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Ohm

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[54] **DIFFERENTIAL ATTENUATOR HAVING A ZERO NET DIFFERENTIAL PHASE-SHIFT**

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[51] **Int. Cl.** **H01p 1/22**

[58] **Field of Search** ..... 333/31 A, 81 R, 81 B

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[57] **ABSTRACT**

A differential attenuator having a substantially zero net differential phase-shift. The aforesaid zero net differential phase-shift is realized by disposing phase-shift means within the attenuator to provide a differential phase-shift which cancels the differential phase-shift induced by the attenuator attenuating elements.

12 Claims, 3 Drawing Figures

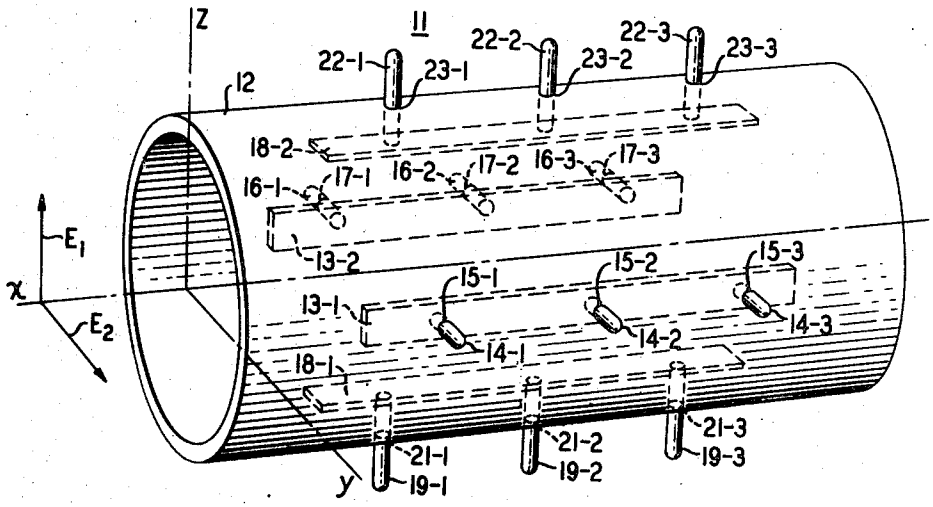


FIG. 1

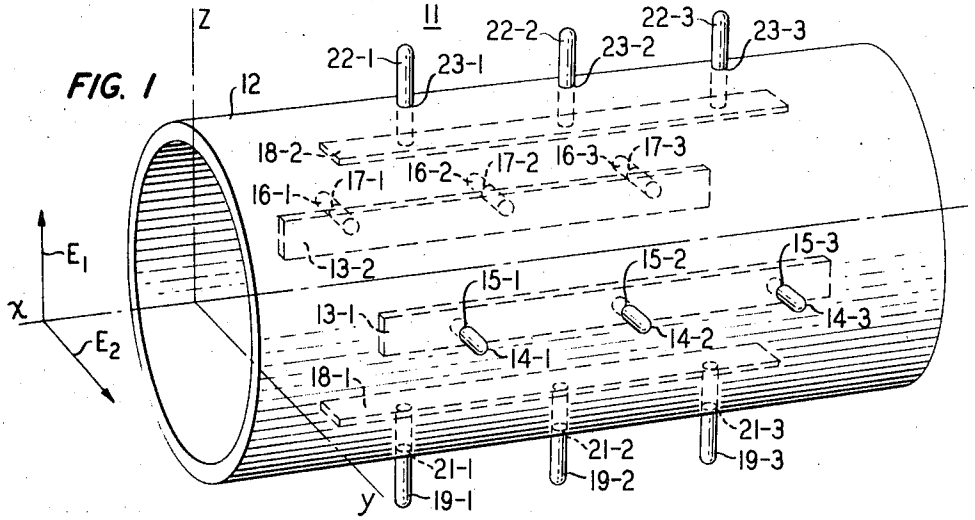


FIG. 2

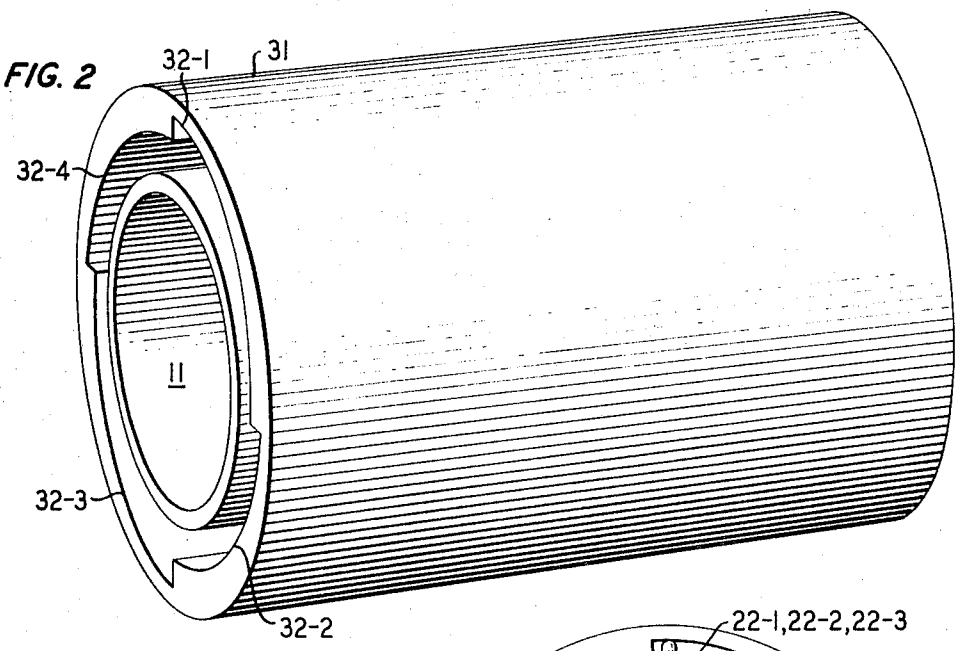
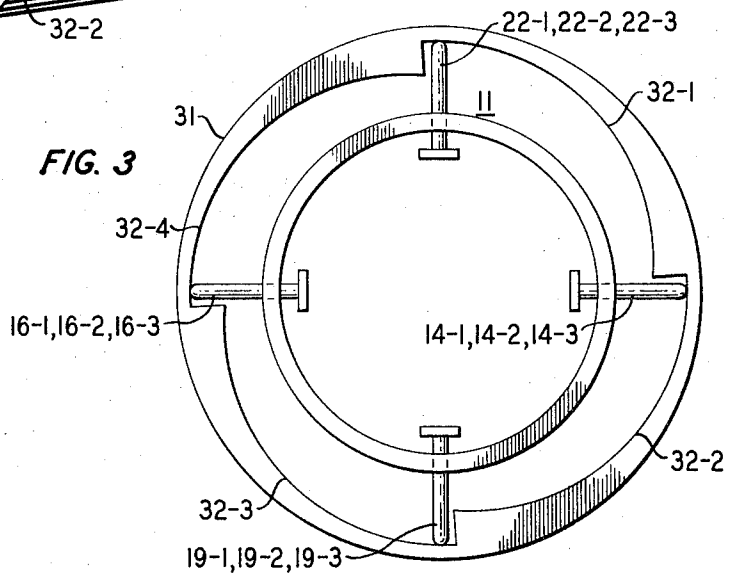


FIG. 3



DIFFERENTIAL ATTENUATOR HAVING A ZERO NET DIFFERENTIAL PHASE-SHIFT

BACKGROUND OF THE INVENTION

This invention relates to microwave transmission systems employing dual polarizations and, in particular, to microwave attenuators for use in such systems.

It is well known in the microwave art to simultaneously transmit two information signals via two orthogonal polarizations. In such dual polarization systems, it may become necessary to provide different amounts of attenuation along the two orthogonal polarization directions, as for example, when it is desired to orthogonalize the two transmitted polarizations after they have been nonorthogonalized as a result of imperfections in the transmission media. Devices for providing different amounts of attenuation along first and second orthogonal directions are known in the microwave art. Such devices will be referred to herein as differential attenuators and the difference in attenuation provided along the orthogonal directions as a differential attenuation.

