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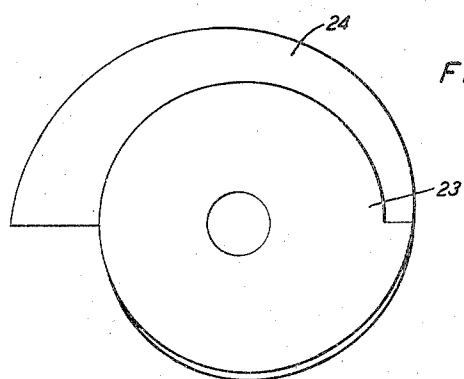
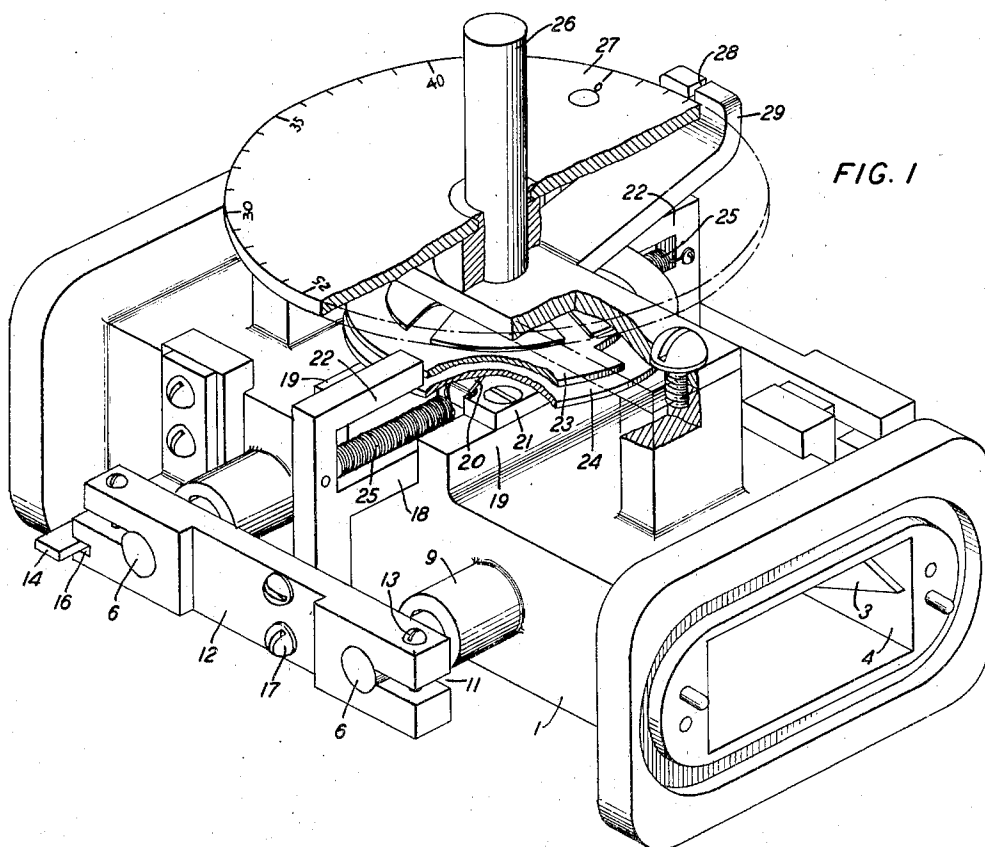
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2,491,662

ATTENUATOR

Filed March 30, 1945

2 Sheets-Sheet 1



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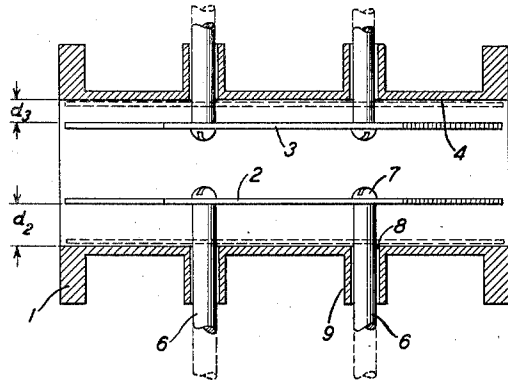


