Feb. 20, 1951 A. G. FOX 2,542,185

ROTATABLE ATTENUATOR WITHOUT PHASE SHIFT

Filed Dec. 11, 1946

FIG. 1

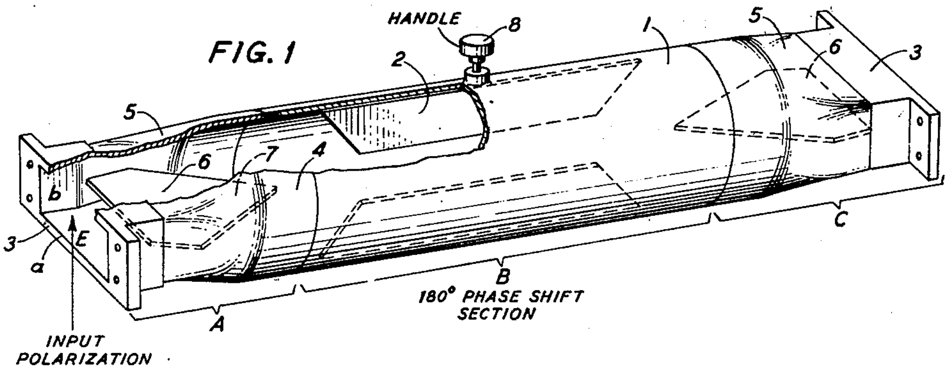


FIG. 2

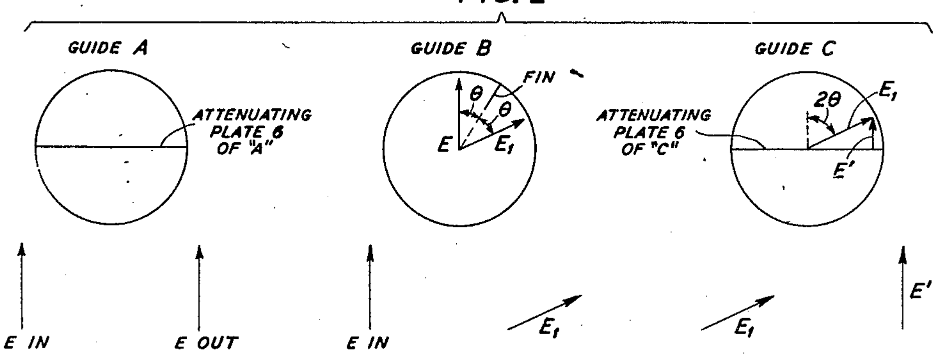


FIG. 3

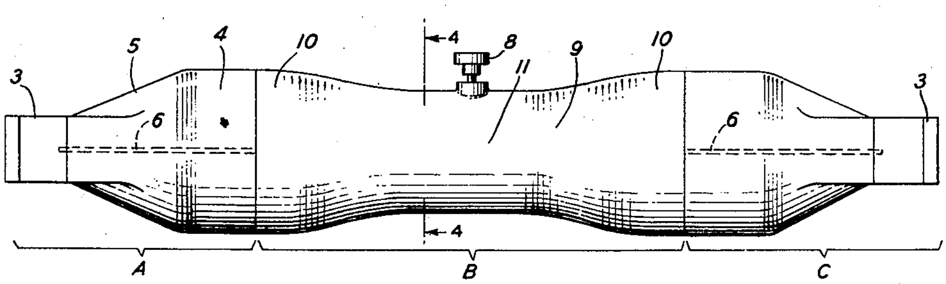
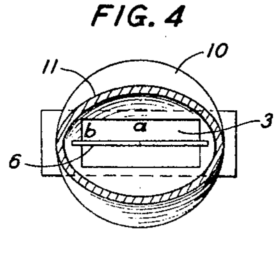


FIG. 4



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2,542,185

ROTATABLE ATTENUATOR WITHOUT PHASE SHIFT

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1 Claim. (Cl. 178—44)

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This invention relates to variable attenuators for wave guides.

An object of the invention is to variably attenuate electromagnetic waves in a wave guide without concomitantly introducing a phase change in the output as the attenuation is adjusted.

