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ANTENNA FOR RADIATING CIRCULARLY POLARIZED WAVES

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FIG. 1

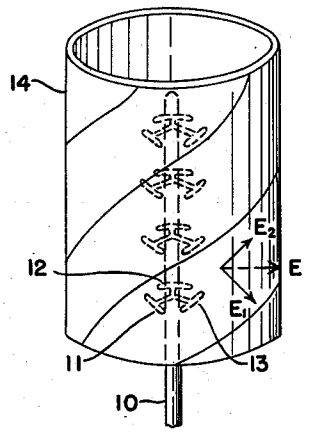
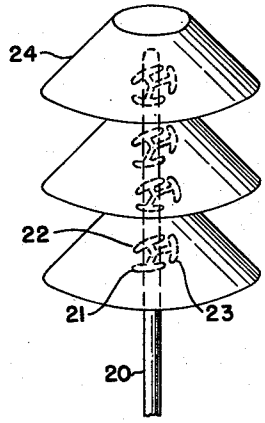


FIG. 2



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ANTENNA FOR RADIATING CIRCULARLY POLARIZED WAVES

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1 Claim. (Cl. 250—33.51)

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This invention relates in general to antennas and more particularly to antennas in which the resultant radiation is circularly polarized.

Normally antennas have the electromagnetic radiation emanating from them polarized in one plane, usually a plane either perpendicular to the ground or horizontal to the ground, giving rise to either vertical polarization or horizontal polarization, respectively. Horizontal polarization may be caused by the elements of the antenna, say a number of dipoles, being positioned horizontally with respect to the ground. The electric field radiated from these dipoles is oriented in a horizontal direction. This may be represented by an electric field, or E, vector horizontal in space. That is, a voltage will be induced in a receiving antenna placed within range of the above mentioned dipoles only if this receiving antenna has a component along its length in the horizontal direction, neglecting effects from outside objects. The maximum voltage will be induced in this receiving antenna when it is parallel in space to the dipoles. The same analysis may be applied to vertical polarization, which may be represented by an electric field, or E, vector vertical in space.

For some purposes it is desirable to have the radiation pattern from an antenna system circularly polarized. In this case the angle of polarization is constantly changing. It may be represented by an electric field, or E, vector rotating in space at a constant angular velocity ω radians per second, where $\omega=2\pi f$, f being the frequency of oscillations of the radio-frequency generator causing the field in cycles per second. It may furthermore be seen that a receiving antenna need not be oriented in a direction substantially parallel in space to the transmitting antenna, because a large voltage will be induced in it once each angular cycle if the waves are circularly polarized.

Among the objects of this invention, therefore, are:

1. To provide an antenna system for producing electromagnetic radiations.

2. To provide such a system in which is incorporated a means to cause the polarization of the radiation to be circular.

In accordance with the present invention there are provided two embodiments of a means for changing linear polarized waves to circularly polarized waves. The first incorporation hereof involves a dipole antenna array with dielectric strips wound about the antenna and at a short distance from it. These dielectric strips are chosen of a fibrous material in which the dielectric constant along the fibers is different from that normal to the fibers. The orientation of the dielectric fibers must be substantially 45° from the polarization of the dipoles forming the array. Taking into account the difference in the dielectric constants for waves having their electric vectors parallel to and those having their electric vectors perpendicular to the fibers, a thickness of the dielectric is chosen so that the difference in time of passage of the two abovementioned electric vectors will be a quarter of a cycle. This will produce the circular polarization desired.

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The second embodiment provides a dielectric housing for an antenna in which the outer surface of the housing makes a high angle of incidence with respect to the polarization of the wave from the antenna. The dipoles are oriented at substantially 45° with respect to the vertical. The properties of the housing are such that reflection off the interior walls causes different effective path lengths for the horizontal component of the electric vector and for the vertical component. The result is a circularly polarized wave.

This invention will best be understood by reference to the drawings in which Figs. 1 and 2 show two embodiments of the present invention.

Referring now to the description of one embodiment of the apparatus and to Fig. 1, there is shown a functional diagram of an antenna array which is essentially non-directional in the azimuthal horizontal plane. To lead-in member 10 there are coupled four groups of curved dipoles, such as the group containing dipoles 11, 12, and 13. These dipoles are of such a curvature that all those of a group lie along the circumference of the same circle. The antenna array is usually oriented so that the azimuthal plane is the plane of the aforementioned circle. Any number of groups of dipoles may be used, the greater the number of groups, the narrower will be the beam of the radiation pattern of the array in a plane perpendicular to the azimuthal plane. It is understood that the system is not limited to this type of non-directional array. Also, if a uniform azimuthal radiation pattern is not desired, the system should not be limited to a non-directional type of array.

A housing 14 is placed about the antenna array which consists of strips of dielectric material wound around the array at an angle of substantially 45° with the plane of the dipoles, the azimuthal plane. This dielectric material must be such that it have a different effective dielectric constant along the direction of winding than normal to the direction of winding. One substance having this property is so-called "Polyfiber." Another method of obtaining this property is to use a number of closely-spaced thin conducting wires wound in a direction substantially 45° to the plane of the dipoles. The size and spacing of the wires must be carefully chosen. The latter construction is therefore equivalent in effect to a dielectric material such as housing 14 of Fig. 1 or housing 24 of Fig. 2.

