United States Patent

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[73] Assignee **The United States of America as represented by the Secretary of the Navy**

[54] **POLARIZATION ROTATOR**
5 Claims, 5 Drawing Figs.

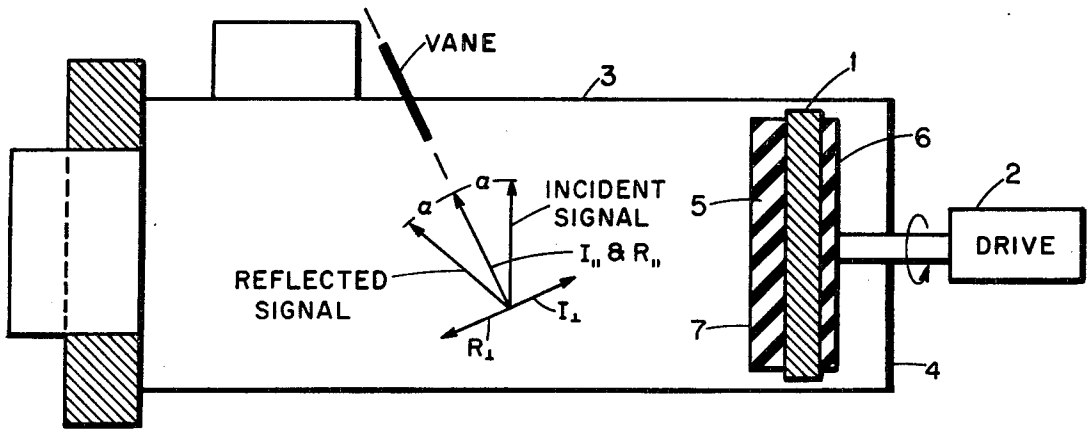
[52] **U.S. Cl.** ..... **333/21 A, 333/98**
[51] **Int. Cl.** **H01p 1/16**
[50] **Field of Search** ..... 333/21, 21 A, 98, 7; 343/756, 909

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ABSTRACT: A microwave polarization rotator is disclosed wherein a conducting vane, mounted for rotation about the longitudinal axis of a circular waveguide and placed ahead of a shorting plate which closes one end of the waveguide, is disposed within a dielectric disk which operates as a frequency-compensating means for effectively broadbanding the apparatus.



