Nov. 20, 1956 R. A. KIRKMAN 2,771,605

OMNIDIRECTIONAL ANTENNA

Filed Oct. 11, 1954

Fig. 1

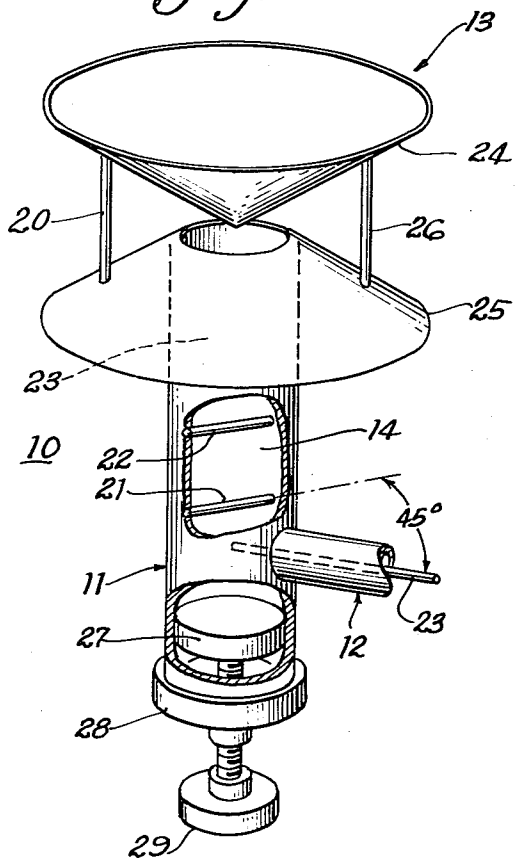


Fig. 2

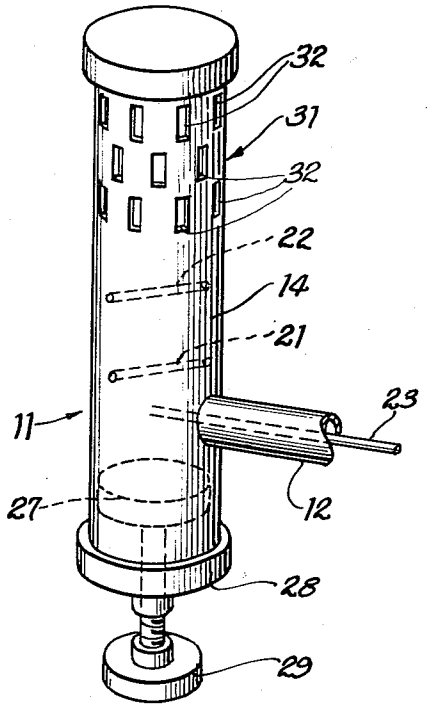


Fig. 3

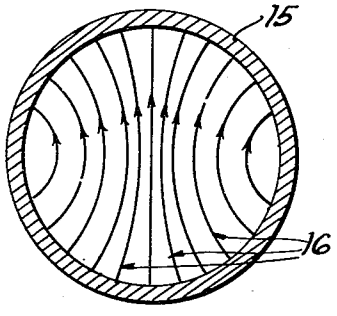
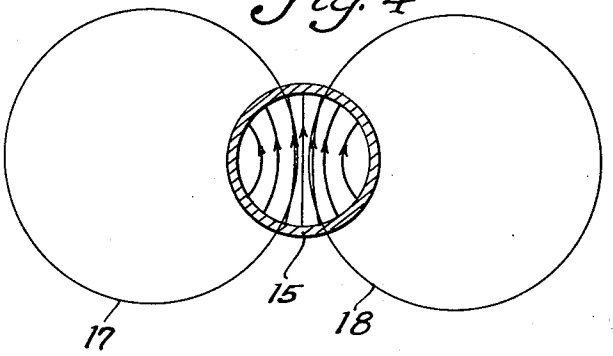


Fig. 4



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OMNIDIRECTIONAL ANTENNA

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7 Claims. (Cl. 343—771)

This invention relates to microwave apparatus, more particularly to apparatus and methods for radiating omnidirectionally microwaves which are polarized in particular planes, and it is an object of the invention to provide improved apparatus of this character.