A prior art differential attenuator might comprise a section of circular waveguide having disposed therein thin, elongated members or vanes, each comprising a lossy or attenuating dielectric material having a dielectric constant greater than one. The vanes are symmetrically arranged with respect to the waveguide axis and are so situated as to provide an increase in the attenuation constant of the guide in substantially one or the other of two orthogonal directions. Waves polarized in the direction in which the attenuation constant is increased are therefore attenuated to a greater degree than waves polarized in the other orthogonal direction and thus the desired difference in attenuation (i.e., differential attenuation) is achieved.

While the aforesaid differential attenuators are known to exhibit adequate attenuating properties, they are known to also exhibit undesirable phase-shift properties. In particular, since the attenuating vanes each comprise a dielectric material whose dielectric constant is greater than 1, their tendency is to induce not only an increase in the attenuation constant of the guide along one of the orthogonal directions but an increase in the phase constant as well. Thus waves polarized in that direction are shifted in phase as well as attenuated to a greater degree than corresponding waves in the other orthogonal direction. This differential phase-shift along the orthogonal directions is undesirable in that it tends to cause polarization rotations and/or conversions.

It is, therefore, a broad object of the present invention to provide a microwave differential attenuator which exhibits a substantially zero differential phase-shift.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, the above-mentioned and other objectives are realized by including within the waveguide section of the aforesaid prior art type attenuator, phase-shift means for providing a phase-shift substantially equal in magnitude but opposite in sense to that induced by the attenuator attenuating vanes. More particularly, two other vanes, each comprising a nonlossy dielectric material having a dielectric constant greater than one (i.e., an insulator) are symmetrically disposed within the guide relative to the guide axis. These vanes are positioned normal to the plane of the attenuating vanes and thus induce an increase in the phase constant of the guide along the orthogonal to the direction in which the attenuating vanes induced such an increase. As a result, a differential phase-shift arises which is of opposite sense to that created by the attenuating vanes. By appropriate selection of the distance of the nonlossy vanes from the guide axis, the magnitude of the differential phase-shift generated by these vanes is made equal to the magnitude of the phase-shift induced by the attenuating vanes. As a result, a substantially zero net differential phase-shift is exhibited by the attenuator.

DESCRIPTION OF THE DRAWINGS

The above and other features and aspects of the present invention will become more apparent upon consideration of the following detailed description taken in conjunction with the following drawings in which:

FIG. 1 shows an attenuator in accordance with the principles of the present invention;

FIG. 2 shows a second embodiment of the present invention in which means are provided for continuously varying the attenuation of the attenuator of FIG. 1 while simultaneously maintaining the net differential phase-shift of the attenuator at substantially zero; and

FIG. 3 shows a front view of the attenuator of FIG. 2.

DETAILED DESCRIPTION

Before entering into a discussion of FIG. 1, it should be noted that the terms "direction of polarization" and "polarization direction" are used herein to refer to the direction of the electric field of a propagating electromagnetic wave while the terms "plane of polarization" and "polarization plane" are used to refer to the plane defined by the aforesaid polarization direction and the wave propagation direction.

In FIG. 1, a differential attenuator 11 in accordance with the invention is shown situated in a reference coordinate system depicted by a mutually perpendicular set of axes x, y and z. The orthogonal z and y directions, respectively, of the reference system define the polarization directions of two orthogonal waves E_1 and E_2 which are to be attenuated by attenuator 11. The x direction, on the other hand, defines the propagation direction of the aforesaid waves. The plane of polarization of the E_1 wave is thus represented by the x-z plane, while the plane of polarization of the E_2 wave is represented by the x-y plane.