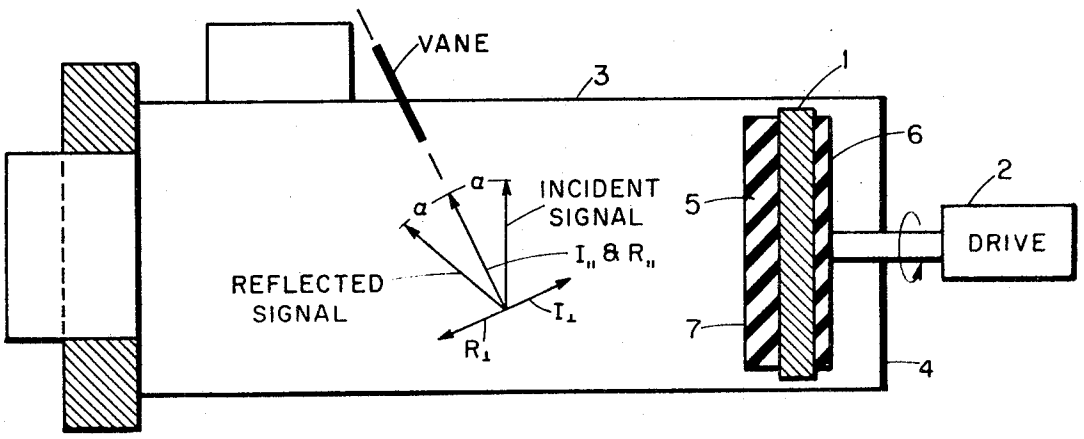


Fig. 1

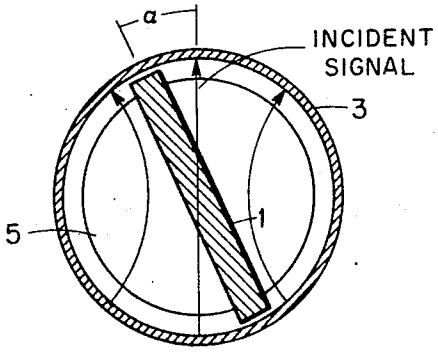


Fig. 2

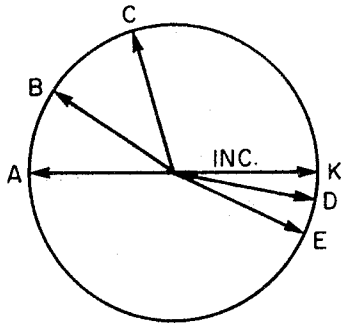


Fig. 3

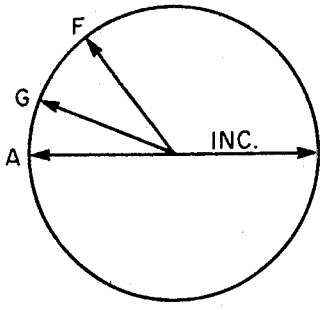


Fig. 4

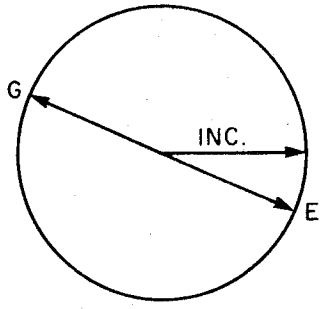


Fig. 5

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POLARIZATION ROTATOR

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to microwave transmission apparatus and, more particularly, to a single-port waveguide component which is capable of changing the polarization of incident electromagnetic energy.

There are available in the microwave art reflection polarization rotators which receive incident electromagnetic energy, effect control of the polarization of this energy and, thereafter, reflect it back towards its source. These devices, as is well known, find a wide variety of applications in closed waveguide systems or in radiating systems as, for example, continuously variable phase shifters or power dividers.

One of the reflection polarization rotators that is utilized with circular waveguides consists of a conducting vane mounted for rotation about the longitudinal axis of the waveguide and spaced ahead of an end-shorting plate a distance corresponding to one-quarter wavelength of the electromagnetic energy.

The action of the vane as a polarization rotator can be best explained by means of suitable vector diagrams wherein the linear polarization signal propagating down the waveguide is resolved into two vectors, one parallel to the vane and the other perpendicular thereto. These incident components, as is well known, react differently within the polarization rotator. For example, the component parallel to the vane is reflected at the leading edge of the vane and is inverted at this point, whereas the component perpendicular to the vane does not experience such an inversion until it reaches the shorting plate. Since the rotating vane is one-quarter wavelength ahead of the shorting plate, the perpendicular component travels one-half wavelength more than the parallel component. Thus, at a reference point down the waveguide, for example, one-half wavelength ahead of the vane, the component normal to the vane has a net change in phase of 180° while that component parallel to the vane has a zero change in phase. Consequently, if the vane makes an angle α with the incident signal polarization, the resultant of the two reflected components, that is, the parallel and the perpendicular, will show that the polarization of the reflected signal is at an angle of 2α with this incident signal. The vane and the shorting plate behind consequently perform as a polarization rotator wherein the polarization of the reflected signal is a function of the angular position of the vane.

If, for example, an orthogonal mode diplexer is positioned at the input of the polarization rotator, that component of the reflected signal which, for example, is normal to the input signal may be separated from the remainder of the signal and directed out of the waveguide through a side port. The other component of the reflected signal may be isolated from the input signal by utilizing a nonreciprocal circulator. In such an arrangement, the input signal may be divided in a proportion governed by the angular position of the rotating vane.

Functionally, the above described apparatus performs like a rotating half-wavelength plate. The advantage of employing the rotating vane, however, is the greater mechanical simplicity of this construction and the smaller space required for the apparatus. Because of the very low inertia of the moving vane, faster scanning and switching cycles are obtainable.

The rotating vane assembly, as mentioned hereinbefore, operates most effectively at a particular frequency, namely, that frequency whose one-quarter wavelength corresponds to the spacing between the leading edge of the vane and the shorting plate. It is, therefore, bandwidth limited. At frequencies other than the above, the reflected signal components that are parallel and perpendicular to the vane no longer have the same relative phase and, consequently, their combination does not result in a linearly polarized signal at the 2α angle. What is produced is an elliptically polarized signal whose specific characteristics depend upon the amplitudes of these components and the phase therebetween. If the reflected components produce an elliptically polarized signal, it will be appreciated, the operation of the apparatus is degraded since, in the case mentioned above, the different components of the reflected signal cannot be isolated from the input signal by the devices described and the vane position will not serve to divide the input signal into the proportions desired.

It is, accordingly, a primary object of the present invention to provide a rotating vane type of microwave polarization rotator which has a relatively wide band.

A second object of the present invention is to provide an improved polarization rotator wherein a rotating vane positioned ahead of a shorting plate in a circular waveguide is disposed within a dielectric disk which rotates therewith.

