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TILTED SLOT ANTENNA

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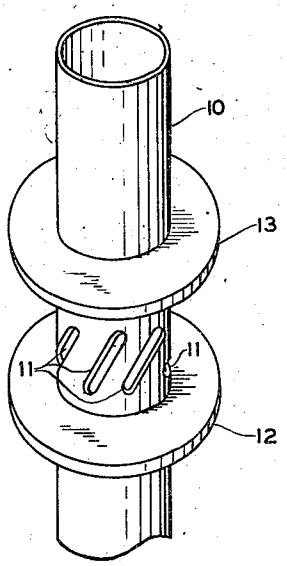
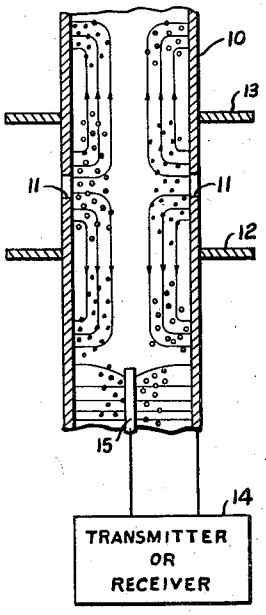


FIG. 1

FIG. 1A



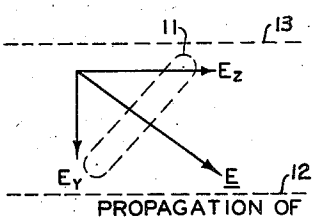


FIG. 2

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TILTED SLOT ANTENNA

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The present invention relates to ultra-high frequency antennas and more particularly to antennas having circular polarization.

There exist numerous applications entailing the use of an ultra-high frequency, omni-directional antenna. For example, in radio beacons, it is desirable that the radiation pattern be circular so that the field strength for a given distance from the antenna is substantially the same for any direction with respect to the antenna.

Also an antenna having the characteristics for producing circularly polarized radiation may, for example, be used as a beacon capable of operating in connection with either vertically or horizontally polarized communication systems including radio object-locating systems.

It is the primary object of this invention to provide an antenna in the form of a slotted wave guide or coaxial line which is adapted to radiate circularly polarized electromagnetic waves of energy.

Another object of the invention is to provide a slotted wave guide or coaxial line antenna system which is substantially omni-directional in one plane and which is relatively sharply directional (to a controllable extent, if desired) in a plane perpendicular to the first-mentioned plane, and moreover in which the energy waves radiated therefrom are circularly, vertically or horizontally polarized depending on the angular relation of the slots relative to the longitudinal axis of the wave guide or coaxial line.

It will be understood that polarization as referred to in this description and the appended claims is defined in the sense used in the radio art rather than in the optical sense, and refers to the direction of the electric vector rather than that of the magnetic vector.

Generally stated, these objects are attained by the use of an antenna structure in the form of a coaxial line or wave guide ringed by a plurality of similarly tilted slots. A pair of parallel reflecting plates are externally arranged with respect to the slots whereby a wave guide effect is realized. The orientation of the slots are such that a 90-degree phase shift is obtained between the voltage vector components of energy radiated from the slots, thereby producing a substantially circular radiation pattern.

For a better understanding of this invention, as well as other objects and features thereof, reference is had to the following detailed description to be read in connection with the accompanying drawing wherein:

Fig. 1 shows in perspective a preferred embodiment of an antenna structure in accordance with the invention,

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Fig. 1A shows a sectional view of Fig. 1 together with an illustration of the source and form of the wave supplied thereto, and

Fig. 2 is a voltage vector diagram of energy propagated from one slot in the antenna structure of Fig. 1.

Referring now to the drawing and more particularly to Fig. 1, there is illustrated, by way of example, a circular polarization antenna comprising a wave guide 10, having a circular cross section, connected to the output of a transmitter or receiver apparatus as shown in Fig. 1A. Wave guide 10 has a plurality of tilted slots 11 cut therein at equi-spaced positions along the circumference thereof, and a pair of annular, parallel, reflecting plates 12 and 13 encircling guide 10 above and below the area of slots 11. The reflecting plates 12 and 13 are spaced at least a half wavelength and preferably not more than a wavelength apart. Plates 12 and 13 are sufficiently large and extend radially for a distance preferably more than a quarter wavelength from the wave guide 10 to produce an appreciable wave guide effect on the energy radiated from slots 11 which are preferably tilted at approximately 60 degrees from the horizontal when wave guide 10 is in its contemplated vertical position. If desired a series of such slots and plates may be spaced along the length of wave guide 10 in proper phase relationship to produce a combined pancake type beam pattern.

The theory underlying the invention may be understood by referring to Fig. 2 showing a vector diagram of the energy radiated from a slot 11. The direction of propagation from slot 11 is perpendicular to the plane of the drawing. Vector E, therefore, represents the voltage of radiated energy, being perpendicular to the slot.

Considering operation of the antenna from the transmitting point of view it will be evident that the radiation energy issuing from slot 11 must have plane polarization in a direction perpendicular to the axis of the slot as represented by vector E; otherwise the slot will not radiate energy. If the energy in the guide is of a mode which can be resolved to have an electric component in that direction, it will be suitable for feeding the guide. Furthermore, the electric component should be symmetrical around the inner circumference of the guide to radiate effectively from all the slots which symmetrically encircle the guide.

Conversely from the receiving point of view

the slot can only accept energy having a component of its electric vector in a direction perpendicular to the slot as shown by the vector E.