Attenuator 11 comprises a section of waveguide 12 which is illustratively depicted as having a circular cross-section. The axis of waveguide 12 is aligned with the x coordinate direction and thus with the propagation direction of waves E_1 and E_2. Disposed within waveguide 12 is a pair of thin, elongated members or vanes 13-1, 13-2 having thicknesses smaller than their widths and widths smaller than their lengths. Each of the latter vanes comprises a lossy or attenuating dielectric material having a dielectric constant greater than 1. Typically such vanes can be realized by coating a dielectric material which is essentially lossless with a resistive sheet such as, for example, a thin film of michrome.

Vanes 13-1 and 13-2 are symmetrically arranged relative to the waveguide axis and each is disposed in a

plane parallel to the x-z polarization plane. More particularly, each vane is arranged in its respective plane with its length along the guide axis and its width parallel to the z direction (i.e., the E_1 polarization direction).

A first plurality of rodlike members, shown illustratively as members **14-1** to **14-3**, extend through apertures **15-1** to **15-3**, respectively, in the waveguide wall and are affixed to vane **13-1** to support the vane within the guide. The rods **14** are slidably mounted in their respective apertures and thus enable movement of vane **13-1** in the y direction, either toward or away from the guide axis. Similarly, a second plurality of rodlike members, illustratively shown as rods **16-1** to **16-3**, extend through apertures **17-1** to **17-3** in the waveguide wall and are affixed to vane **13-2** to support this vane within the guide. These rods are also slidably mounted within their respective apertures thereby permitting movement of vane **13-2** in the y direction.

Since vanes **13-1** and **13-2** are lossy, their insertion within guide **12** has the effect of increasing the attenuation constant of the guide. Because of the manner in which the vanes are positioned, however, the aforesaid increase in attenuation constant is confined substantially to the z direction and, little or no increase in attenuation constant is induced in the orthogonal y direction. The E_1 wave which is polarized in the z direction is thus attenuated by the guide to a greater degree than the E_2 wave which is polarized in the orthogonal y direction. Attenuator **11** thus provides the desired differential attenuation between two orthogonally polarized E_1 and E_2 waves.

It should be noted that the aforesaid differential attenuation provided by attenuator **11** can be varied by simultaneously moving both the vanes **13-1** and **13-2** toward or away from the axis of guide **12.** In particular, the closer the vanes are to the guide axis the greater will be the induced increase in the attenuation constant. Thus movement of the vanes toward the axis causes an increase in differential attenuation, while movement of the vanes away from the axis causes a corresponding decrease in differential attenuation.

While vanes **13-1** and **13-2** result in a desired differential attenuation, the vanes have an additional undesirable effect. More particularly, since the vanes comprise a material whose dielectric constant is greater than **1,** their presence within the guide induces an increase in the phase constant as well as the attenuation constant of the guide. This increase in the guide phase constant is for the same direction of electric field as the increase in the attenuation constant (i.e., in the z direction). As a result, attenuator **11** exhibits an unwanted differential phase-shift, with the E_1 wave being shifted in phase to a greater degree than the E_2 wave.

In accordance with the principles of the present invention, the aforesaid unwanted differential phase-shift is substantially canceled by including within guide **12** a second set of vanes, **18-1** and **18-2.** As in the case of vanes **13-1** and **13-2,** vanes **18-1** and **18-2** have thicknesses smaller than their widths and widths smaller than their lengths. Moreover, each vane is supported in position within the guide by a plurality of slidably mounted rodlike members. In particular, rods **19-1** to **19-2** passing through apertures **21-1** to **21-3,** respectively, are used to support vane **19-1,** while rods **22-1** to **22-3,** passing through apertures **23-1** to **23-3** respectively are used to support vane **18-2.**

Each of the vanes **18-1** and **18-2** comprise a substantially nonlossy dielectric material whose dielectric constant is greater than **1.** Since vanes **18-1** and **18-2** are nonlossy, they do not alter the attenuation constant of the guide and thus have substantially no effect on the differential attenuation induced in the guide by vanes **13-1** and **13-2.** However, since the vanes comprise a dielectric material whose dielectric constant is greater than one, their presence within the guide does cause an increase in the guide phase constant. By arranging the vanes in planes parallel to the x-y polarization plane (i.e., normal to the plane of vanes **13-1** and **13-2**) with their lengths and widths, respectively, parallel to the x and y directions, the aforesaid induced increase in phase constant is substantially confined to the y direction with little or no increase being induced in the orthogonal z direction. As a result, vanes **18-1** and **18-2** cause the E_2 wave which is polarized in the y direction to be shifted in phase to a greater degree than the E_1 wave which is polarized in the orthogonal z direction.