FIG. 3

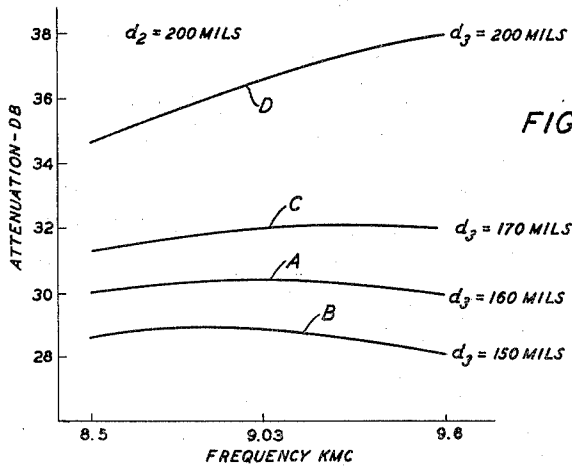


FIG. 4

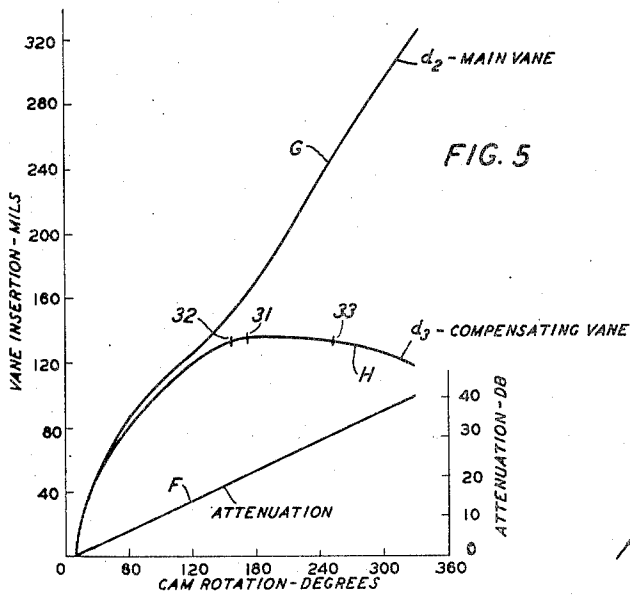


FIG. 5

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ATTENUATOR

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This invention relates to attenuators and more particularly to those for use with wave guides.

The principal object of the invention is to minimize the change in the attenuation of a wave guide attenuator caused by varying the frequency over a selected range.

Another object is to make the attenuation of a variable wave guide attenuator a linear function of the angular rotation of a control shaft while maintaining the condition of minimum attenuation variation with frequency.

A wave guide attenuator may comprise one or more resistive vanes positioned longitudinally within the guide. The attenuation introduced by such an attenuator depends, for one thing, upon the intensity of the electric field at the location of the vane. Therefore, in order to vary the attenuation the vane may be moved from a position of one intensity to a position of greater or less intensity. For example, two vanes may be positioned opposite each other and means provided for moving them from the side of the guide toward each other to the center. However, if the vanes are symmetrically positioned and moved at the same rate, the attenuation at any particular setting may not be sufficiently constant with frequency.

In accordance with the present invention the change in attenuation with frequency is very much reduced by positioning the vanes unsymmetrically and moving them at different rates so chosen that, for any setting, the attenuation has a minimum variation with frequency over a selected range. The positions of the two vanes may, for example, be controlled by two cams on a single shaft. As an added feature, the cams may be so shaped that the attenuation varies linearly with the angular rotation of the shaft.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawings, in which like reference characters refer to similar or corresponding parts and in which:

Fig. 1 is a perspective view, partly cut away, of a variable double-vane wave guide attenuator in accordance with the invention;

Fig. 2 is a plan view of the cams used in the attenuator;

Fig. 3 is a horizontal sectional view of a portion of the attenuator showing the vanes in their extreme positions;

Fig. 4 gives the attenuation-frequency characteristics over a selected range for a fixed main vane insertion and different compensating vane insertions; and

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Fig. 5 shows the insertion of the vanes and the attenuation of the attenuator, both plotted against the angular rotation of the cams.

As shown in Figs. 1 and 3 the attenuator comprises a section of wave guide 1 of rectangular cross section within which are two resistive elements 2 and 3 in the form of vanes having ends which are tapered to reduce reflection. The vanes 2 and 3 are positioned longitudinally opposite each other in the guide 1, with their major planes parallel to a side 4 of the guide 1 having the shorter transverse dimension. Each of the vanes 2 and 3 is attached to the ends of two rods 5 by the screws 7. The rods 6 pass through the side 4 of the guide 1 through holes 8 which are large enough in diameter to clear the rods 6 all around. Collars 9 attached to the sides 4 on the outside surround the rods 6 and help to prevent the escape of energy.