It follows that within the circular guide shown, the preferred mode that can be employed is the $TM_{0,1}$ mode. Its rectangular guide counterpart, the $TM_{1,1}$ mode, could be used with a slotted rectangular guide.

The $TE_{1,1}$ fundamental mode in the circular guide would be ineffective since it is unsymmetrical and would provide radiation from only a part of the slots which symmetrically encircle the guide shown in Fig. 1 and hence would not be employed. However, its rectangular guide counterpart, $TE_{0,1}$ mode can and would preferably be employed in a rectangular wave guide where the slots 11 would be located in only the wider surfaces of the guide.

The terminology for modes in wave guides as here employed is that given in "Radar Electronic Fundamentals," published by the Bureau of Ships of the Navy Department, page 369.

Fig. 1A is a cross section view of Fig. 1 and illustrates the introduction of a wave of the preferred fundamental mode $TM_{0,1}$ supplied by generator 14 via connections to the wall of the guide and to an exciting element 15. The conventional representation for magnetic and electric lines of force within the guide is employed in this illustration.

For purposes of illustration, vector E is divided into two component vectors—E_z and E_y. Since vector E_z lies in the plane of parallel reflectors 12 and 13, it is effectively contained in a wave guide and will no longer have free space velocity. Consequently, vector E_z will lag vector E_y. There will also occur a slight amount of attenuation of vector E_z due to conduction losses, with the net result, if proper adjustments are made in the angle of slot 11, that vector E_y and E_z will be 90 degrees out of phase with each other and of equal absolute magnitude. This results in a circular polarized wave radiating from the antenna with a complete 360 degree azimuth coverage. It will be seen that different types of horizontal or vertical polarization effects may be obtained by varying the tilt of slots 11. In other words various degrees of elliptical polarization may be had; the most desirable degree, of course, being the circular polarization as described above.

Although the invention has been illustrated in a preferred embodiment entailing a circular wave guide 10, it is to be understood that the invention is operable with a rectangular guide or a coaxial line and external reflecting plates.

While there has been described what is at present considered a 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 aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In an antenna arrangement, the combination comprising a wave guide, having a slot therein, connected to a source of wave energy, and a pair of parallel reflector plates arranged with said slot therebetween so as to have a wave guide effect on energy radiated therefrom, said slot being tilted at an angle relative to the planes of said plates different from 90° and 0° whereby one of the vector components of the voltage vector of energy propagated from the slot lies in the plane of said parallel plates.

2. A circularly polarized antenna comprising a wave guide having a plurality of tilted slots equi-spaced around the periphery thereof, and a pair of reflector plates arranged in parallel above and below said slots at least one-half wavelength apart at the operating frequency, said slots being tilted at an angle different from 90° and 0° relative to the planes of said plates whereby one of the vector components of the voltage vector of energy propagated from the slot lies in the plane of said parallel plates.

3. A circularly polarized antenna comprising a circular wave guide having a plurality of tilted slots equi-spaced around the circumference thereof, and a pair of annular reflecting plates encircling said wave guide arranged in parallel above and below said slots at least one-half wavelength apart at the operating frequency, said slots being tilted at an angle different from 90° and 0° relative to the planes of said plates whereby one of the vector components of the voltage vector of energy propagated from the slots lies in the plane of said parallel plates.

4. A circularly polarized antenna comprising a waveguide having a plurality of tilted slots equi-spaced around the circumference of the waveguide, means for supplying microwave energy to said guide, said energy having an electric vector component normal to the axes of said slots, and a pair of annular reflecting plates encircling said waveguide arranged in parallel above and below said slots at least one-half wavelength apart at the frequency of said microwave energy, said slots being tilted at an angle different from 90° and 0° relative to the planes of said plates whereby one of the vector components of the voltage vector of energy propagated from the slots lies in the plane of said parallel plates.

5. An antenna comprising a circular wave guide having a plurality of slots equi-spaced around the circumference thereof, and a pair of annular reflecting plates secured around said wave guide arranged parallel to each other above and below said slots at least one-half wavelength apart at the operating frequency, the radial width of said plates being more than a quarter of the wavelength of said operating frequency, said slots being tilted at an angle of substantially 60 degrees relative to the cross-sectional plane of said wave guide whereby one of the vector components of the voltage vector of energy radiated from said slots lies in the plane of said parallel plates, said vector component being so affected by said plates and attenuated that the same will be 90 degrees out of phase with and of equal magnitude to the other voltage vector component whereby circularly polarized radiation will be produced.

6. An antenna structure for transmitting and receiving elliptically polarized waves which may be defined from the transmission point of view, as comprising a waveguide portion having a slot shaped aperture for radiating a plane polarized wave, means comprising a pair of waveguide surfaces spaced apart by at least a half of the operating wave length and disposed about said slot at an angle different from 90° and 0° relative to the direction of said slot for changing the velocity of a component of said wave over a predetermined length of path, said surfaces extending from said waveguide such a distance as to provide a time quadrature displacement of said component thereby effectively to radiate an elliptically polarized wave.

7. An antenna for transmitting and receiving elliptically polarized electromagnetic wave energy, comprising a waveguide provided with a slot

and a pair of parallel plates positioned adjacent said slot and with said slot therebetween and with the planes of said plates at an angle to the length of said slot different from 90° and 0° whereby said plates have a waveguide effect on a vector component only of the electromagnetic energy radiated from said slot and said vector component is retarded with respect to the remainder of the radiated electromagnetic energy for producing elliptical polarization.

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