The aforesaid differential phase-shift induced by vanes **18-1** and **18-2** to the waves E_1 and E_2 is thus opposite in sense to that induced by vanes **13-1** and **13-2.** As a result, the induced differential phase-shifts tend to cancel one another and the waves E_1 and E_2 depart attenuator **11** having substantially the same phase relationship as when they entered. The attenuator, therefore, exhibits a substantially zero net differential phase-shift with respect to the orthogonal E_1 and E_2 polarizations.

The precise positioning of vanes **18-1** and **18-2** to effect substantially complete cancellation of the differential phase-shift induced by vanes **13-1** and **13-2** is dependent, amongst other things, upon their own dielectric constant of vanes **13-1** and **13-2** and the distance of the latter vanes from the guide axis. Once having selected the dielectric constants for both pairs of vanes, however, for any given position of vanes **13-1** and **13-2,** the distance which vanes **18-1** and **18-2** must be placed from the waveguide axis to result in a substantially zero net differential phase-shift can be empirically determined.

As indicated above, the differential attenuation provided by attenuator **11** can be varied by simultaneously moving vanes **13-1** and **13-2** toward or away from the guide axis. In such cases, however, the position of the vanes **18-1** and **18-2** must also be varied in order to maintain the substantially zero net differential phase-shift condition. As with the attenuation, the closer the vanes **13-1** and **13-2** are to the guide axis, the larger will be the induced increase in phase constant. Thus, movement of the vanes toward the axis causes an increase in the differential phase-shift, while movement away results in a decrease in the differential phase-shift. Similarly, however, movement of vanes **18-1** and **18-2** toward the guide axis increases the differential phase-shift induced by these vanes while movement away decreases the induced differential phase-shift. Thus, simultaneous movement of vanes **18-1** and **18-2** in the same sense, relative to the guide axis, as vanes **13-1** and **13-2** will tend to result in a zero net differential phase-shift and a varying differential attenuation.

FIG. **2** shows an arrangement in which means are provided for simultaneously moving vanes **13-1** and **13-2** and vanes **18-1** and **18-2** in the same sense relative to the waveguide axis. Thus, the arrangement of FIG.

2 provides a variable differential attenuation but a substantially zero net differential phase-shift.

In FIG. 2, attenuator 11 is disposed within a cylindrical housing 31 which is rotatable relative to the attenuator. Housing 31 has an inner surface facing the attenuator which is divided into four camlike surfaces 32-1, 32-2, 32-3 and 32-4. As seen more clearly in FIG. 3, which is a frontal view of FIG. 2, each camlike surface is in contact with the rods associated with one of the vanes of attenuator 11. In particular, rods 21-1 to 21-3 ride on camlike surface 32-1, rods 14-1 to 14-3 ride on camlike surface 32-2, rods 18-1 to 18-3 ride on camlike surface 32-3, rods 16-1 to 16-3 ride on camlike surface 32-4. Movement of corresponding vanes, therefore, is controlled by alternate camlike surfaces. Tension springs (not shown) attached to each rod maintain each rod in contact with its respective surface.

In operation, a counterclockwise rotation of housing 31 causes the supporting rods of each of the vanes 13-1, 13-2 and 18-1 and 18-2 to ride on a lower portion of their respective camlike surface. Thus the rods supporting each vane are simultaneously moved toward the axis of the guide, thereby simultaneously moving each of the vanes toward the axis. Conversely, a clockwise rotation of the housing 31 causes the supporting rods of each vane to ride on a higher point of their respective camlike surface, thereby simultaneously moving the rods and, thus, the vanes away from the guide axis.