It is a further object of the invention to provide improved microwave apparatus and methods for radiating omnidirectionally microwaves which are polarized in a horizontal plane.

It is a further object of the invention to provide apparatus and methods for radiating omnidirectionally microwaves which are polarized vertically.

In carrying out the invention in one form, improved microwave apparatus is provided comprising a wave guide including means for circularly polarizing a wave traveling therein, and relatively stationary means at the exit of said guide equally effective in all directions at right angles to the wave guide for radiating the circularly polarized wave.

In carrying out the invention in another form, an improved method of radiating omnidirectionally in a plane an electromagnetic wave is provided comprising generating a non-uniform field pattern of the wave in space in a plane and rotating the field pattern at a very rapid rate.

This application is a continuation-in-part of my copending application Serial No. 106,931, filed on July 26, 1949, now abandoned.

For a more complete understanding of the invention, reference should be had to the accompanying drawing, in which:

Figure 1 is a vertical view in perspective and partially broken away of one form of apparatus embodying the invention;

Fig. 2 is a view similar to Fig. 1 of another form of the invention;

Fig. 3 is a diagrammatic view of a vertical cylindrical wave guide showing a transverse electric field of the dominant mode being propagated therein; and

Fig. 4 is a diagrammatic view of the transverse electric field pattern set up at the end of the cylindrical wave guide of Fig. 3.

Referring to the drawing, there is shown microwave apparatus **10** comprising a wave guide **11**, a coaxial conductor **12** for supplying the wave to the guide, and a bi-conical antenna **13** at the end of the guide for radiating the wave. By way of example, it is supposed that the wave being propagated is a transverse electric wave of dominant mode, although other modes may be used.

Between the coaxial conductor **12** and the bi-conical antenna **13** is a section of the guide designated by the numeral **14** which circularly polarizes the wave propagated in the guide.

If it is supposed that the vertical cylinder **15** of Fig. 3 has a transverse electric wave of dominant mode being propagated therein, the electric field pattern may be represented by a series of curved lines **16** extending across the guide or pipe. This wave is linearly polarized in a horizontal plane. If the pipe is open at the top and the

wave is allowed to emanate therefrom, i. e., energy is radiated into space, an azimuthal field pattern is formed. The azimuthal field pattern in such a case may be represented as a figure of eight shown by the circles **17** and **18** of Fig. 4. That is to say, maximum field intensity exists in both directions at right angles to the electric field lines of force and zero intensity exists in the direction at right angles to the direction of maximum intensity. With such a field pattern or radiation pattern energy is radiated predominantly in the direction of maximum intensity and no energy is radiated in the direction of zero intensity, there beng varying amounts of energy radiated in between.

When the radiation field of Fig. 4 is made to rotate at a high rate of angular velocity, an equal amount of energy will be radiated into each sector around the axis of the guide **15** during any relatively long period of time. If the field pattern is rotated 90 degrees, the direction of maximum intensity exists where the intensity previously was zero; if it is rotated 180 degrees, the direction of maximum intensity is the same as originally; and if it is rotated 270 degrees, the direction of maximum intensity again exists where it was originally zero.

Rotating the field pattern rapidly enough causes the direction of maximum intensity to exist for the same length of time in all sectors during any relatively long interval of time, so that during that interval the same amount of radiation takes place into all sectors.

The rapid rotation of the horizontally polarized field of Fig. 3, and consequently of the radiation field of Fig. 4, may be obtained by circularly polarizing the field inside of the guide.

When the field is circularly polarized, the field rotates at a rate equal to the frequency of the wave given by the relationship

$$f=\frac{c}{\lambda}$$

where f is the frequency in cycles per second, c is the velocity of light in centimeters per second, and λ is the wave length in centimeters. Since the pipes used for wave guides are relatively small, the wave lengths which can be propagated therein are short, the frequency is very high, being in the order of billions of cycles per second, and, consequently, the rate of field rotation is very high. To all intents and purposes, in such a case the azimuthal field pattern is omnidirectional. That is, all sectors receive the same amount of energy during any relatively long interval of time; for example, an interval of the order of one millionth of a second.

It will be apparent that mechanically rotating antennas are not possible because sufficiently high rates of rotation are not obtainable to radiate energy uniformly into all sectors. Hence, according to the invention, the apparatus is relatively stationary and field rotation is produced in one form of the invention as described.