Another object of the invention is to continuously attenuate electromagnetic waves in a wave guide by means of a rotating guide section without introducing any change in output phase as the attenuation is adjusted.

Another object of the invention is to attenuate linearly polarized waves in accordance with a cosine function of the angle of rotation of its polarization, without introducing phase shifts.

Another object of the invention is to attenuate waves transmitted bilaterally through a wave guide without introducing shifts in phase or impedance mismatch.

A feature of the invention is a rotatable 180-degree differential phase shift section of wave guide connected between two stationary wave guide sections, each of the latter being provided with quadrature polarization suppressing devices.

Fig. 1 illustrates a rotatable attenuator in accordance with the invention;

Fig. 2 is an explanatory electric force vector diagram;

Fig. 3 is a modified rotatable attenuator; and

Fig. 4 is a section thereof taken along line 4—4.

Rotatable wave guide attenuators have heretofore been disclosed, for example, in the United States patent applications of A. E. Bowen, Serial No. 715,588, now Patent No. 2,531,194, issued November 21, 1950, and Serial No. 715,589, filed concurrently herewith. Such attenuators are characterized by a capability of attenuating linearly polarized waves as a trigonometric function of θ, the angle of rotation, without concomitant change of polarization direction.

Variable wave guide attenuators, utilizing resistance films or the like, have been known to introduce undesired phase shifts along with the desired changes in attenuation. However in precision microwave work, a need often arises for wave guide attenuators which can be varied without changing the phase of the transmitted wave.

In accordance with an embodiment of the invention, a rotatable attenuator is provided consisting of three wave guide sections A, B, C, the intermediate one B being rotatably connected to the stationary sections A, C, respectively. The wave guide section B is a rotatable phase shifter having a differential phase shift of 180 electrical degrees. The stationary end sections A, C are each provided with quadrature polarization suppressors in the form of attenuating plates, reflecting septa or polarization discriminators in the form of rectangular pipe sections.

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Referring to Fig. 1, there is shown a two-way or bilateral attenuator comprising cylindrical wave guide sections A, B, C.

The intermediate wave guide member B is a 180-degree differential phase shift section, coupled to the stationary end sections A, C by rotatable pipe joints, as more fully disclosed in the aforementioned, concurrently filed Bowen application. It may consist of a short length of cylindrical pipe 1, loaded by a metallic fin 2, more fully disclosed in the United States application of W. A. Tyrrell, Serial No. 590,365, filed April 26, 1945. Alternatively, it may be a cylindrical pipe, loaded with shunt rods as disclosed in the United States application of A. G. Fox, Serial No. 464,333, filed November 3, 1942, which has issued as United States Patent 2,438,119, May 23, 1948.

The stationary wave guide sections A, C are identical. Each comprises a rectangular wave guide portion 3, a circular pipe 4 integral therewith and connected thereto by a tapered, impedance matching transformer section 5. The rectangular pipe 3 is dimensioned and proportioned so as to only transmit waves of one polarization, for example, waves polarized vertically. The cross-sectional dimensions a, b of the rectangular guide 3 are:

$$a > \frac{\lambda_a}{2}$$

$$b < \frac{\lambda_a}{2}$$

where λ_a is the wavelength in air. The circular pipe 4 contains therein a diametral resistance film absorber or attenuating plate 6 with tapered, impedance matching terminals 7. The plate 6 will absorb all waves polarized at right angles to the input polarization.

The operation of the rotatable attenuator A, B, C is as follows: An incident wave (E_{in}) entering section A from the left is initially linearly polarized, whereby E_{in} is perpendicular to side a of the rectangle and plate 6, respectively. The incident wave E_{in} passes freely through guide section A, unaffected in amplitude (see Fig. 2) and enters section B, the 180-degree phase shift section. If the guide sections A, B, C are arranged in alignment, so that the attenuating plates 6 and fins 2 are coplanar then the incident wave will pass through the entire system A, B, C unchanged in phase and amplitude. However, if the intermediate guide section B is rotated, so that the fin 2 is inclined θ degrees to the perpendicular of plane 6—6, then the wave will emerge from section B, unchanged in amplitude, but with its polarization vector rotated through an angle 2θ, as more fully explained in the aforementioned United States applications of A. G. Fox, Serial No. 464,333 filed November 3, 1942, issued as United States Patent 2,438,119, May 23, 1948, and W. A. Tyrrell, Serial No. 590,365, filed April 26, 1945.