It is to be understood that the embodiments described herein are merely illustrative, and that numerous and varied other arrangements can be readily devised in accordance with the teachings of the present invention without departing from the spirit and scope of the invention. In particular, other mechanical means can be used to provide movement of the vanes of attenuator 11 in the manner provided by housing 31. Additionally, waveguide sections other than those having circular cross-sections can be employed for guide 12. In such cases, account must be taken for the inherent differential phase-shift caused by the different guide cross-sections, i.e., the differential phase-shift induced by vanes 18 must be such as to cancel both the differential phase-shift induced by vanes 13 and the inherent differential phase-shift resulting from the particular guide cross-section.

What is claimed is:

1. A microwave differential attenuator comprising:
a section of conductively bounded waveguide;
a first means for increasing the attenuation constant and phase constant of said guide along a first polarization direction relative to an orthogonal polarization direction;
and a second means for increasing the phase constant of said guide along said orthogonal polarization direction relative to said first polarization direction by an amount which results in said phase constant in said orthogonal polarization direction being equal to said increased phase constant in said first polarization direction.

2. A differential attenuator in accordance with claim 1 in which the increase in said phase constant along said polarization directions is equal.

3. A differential attenuator in accordance with claim 1 in which said first means comprises a lossy dielectric member having a dielectric constant greater than 1 and in which said second means comprises a nonlossy dielectric member having a dielectric constant greater than 1.

4. A microwave differential attenuator comprising:
a section of conductively bounded waveguide;
first means disposed within said waveguide for producing a differential attenuation and a differential phase-shift along first and second orthogonal directions;
and second means disposed within said waveguide for producing a differential phase-shift along said directions which is opposite in sense to that produced by said first means and which has a magnitude which results in a substantially zero net differential phase-shift along said directions.

5. A differential attenuator in accordance with claim 4 in which the said first and second means produce differential phase-shifts of equal magnitude.

6. A differential attenuator for providing a differential attenuation to waves having first and second orthogonal polarization directions comprising:
a section of conductively bounded waveguide having its axis orthogonal to each of said first and second polarization directions;
a pair of lossy dielectric vanes symmetrically disposed within said waveguide with respect to the axis thereof, each of said vanes having a dielectric constant greater than 1 and each being arranged in a plane parallel to the plane defined by said first polarization direction and said axis, said vanes being such as to induce an increase in the attenuation constant and the phase constant of said waveguide along said first polarization direction relative to said second polarization direction;
and a pair of nonlossy dielectric vanes disposed symmetrically within said waveguide with respect to the axis thereof, each of said vanes having a dielectric constant greater than 1 and each being arranged in a plane which is orthogonal to the planes of said lossy vanes, said nonlossy vanes being such as to induce an increase in the phase constant of said waveguide along said second polarization direction relative to said first polarization direction by an amount for which said phase constant in said second polarization direction is made equal to said increased phase constant in said first polarization direction.

7. A differential attenuator in accordance with claim 6 in which said guide has a circular cross section.

8. A differential attenuator in accordance with claim 6 in which each of said vanes has a thickness smaller than its width and a width smaller than its length and in which said lossy vanes are arranged with their lengths parallel to said axis and their widths parallel to said first polarization direction, and said nonlossy vanes are arranged with their lengths parallel to said axis and their widths parallel to said second polarization direction.

9. a differential attenuator in accordance with claim 6 which includes, in addition:
support means for movably supporting each of said vanes within said guide;
and means for moving each of said vanes within said guide.

10. A differential attenuator in accordance with claim 9 in which said vanes are simultaneously moved in the same sense relative to the guide axis.

11. A differential attenuator in accordance with claim 9 in which there are a plurality of apertures in the waveguide wall adjacent to each of said vanes and in which said support means comprises first, second, third and fourth pluralities of rodlike members, the rodlike members of each of said pluralities being affixed to one of said vanes and slidably mounted in the apertures adjacent to that one vane.

12. A differential attenuator in accordance with claim 11 in which said means for moving comprises a rotatable housing into which said guide is inserted, said housing having an inner surface facing said guide including four camlike surfaces, each of said camlike surfaces being in contact with the plurality of rodlike members associated with one of said vanes.

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