A functional diagram of a second embodiment

of the invention is shown in Fig. 2. Essentially the same type of array is used here as in the apparatus of Fig. 1, and the same limitations are to be applied. The plane of the dipoles, however, must be at 45° with respect to a plane normal to the axis of the lead-in member. To the lead-in member 20 is coupled a number of groups of dipoles, one such group being represented by dipoles 21, 22 and 23. A housing 24 of a material having a large dielectric constant is placed about the array, the shape of this housing being essentially that of a number of stacked truncated cones.

Referring now to the operation of the first embodiment of the invention, and to Fig. 1, it is seen that the polarization of the radiation from the dipoles is horizontal, being in the azimuthal plane. If the E vector shown in Fig. 1 represents the electric field emanating from the antenna at a certain azimuth angle, it is seen that it may be broken down into two components, one, vector E_1, being normal to the direction of the fibers of the dielectric strip, and the other, vector E_2, being in the direction of the fibers. Since this material has different dielectric properties in directions parallel to, and normal to, the fibers, the phase shift for electric field components such as E_1 will not be the same in passing through the housing as the phase shift for components such as E_2. If the thickness of the dielectric strips is chosen so that the difference in phase shift of the E_1 and E_2 components is a quarter wavelength, the field outside the housing will be circularly polarized. The resultant electric field vector emanating from the housing will be rotating at an angular velocity ω radians per second. The condition described above may be explained by the following equation:

$$\frac{\alpha\sqrt{\epsilon_2}}{\lambda}-\frac{\alpha\sqrt{\epsilon_1}}{\lambda}=\frac{1}{4}$$

where

$$\alpha\sqrt{\epsilon_2}/\lambda$$

is the phase shift of the E_2 vector in passing through the dielectric housing and

$$\alpha\sqrt{\epsilon_1}/\lambda$$

is the phase shift of the E_1 vector in passing through the dielectric housing, and where:

d=thickness of dielectric wall in the same dimensions as λ

λ=wavelength of radiations from the antenna array in the same dimensions as d

ϵ_1=effective dielectric constant of housing for E_1 vector—dimensionless

ϵ_2=effective dielectric constant of housing for E_2 vector—dimensionless

From this the thickness of the wall is derived:

$$\alpha=\frac{\lambda}{4(\sqrt{\epsilon_2}-\sqrt{\epsilon_1})}$$

The same results may be achieved by winding the dielectric strips in a direction parallel to the azimuthal plane, and orienting each individual dipole so that it makes an angle of substantially 45° with the azimuthal plane.

Referring now to the operation of the second embodiment of the invention and to Fig. 2, it is seen that since the material of housing 24 has a large dielectric constant, a portion of the radiation from the array will be reflected from the inside of the outer surface of the housing. This outer surface is made to have a large angle of incidence with respect to the orientation of the dipoles. Due to this large angle of incidence, waves having different polarizations will have different reflecting properties. If the radiation from the dipoles is broken down into two vectors perpendicular to one another, it is seen that a portion of the electromagnetic energy will reflect from the inside of the walls in such a manner that the paths for the two abovementioned vectors will be of different lengths. If the angle of incidence is large enough and the size of the housing and the dielectric constant of the housing material are carefully chosen, there will be some energy emanating from the device in which one electric field vector has a path length that is a quarter of a wavelength different from the length of the path of the other electric field vector normal to the first. Thus there will be a component of the radiated wave having circular polarization.

Any number of cones may be used in the housing structure, the number shown in Fig. 2 being such that the base of the structure does not become too large.

While there has been described what is at present considered the preferred embodiment of the invention it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claim to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

Apparatus for radiating circularly polarized electromagnetic waves with an omnidirectional radiation pattern in at least one plane comprising an antenna for radiating plane polarized waves omnidirectionally in at least one plane and a fibrous material in the form of a strip arranged in a spiral about said antenna at least in said one plane, the fibres of said strip being parallel to the length of said strip, said fibrous material having an effective dielectric constant for waves polarized in a plane parallel to the direction of the fibers differing from that for waves polarized in a plane normal to the direction of the fibers, said material being arranged with the fibers at an angle of substantially 45° with respect to the direction of polarization of waves from said antenna, a dimension of said material in the direction of propagation of waves from said antenna therethrough being designed to provide a space phase difference of a quarter of a period at the operating frequency of said antenna for the two components of the waves from said antenna that are polarized in the planes parallel to and normal to said fibers respectively.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,841,654	Korschenewsky	Jan. 19, 1932
2,190,816	Wheeler	Feb. 20, 1940
2,243,677	Lindenblad	May 27, 1941
2,350,331	Salinger	June 6, 1944
2,413,085	Tiley	Dec. 24, 1946
2,464,269	Smith	Mar. 15, 1949

FOREIGN PATENTS

Number	Country	Date
668,231	Germany	Nov. 23, 1938