Referring to Fig. 1, the portion **14** constitutes means for circularly polarizing the wave. This means comprises a portion of the wave guide having the same diameter as the wave guide proper, and a pair of conducting rods **21** and **22** extending diametrically across the guide at an angle of 45 degrees to the direction of the central conductor **23** of the coaxial conductor **12**. The central conductor **23** is a probe for exciting the guide with the wave to be propagated therein.

By choosing the diameter of the rods and the spacing between them properly, circular polarization of the wave may be obtained. It is understood in this art that conducting rods placed in a wave guide cause a phase change in waves polarized in a direction parallel to the direction of the rods, but do not cause any phase change in waves polarized at right angles to the direction of the rods, pro-

vided that the rod diameter is small compared to the wave length and the guide diameter. Since a wave propagated through the guide may originally be oriented so that it has components parallel and perpendicular to the rods, it will be apparent that one component will have a phase lead over the other, the amount depending upon the diameter and the spacing of the rods. Moreover, the rods may be placed at 45 degrees to the direction of the electric field so that the parallel and perpendicular components are equal. If the diameter of the rods chosen is such that the inductive susceptance thereof is twice the characteristic admittance of the wave guide, and if the longitudinal spacing between the rods is three-eighths of a wave length, then a phase change between the two components of the wave of 90 degrees is obtained. Or the resulting wave, being propagated along the wave guide portion **23**, i. e., following portion **14**, is circularly polarized, though still in a horizontal plane.

While one form of means for producing plane circular polarization has been described, it will be understood that others may be used, such, for example, as properly dimensioned and placed diametrically opposed metallic fins or a dielectric plate in the guide.

A circularly polarized wave as by the section **14** will be radiated out of the open end of the guide and will be radiated omnidirectionally, as already has been described. However, the vertical field pattern of the wave being so radiated is such that much of the energy is directed upwardly rather than in the horizontal or outflowing direction. Accordingly, the bi-conical antenna **13** comprising the cones **24** and **25** is placed above the wave guide in order to concentrate the energy in the horizontal plane, and to radiate the wave which is polarized in a single plane, the dimensions and the angle of the cone being chosen as is well understood to produce the desired vertical field pattern. Cone portion **25** may be attached directly to the upper end of the guide, and cone portion **24** is spaced upwardly therefrom by some form of mechanical support, such, for example, as the insulating rods **20** and **26**. The energy radiated from the bi-conical antenna will have a vertical electrostatic vector and is thus referred to as vertically polarized energy as described above.

The apex of the cone portion **25** is open to permit the wave to emanate therefrom, whereas the cone portion **24** has a sharp apex lying on the axis of the guide. The spacing of the cone portion **24** above the cone portion **25** is such as to match the impedance of the bi-conical antenna to the impedance of the wave guide so as to prevent reflection of the wave.

The connection between rods **20** and **26** and the cone portions may be adjustable, if desired, in order to obtain the impedance match, or they may be fixed as shown after the impedance match has been made.

Inside of the lower end of the wave guide **11**, a plunger **27** is threaded in a cap **28**. By rotating a knob **29** the position of the plunger **27** relative to the portion of conductor **23** inside of the guide may be changed so as to produce an impedance match at this point. Preferably, plunger **27** is spaced one-quarter wave length or multiples thereof below the conductor **23**, the adjustment of the plunger being such that spacing from zero to one-quarter wave length or multiples thereof may be obtained.

The embodiment of the invention shown in Fig. 2 is similar to the embodiment of Fig. 1 in respect to the wave guide **11** in general, the coaxial conductor **12** for exciting the guide, and the portion **14** for circularly polarizing in a horizontal plane the linearly polarized wave supplied to the guide. The embodiment of Fig. 2 differs from the embodiment of Fig. 1 in its inclusion of a wave guide section **31** having a series of narrow longitudinal slots **32** equally spaced around the periphery of the guide.

Each slot **32** serves to radiate outwardly therefrom, the radiation from all of the slots combining to produce a radiation pattern which to all intents and purposes is continuous in the horizontal plane, since the electric field inside the guide is circularly polarized. In order to obtain the desired vertical field pattern a series of rows of slots is used. In the figure, three rows are shown by way of example, the slots of one row being staggered relative to the slots of the row above or below, but any number of rows may be chosen, as is known in this art.