Another object of the present invention is to provide a reflection polarization rotator which has a frequency compensation means which effectively broadbands the apparatus.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic illustration of an arrangement wherein the polarization rotator is employed with orthogonally disposed, rectangular waveguide sections;

FIG. 2 is a transverse sectional view through the vane showing its relationship to the dielectric disk; and

FIGS. 3, 4 and 5 are impedance vector diagrams plotted on a Smith impedance chart.

Referring now to FIG. 1 of the drawings, it will be seen that the polarization rotator consists of a conducting vane 1, which is adapted to be rotated by drive 2 about the longitudinal axis of symmetry of a circular waveguide 3. This waveguide section is terminated in a shorting plate 4. Vane 1, according to the invention, is disposed within a dielectric disk 5. And, as perhaps better shown in FIG. 2, it has a length slightly greater than the diameter of the dielectric disk so that small end portions thereof extend beyond the dielectric disk in proximity to the inner wall surface of the circular waveguide. The extension of the vane beyond the dielectric disk prevents damage to the dielectric in the case of arcing-over of the conducting vane in the presence of strong electric fields.

By mounting the rotating vane within the dielectric disk, the frequency sensitivity of the polarization rotator is reduced. As mentioned hereinbefore, without this dielectric disk, the leading edge of the rotating vane should be one-quarter wavelength away from the shorting plate. At this frequency the signal components that are parallel and perpendicular to the vane remain in phase at the leading edge of the vane. Consequently, at a reference point, for example, one-half wavelength ahead of the vane, the component parallel to the vane will have had zero phase shift, while the perpendicular component will have had a 180° phase shift. If the vane is at an angle α with the incident signal and if this signal polarization at this point is in a vertical direction, the reflected polarization at this same point then will be at an angle 2α therewith, as shown in the vector diagram included in FIG. 1.

If the frequency of the incident electromagnetic signal changes, the distance from the leading edge of the vane and the shorting plate will no longer be a quarter wavelength. Consequently, the reflected components at the leading edge of the vane will no longer be in phase and their resultant at the reference point will be a reflected signal, not of linear polarization, but of elliptical polarization. The inclusion of the dielectric disk in the rotator serves to, in effect, keep the parallel and the perpendicular component in proper phase at the face of the dielectric over the frequency band. If this is accomplished, then the linear polarization of the reflected signal will be preserved.

The characteristic impedance of a circular wave guide may be expressed as

$$Z=\frac{K\lambda_g}{\sqrt{\epsilon}\lambda_0}=\frac{K\lambda_g}{\lambda} \quad (1)$$

where ϵ is the dielectric constant and K is a proportionality factor.

The ratio of the characteristic impedance of the circular wave guide with air and with a dielectric is

$$(2) \qquad R=\lambda_g^A/\lambda_g^D$$

where λ_g^A is guide wavelength with air filled guide and λ_g^D is guide wavelength with dielectric filled guide. This ratio increases as the frequency decreases because λ_g^A increases at a faster rate than λ_g^D. It is this variation that provides a means of compensating the frequency sensitivity of the quarter wavelength spacing in the rotator.

The compensating action of the dielectric disk may, perhaps, best be understood by considering the impedance transformations which occur within the waveguide as plotted on a Smith impedance chart. If one considers the prior art arrangement where the dielectric disk is omitted and the rotating vane is acting alone, then, starting at the shorting plate 4 and moving towards the signal source, the impedance for the component of signal normal to the vane is zero at this plate and corresponds to vector A in FIG. 3. If the space from the shorting plate to the leading edge of the vane is a quarter wavelength, then the impedance for the normal component at the edge of the vane 8 is infinite as represented by the opposite vector K. At a lower frequency, the reflection vector K is somewhat counterclockwise from the midband position of vector K and at a higher frequency it is somewhat clockwise. The impedance of the component of the signal parallel to the vane is zero at this edge 8 of the vane, and the reflection vector falls at A. Vectors A and K should be 180° —apart. If they are not, then the signal condition within the waveguide at the edge of the vane does not correspond to a linearly polarized signal condition.

The dielectric disk acts so as to, in effect, retard vector K at lower frequencies and to advance vector A until they are 180° apart.

Consider, now, the situation where the dielectric disk is included in the rotator so that a predetermined thickness of dielectric material occurs on both sides of the vane. As in the case just mentioned, the impedance for the component of the signal normal to the vane is again zero at the shorting plate 4 as represented by vector A in FIG. 3. Moving now towards the signal source from this short by the distance to the air-dielectric interface 6 on the face of the dielectric disk, the reflection vector moves clockwise to B. The amount of this displacement, it will be appreciated, depends upon the separation between the back face of the dielectric disk and the shorting plate in terms of the signal frequency. In order to renormalize the impedance and move to the inside of the dielectric disk, the impedance on the air side must be multiplied by the ratio R. This multiplication moves the vector clockwise to a position C. A further transformation in distance to the dielectric-air interface 7 of the disk moves the reflection vector to D. Again renormalizing the impedance to the air side of this interface by dividing by R results in the reflection vector being at E.

