Aug. 12, 1958 G. S. GIFFIN ET AL 2,847,672

ANTENNA ARRAYS

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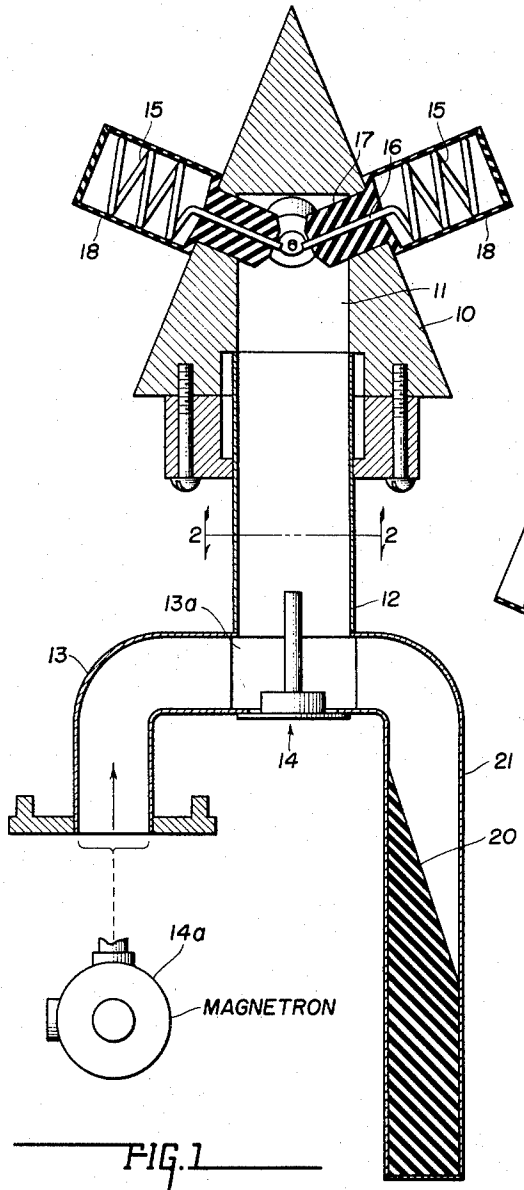

FIG. 1

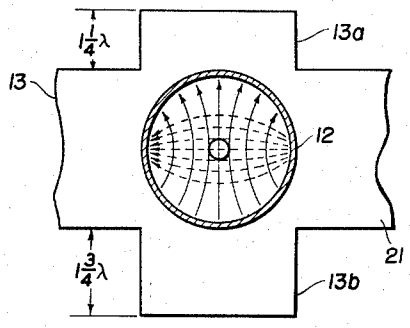

FIG. 2

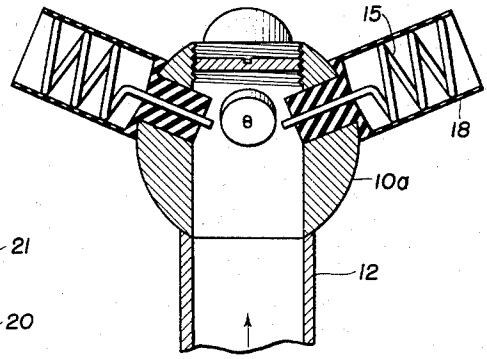

FIG. 3

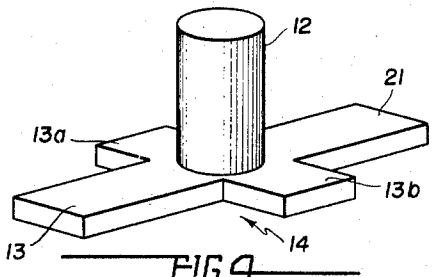

FIG. 4

INVENTORS.
GEORGE S. GIFFIN
DERLING G. KILLION
MARK N. HALLER

BY

George A. Gust

ATTORNEY

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ANTENNA ARRAYS

George S. Giffin and Derling G. Killion, Fort Wayne, Ind., and Mark N. Haller, Galion, Ohio, assignors to International Telephone and Telegraph Corporation

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3 Claims. (Cl. 343—895)

This invention relates to antenna arrays and is particularly directed to arrays for producing a substantially uniform circularly polarized hemispherical field-strength pattern. Still more particularly, this invention is directed to arrays of helical antennas, having a circularly polarized hemispherical pattern, for radiating energy of microwave frequencies.

In the co-pending application entitled "Antenna Arrays," Serial No. 597,686, filed July 13, 1956, in the name of George S. Griffin and Mark Haller, and assigned to the assignee of this application, an antenna array was described comprising a plurality of circularly arranged helical antennas around the side of a cone (or pyramid or sphere). The several helices were energized in phase from a common source of microwaves, and the several helices were appropriately rotated on their axes to produce at overhead points in space additive energy at those points from the several helices.

The object of this invention is to provide an improved antenna array which will radiate microwave energy substantially uniformly in all directions above a plane at the center of which the array is placed.

The objects of this invention are attained by a circular arrangement of separate radiators of the helix type, the arrangement being characterized by each of the radiators having a probe lead extending into circularly spaced points in a round cavity, said cavity communicating with a round waveguide and with a source of circularly polarized microwave energy so that the wave front passing the plane of the probes energizes the several probes successively and in time phase corresponding to the angular displacement of the probes about the circular wall of the cavity.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a sectional view of an antenna array fed by the waveguide of this invention;

Fig. 2 is a section of the waveguide taken on line 2—2 of Fig. 1;

Fig. 3 is a sectional view of another embodiment of this invention; and

Fig. 4 is a perspective view of the waveguide junction shown in Fig. 1.

