in the space required, which is highly desirable in airborne equipment since rods 105, 107, 109 and 111 act both as radiators and phase shifters when properly energized as described above. Furthermore, the ferrite rod antennas have circularly symmetric radiation patterns and are therefore highly suitable for this application.

The operation of the circuit shown in FIG. 2 was described in connection with a conical scanning system but other types of volume scanning are possible utilizing this same circuit by merely varying the peak amplitude of the excitation currents through the control windings or by varying the phase shift between the outputs of phase splitter 24. For example, an elliptical cone pattern may be obtained by either increasing the peak amplitude of one excitation current relative to the other so as to change the amplitude of the beam displacement from the normal along either line 12 or 13 relative to the beam displacement from the normal along the other line or, alternatively, by changing the phase difference between the outputs of phase splitter 24. Spiral scanning of a volume may be obtained by continuously increasing or decreasing the peak amplitude of the excitation currents through the control windings to cause a continuous increase or decrease in the beam displacement relative to the normal to lines 12 and 13 which will result in the beam following a spiral pattern.

While four radiators were chosen to illustrate the invention it is obvious that many combinations of radiators may be used to provide a volume scanning beam according to the invention. Also, the invention is not limited to the use of horn or ferrite rod radiators since many combinations of radiators could be used to provide circularly symmetric beams.

What is claimed is:

1. A conical scanning microwave antenna system comprising, an array of at least four microwave radiators arranged in pairs, microwave phase shifting means for connecting the radiators to a source of microwave energy, and means for operating said phase shifters to continuously vary the phase between the radiators of each pair and maintain said pairs at a 90° phase shift to provide a conically scanning beam.

2. A conical scanning microwave antenna system comprising, an array of at least four microwave radiators arranged in pairs, a separate ferrite microwave phase shifter connected to each radiator for connecting each radiator to source of microwave energy, a control coil adjacent each phase shifter for operating the phase shifters as a function of control coil excitation current, and means connected to said control coils for supplying excitation current therethrough to continuously vary the phase between the radiators of each pair and maintain the pairs of radiators at a 90° phase shift to provide a conically scanning beam.

3. A volume scanning microwave antenna comprising, four horn radiators each of which simultaneously provides a circularly symmetric radiation pattern normal to a fixed plane, said radiators being mounted in a balanced array of pairs on two orthogonal axes contained within the said plane, separate ferrite microwave phase shifters connected to each radiator for connecting each radiator to a source of microwave energy, a control coil adjacent each phase shifter for operating the shifters as a func-

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tion of control coil excitation current, and means connected to said coils for supplying alternating excitation currents therethrough to continuously vary the phase between the radiators of each pair and maintain the pairs of radiators at a 90° phase shift to provide a conical scanning beam.

4. A scanning device as defined in claim 3 in which the alternating currents supplied to the control coils associated with the different pairs have equal amplitudes to provide a conical scanning beam.

5. A volume scanning microwave antenna comprising, four ferrite rod type radiators each of which simultaneously provides a circularly symmetric radiation pattern normal to a fixed plane, said radiators being mounted in a balanced array of pairs on two orthogonal axes contained within the said plane, means for connecting each of the radiators to a source of microwave energy, a control coil adjacent each ferrite radiator for shifting the phase of the radiation as a function of the control coil excitation current, and means connected to said coils for supplying alternating excitation currents therethrough to continuously vary the phase between the radiators of each pair and maintain the pairs of radiators at a 90° phase shift to provide a conical scanning beam.

6. A scanning device as defined in claim 5 in which the alternating currents supplied to the control coils of the different pairs have equal amplitudes to cause the resultant radiation to describe a cone.

7. A conical scanning microwave antenna comprising at least four microwave radiators arranged in pairs, means connected to said radiators for coupling them to a source of microwave energy and arranged to continuously vary the phase between the radiators of each pair and maintain the said pairs at a 90° phase shift to provide a conically scanning beam.

8. A volume scanning microwave antenna comprising a plurality of microwave radiators each of which simultaneously provides a circularly symmetric radiation pattern normal to a fixed plane, said radiators being mounted in a balanced symmetric array of pairs on two orthogonal axes contained within the said fixed plane, means for connecting the radiators to a source of microwave energy and means for electrically continuously varying the phase between the radiators of each pair and maintaining said pairs at a 90° phase shift to provide a conically scanning beam.

References Cited in the file of this patent

UNITED STATES PATENTS

2,409,944	Lougren	Oct. 22, 1946
2,444,425	Busignies	July 6, 1948
2,581,348	Bailey	Jan. 8, 1952
2,841,791	Schlicke	July 1, 1958
2,844,799	Fox	July 22, 1958
2,863,144	Herscovici et al.	Dec. 2, 1958

FOREIGN PATENTS

794,509	Great Britain	May 7, 1958
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OTHER REFERENCES

Pub. I, IRE Convention Record, part I., vol. 4, page 84, March 22, 1956.

Pub. II, IRE Convention Record, part V, vol. 4, pp. 95-96, March 22, 1956.