The vector diagram (Fig. 2) shows schematically how the input wave E_{in} passes through guide section B and emerges as vector E_1, unchanged in amplitude but rotated in polarization through an angle 2θ.

In passing through guide section C, the wave E_1 may be resolved into two components; one parallel to the attenuating plate 6 thereof and the other perpendicular thereto. The former will be totally absorbed and the latter will be transmitted on toward the load (not shown).

From the vector diagram (Fig. 2) it will be apparent that the wave which emerges from the system A, B, C is the unabsorbed component E′, perpendicular to plate 6.

E′ is related to E_1, the wave incident on section C by

$$E' = E_1 \cos 2\theta \quad (1)$$

or the amplitude of the emergent wave E′ is proportional to the cosine of the angle through which the incident, linear polarization of E_{in} was rotated, and hence can be made to vary from 100 per cent transmission to zero.

It should be apparent, however, that the resolution of the wave E_1 into orthogonal components in its passage through section C does not in any way change the time phase of the component E′ which emerges as the output polarization.

Hence, the output wave E′ emerges with no alteration in phase, as the 180-degree phase shift section B is rotated. Its amplitude however is relative to the input amplitude reduced, proportional to cos 2θ, where (2θ) is the angle through which the input polarization has been rotated.

It should be noted that there is no requirement for parallelism between the input and output polarizations. Thus, the output signal may be taken off at any desired angle of polarization with respect to the input, and the attenuation will depend only on the cosine of the angle between the polarization of the waves leaving the rotor 1 and the polarization in the output guide 3.

For waves traveling in the opposite direction, from right to left, the action of the rotatable attenuator A, B, C is the same as described, due to the symmetry of the arrangement of corresponding parts.

The rotatable attenuator A, B, C illustrated in Fig. 3 is a modification of the form shown in Fig. 1 and differs therefrom only in the 180-degree phase shift section B. Here, the section B is a cylindrical wave guide pipe 9, squashed into an elliptical cross-section near the middle thereof. The transition from circular 10 to elliptical cross-section 11 is gradual to provide a tapered impedance transformer and maintain an impedance match throughout. The number of degrees of differential phase shift will be determined by the amount of flattening produced and by the length of guide section B which has been flattened. The deformed central portion 11 serves to split the wave being propagated therethrough into two quadrature components and to speed up waves of one orientation with respect to those having an orientation at right angles thereto.

Fig. 4 shows the cross-sectional configurations of the squashed 180-degree phase shift section B, wherein the contour is elliptical at 11 and circular at 10 near the ends thereof.

For some applications, the rotatable attenuator may dispense with the rectangular pipe ends and be comprised of three circular sections of wave guide A, B, C as disclosed in the aforementioned Bowen application, Serial No. 715,589 concurrently filed herewith. Likewise, in lieu of the cross-component absorbing plates 6 as disclosed in this application, one may utilize an integral conductive septum and absorption plate for enhanced suppression of quadrature polarizations as disclosed in said Bowen application.

What is claimed is:

A bilateral wave guide attenuator with constant phase shift for linearly polarized input waves comprising a pair of stationary wave guides spaced apart and having a common longitudinal axis, each of said guides being provided with a longitudinal attenuating plate in a common plane containing said axis, means at the free ends of said guides adapted to pass waves linearly polarized perpendicularly to said plates and suppress the orthogonal polarizations, a 180-degree differential phase shift section comprising a wave guide rotatably connected to each of said stationary sections and having a longitudinal fin, means for rotating said fin and section through an angle θ with respect to the normal to said plates whereby continuous attenuation without concomitant phase change is provided.

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