The impedance for the component of signal parallel to the vane is again zero at the leading edge 8 of the vane which is now embedded in the dielectric disk. Again, as shown in FIG. 4, this condition is represented by vector A in the impedance diagram. Transforming in distance through the dielectric to the outside dielectric-air interface 7 places the reflection vector at F. And renormalizing the impedance to the air side of this interface by dividing the impedance by the ratio R moves the reflection vector to G.

The reflection vectors on FIGS. 3 and 4 may be correlated by superimposing the incident signal components, which are the horizontal vectors that start at the center of the Smith diagram and extend towards the right. This can be done because the two incident signals are in phase by virtue of being components of a linearly polarized signal. As shown in FIG. 5, when this is done, the relative phases of the reflected output components correspond to the vectors E and G in this figure. If the dielectric is properly dimensioned and spaced with respect to the shorting plate, these vectors should be 180° apart as shown in this figure.

The compensation action of the dielectric material can now be appreciated by considering the effects of a decrease in the frequency of the electromagnetic signal. When this occurs, the magnitude of the transformation steps from vectors A to B and C to D in FIG. 3 decrease. Likewise, the transformation step from —A to F in FIG. 4 decreases. This causes vectors E and G to advance counterclockwise, with E advancing much more than G, tending to destroy the desired 180° relationship. However, the renormalizing steps B to C and D to E in FIG. 3 and F to G increase as a result of the increasing value of R. This has the result of causing vector E to retard and vector G to advance, tending to restore the 180° relationship. Thus, with the proper choice of parameters, that is, by a selection of the distance from the shorting plate to the back face of the dielectric disk, the thickness of this disk and the disposition of the vane within this disk, the vectors E and G in FIG. 5 may be held very close to 180° over a reasonable bandwidth.

Although the arrangement shown in FIG. 1 results in a predetermined thickness of dielectric material on each side of the vane, it should be appreciated that the same results may be realized, for example, by locating the vane on the back side of the disk, provided, of course, the dimensional conditions necessary to maintain the proper phase relationships of the reflected signal components are maintained.

What is claimed is:

1. A broadband microwave-energy signal-polarization rotator comprising, in combination,

a hollow, circular, waveguide section closed off at one end by a conducting surface, the open end serving as an input terminal for a band of linearly polarized, microwave energy signals;

a conducting vane positioned inside said section and spaced from said conducting surface;

means for rotating said vane about the longitudinal axis of symmetry of said waveguide section;

said vane and said conducting surface reflecting those components of said microwave energy signals which are parallel to and perpendicular to said vane, respectively; and

a dielectric device positioned at said vane for insuring the proper phase relationship of said reflected components over said band so that a linearly polarized, reflected signal is propagated —down said waveguide section towards the open end thereof.

2. A broadband microwave-energy polarization rotator comprising, in combination,

a section of hollow, circular waveguide, one end of said section being closed by a conducting surface and the other end serving as the input terminal for a band of linearly polarized microwave energy signals;

a conducting vane positioned inside said section ahead of said conducting surface;

means for rotating said vane about the longitudinal axis of symmetry of said section; and

a layer of dielectric material contacting said vane and covering a substantial portion of the cross-sectional area of said waveguide section,

the spacing between said conducting surface and said vane and the thickness of said layer being such that the two components of said microwave energy signals which are reflected at said surface and at said vane have the proper phase relationship at the surface of said layer facing said input terminal so as to maintain the linearly polarized condition of the reflected signal whose polarization has been rotated by said vane.

3. A broadband microwave-energy polarization rotator comprising, in combination,

a hollow, circular waveguide section closed off at one end;

a conducting vane positioned inside said section and spaced from said closed end by a fixed distance;

means for rotating said vane about the longitudinal axis of symmetry of said section;

a dielectric disk having a diameter slightly less than the internal diameter of said waveguide section;

said vane being disposed within said dielectric disc such that a predetermined thickness of dielectric material is present on each side of said vane which is related to said fixed distance and the center frequency of the band of microwave signals which are coupled to the open end of said waveguide section during the operation of said polarization rotator.

4. In an arrangement as defined in claim 3,

a microwave signal coupler connected to the open end of said circular waveguide section for introducing said microwave signals and for extracting these signals after their polarization has been rotated by said conducting vane.

5. In an arrangement as defined in claim 3,

wherein the tip ends of said vane project beyond said dielectric disk in close proximity to the inner wall surface of said waveguide section, whereby said dielectric disk is protected against electrical discharges when a high electrical field exists within the waveguide section.

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