As explained in greater detail in the co-pending application, supra, to obtain uniform irradiation of a hemispherical space, the several radiators of a circular array must propagate energy out of phase with respect to each other, and the phase displacement should correspond to the angular displacement of the radiators about the center of the array. In that system, the phase displacements are obtained by rotating one helix radiator about its axis, with respect to rotational position of the next adjacent helix.

According to this invention, similar results are obtained by energizing helices successively by phase displaced energy. The ground plane of the array of helical antennas **15** in Fig. 1 is defined by a metal cone **10** of good electrical conductivity, such as copper. The central cavity or bore **11** on the axis of the cone communicates, through the waveguides **12** and **13**, with the microwave sources **14**. Importantly, the waveguide **12** is so constructed and the excitation of the input end of the waveguide **12** is such that the energy entering the cavity **11** is circularly polarized. The direction or sense of the circular polarization is taken with regard to the winding direction of the helices **15** so that energies at an overhead point in space from the several helices are additive. Circular polarization in waveguide **12** may be effected in a number of ways. For example, the turnstile junction **14**, a device known to those skilled in the art, may be used to transform the wave from the guide **13** to a circularly polarized wave in guide **12**.

Referring more specifically to the embodiment of Fig. 1, equally spaced around the sides of the ground cone **10** are the helical radiators **15**, each constructed of wire wound into spaced turns of the proper diameter and pitch to efficiently radiate the particular microwave energy of source **14***a*, such as a magnetron. Each coil is supported by the lead probe **16** centered in an insulating bushing or sleeve **17** in holes through the side of the cone. The sleeve is conveniently cast or machined with the thimble **18** for enclosing the coil. The inner ends of the lead probes extend into the cavity **11** a distance to most efficiently transfer energy from the cavity to the helix. Any reflecting from the top end of the cavity may be absorbed in the tapered plug **20**, of lossy material, in the stub **21**.

As stated above, the waveguide **12** is excited at its input end, as by turnstile junction **14**, so that circularly polarized energy will enter the cavity **11**. The particular junction shown comprises two short circuited stubs **13***a* and **13***b* at right angles to the feed arm **13** and the round guide **12**. By adjusting the effective electrical length of the stubs so that one is one-half wavelength longer than the other at the operating frequency, then two $TE_{1,1}$-type waves in time and space quadrature may be propagated along guide **12**. If the electric and magnetic lines of one such wave are shown in solid and dotted lines as in Fig. 2, a second set of similar lines could be drawn in the same cross plane in space quadrature to the first set, but the fields of the first and second waves would be 90° apart in time phase. Herein lies the classical analysis of true circularly polarized microwave in a round waveguide. The direction or sense of this wave rotation must, of course, be chosen with regard to the winding direction of the helices **15**, else cancellation, rather than addition, of energy at an overhead point in space will result as explained in the co-pending application, supra.

As the flux lines of two $TE_{1,1}$ modes in time and space of quadrature pass the plane of the circle of probes **16**, the probes are energized sinusoidally and out of phase with respect to each other and at a frequency corresponding to the phase velocity of the lines passing the probe circle. It follows that the phase displacement of the energy between the probes will correspond exactly with the angular displacement of the probes about the cone axis.

It is preferred that the rotational position of the helices in their holes be similar, so that the phase of energy arriving at a point in space from the several helices of the array shall be determined primarily by the time phase of the energy fed to the probe-end of the helices.

Fig. 3 shows how a spherical ground plane device **10***a* may be substituted for the conical ground plane device **10**, of Fig. 1. The plane of the end of each helix is tangential to the adjacent surface of the ground plane.

It is apparent that any figure of revolution may be employed, as well as pyramids.

Experimentation has shown that the field-strength pattern is substantially uniform for such an array throughout the entire hemispherical canopy.

While the principles of the invention have been described in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. An antenna array comprising a circular arrangement of separate radiators of the helix type, the arrangement being characterized by each of the radiators having a probe lead extending into circularly spaced points in a round cavity, said cavity communicating with a round waveguide and with a source of circularly polarized microwave energy so that the wave front passing the plane of the probes energizes the several probes successively and in time phase corresponding to the angular displacement of the probes about the circular wall of the cavity.

2. An array of helical radiators, a probe connected with each radiator, the probes being spaced in a circle, a source of microwave energy, and means for transmitting microwave energy of said source transversely through

the plane of said probes, the polarization of the energy in said plane being circular and of proper rotational sense with respect to the winding sense of the helices for energizing the probes successively and in displaced time phase corresponding to the angular placement of the probes in the circle to indicate an overhead point with in-phase circularly polarized energy from the several radiators.

3. In combination, a plurality of helical antennas, the antennas being arranged in a circle with the axis of the helices defining a right cone, a ground plane device supporting the helices with surfaces of the device adjacent the helices substantially normal to the axis of the helices, said ground plane device having a cavity, circularly arranged probes in the cavity connected, respectively, with said helices, and means for generating a microwave in the cavity, said wave being circularly polarized with sense dependent upon helix winding in the plane of the probes.

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