The operation of embodiment of Fig. 2 may be understood more clearly by considering that currents flow tangentially in the wave guide and spirally upwardly due to the circular polarization of the wave in a horizontal plane wave inside the guide. Since the slots provide interruptions to the flow of these currents, potentials are developed thereacross and consequently radiation therefrom takes place.

The pattern of radiation given by each slot is essentially unidirectional; that is, the radiation takes place outwardly from the slot and is horizontally polarized, which pattern substantially resembles a cardioid. This becomes true progressively more so as the wave length is decreased relatively to the guide diameter. Since the electric field inside of the guide is rotating (due to the circular polarization), it is clear that each slot successively radiates with maximum intensity (opposite to this direction the radiation is zero or minimum) and the wave is radiating at a very high angular rate. The amount of energy being radiated into all sectors during a relatively long interval is the same.

While two forms of means for concentrating the field in a vertical plane and for radiating uniformly in all directions in a plane are shown, it will be understood that others may be used.

While particular embodiments of the invention have been shown, it will be understood, of course, that the invention is not limited thereto since many modifications may be made, and it is, therefore, contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

The invention having thus been described, what is claimed and desired to be secured by Letters Patent is:

1. Microwave apparatus comprising a vertically disposed cylindrical wave guide, energizing means for feeding to said guide a transverse electrical wave of dominant mode polarized in a horizontal plane, means in said guide for circularly polarizing said wave in a horizontal plane, and bi-conical antenna means at the exit of said guide for radiating said wave.

2. Microwave apparatus comprising a vertically disposed cylindrical wave guide, means for feeding to said wave guide a transverse electrical wave of dominant mode polarized in a horizontal plane, means in said guide for circularly polarizing said wave in a horizontal plane, and bi-conical antenna means having substantially the same radiating characteristics in all horizontal directions at the exit of said guide for radiating said wave and for maintaining said wave polarized in a vertical plane.

3. Microwave apparatus comprising a cylindrical wave guide having therein means for circularly polarizing in a plane normal to the axis of said wave guide a wave traveling therein, and bi-conical antenna means at the exit of said guide for radiating said wave vertically polarized in a plane at right angles at the axis of said wave guide and having a rotating field strength pattern.

4. Microwave apparatus comprising a vertically disposed cylindrical wave guide, energizing means for feeding to said guide a transverse electrical wave of dominant mode polarized in a horizontal plane, means in said guide for circularly polarizing said wave in a horizontal plane, and antenna means at the end of said wave guide including a plurality of longitudinal slots spaced around the periphery thereof for radiating said wave into space uniformly in all substantially horizontal directions and maintaining said wave polarized in a plane at right angles to said guide.

5. Microwave apparatus comprising a vertically disposed cylindrical wave guide, means for feeding to said

wave guide a transverse electrical wave of dominant mode polarized in a horizontal plane, means in said guide for circularly polarizing said wave in a horizontal plane, and antenna means at the end of said wave guide including a plurality of longitudinal slots spaced around the periphery of said wave guide, said antenna means being equally effective in all directions and having substantially the same radiating characteristics in all horizontal directions for radiating said wave into space uniformly in all substantially horizontal directions and maintaining said wave polarized in a horizontal plane.

6. Microwave apparatus comprising a vertically disposed cylindrical wave guide, energizing means for feeding to said guide a transverse electrical wave of dominant mode polarized in a horizontal plane, means in said guide for circularly polarizing said wave in a horizontal plane, and antenna means at the exit of said wave guide for transmitting said wave into space uniformly in all substantially horizontal directions with a vector orientation fixed in a predetermined angular relationship to the axis of said wave guide and the horizontal plane.

7. Microwave apparatus comprising a cylindrical wave guide having therein means for circularly polarizing in a plane normal to the axis of said wave guide a wave traveling therein, and antenna means at the termination of said wave guide for radiating said wave uniformly in all substantially horizontal directions in a plane at right angles to the axis of said wave guide, and for radiating said energy with a vector fixed in a predetermined angular orientation relative to the axis of said wave guide and the plane of radiation.

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