The outer ends of each pair of rods 6 associated with one of the vanes 2 or 3 are clamped in the slots 11 at the ends of a yoke 12 by means of the clamping screws 13. A guide 14 positioned in an additional slot 16 at one end of the yoke 12 prevents the yoke from rotating. Each yoke 12 is attached by means of the screws 17 to a guide bar 18 which slides in a transverse groove formed on the upper side of the wave guide 1 by the cross members 19 and covered by the plate 21. The guide bar 18 is forced toward the bottom of the groove by an arcuate spring 20 which is inserted between the plate 21 and guide bar 18 and has its ends bent around the edges of the plate 21. Each guide bar 18 has an arm 22 the end of which is held against the edge of one of the cams 23 or 24 by a helical spring 25. The cams 23 and 24 are affixed to a rotatable shaft 26 which carries a dial 27 graduated in decibels of attenuation. The dial 27 may be read at a slot 28 in the arm 29.

A typical lay out for the cams 23 and 24 is shown in Fig. 2. In accordance with the invention they are so designed that, for any setting of the dial 27, the change in attenuation with frequency over a selected range will be a minimum. In general, this requires that the vanes 2 and 3 have different insertions. That is, the distance d_1 between the side 4 of the wave guide 1 and the vane 3 will differ from the distance d_2 between the opposite side and the vane 2. Fig. 3 shows, in full line, the positions of the vanes 2 and 3 at maximum insertion and, in broken line, their positions at minimum insertion.

The following procedure is suggested for ob-

taining the required data for laying out the cams 23 and 24. Starting with a position at the side of the wave guide 1 the vane 2, which may be called the main vane, is inserted in steps of equal distance d_2 until it reaches its position of maximum attenuation. At each step the vane 3, which may be called the compensating vane, is adjusted in position by trial until a unique insertion d_3 is found which gives the smallest change in attenuation over the desired frequency range.

The curves of Fig. 4 show, for example, typical attenuation-frequency characteristics for a main vane insertion d_2 of 200 mils and various compensating vane insertions d_3 over a selected range of 8.5 to 9.6 kilomegacycles. It is seen that curve A, corresponding to d_3 equal to 160 mils, has the least change in attenuation over the range. For this insertion the attenuation has approximately the same value at the lowest frequency of 8.5 and at the highest frequency of 9.6 and is a maximum at approximately the geometric mean frequency of 9.03 kilomegacycles. These criteria are useful in determining if the optimum insertion d_3 for the compensating vane 3 has been found. For any other insertion d_3 , either larger or smaller, the attenuation change will be increased, as shown by curve B for d_3 equal to 150 mils and curve C for d_3 equal to 170 mils. As is apparent from curve D, if d_3 is made equal to d_2 , 200 mils, the change in attenuation over the range is very greatly increased. It follows, therefore, that for d_2 equal to 200 mils d_3 should be 160 mils. A similar procedure is followed to obtain the optimum compensating vane insertion d_3 for each insertion step d_2 of the main vane 2.

In general, the attenuation is not a linear function of the insertion d_2 of the main vane 2. However, the cams 23 and 24 may be so designed that the attenuation varies linearly with the angle of rotation of the shaft 26. The required curves are shown in Fig. 5. If, for example, the attenuation is to vary from a minimum of zero to a maximum of 40 decibels over an angular rotation from 10 to 330 degrees, the attenuation, read on the right-hand scale, is plotted as a straight line F' against cam rotation as abscissas. Next, the insertion d_2 for the main vane 2 is plotted against the nominal attenuation, for the different insertion steps, to give curve G. The nominal attenuation may be taken as that at the geometric mean frequency. Then the corresponding insertion d_3 for the compensating vane 3 is plotted to give the curve H. Data for the layout of the cams 23 and 24 may be read from the curves G and H, and for the calibration of the dial 27 from the curve F'. At the 10-degree point on the cams the vanes 2 and 3 will be held against the sides of the wave guide 1. To get an insertion of 200 mils for the vane 2, for example, will require a decrease of 200 mils in the distance from the edge to the center of the cam 24.

In operation, electromagnetic waves are impressed upon one end of the attenuator and a suitable load device is connected to the other end. The waves may, for example, be of the transverse electric type, with the electric lines of force parallel to the side 4 of the wave guide 1. The attenuation introduced is determined by the position of the vanes 2 and 3, under the control of the shaft 26 and the cams 23 and 24, and may be read on the dial 27. For any setting, however, the vanes 2 and 3 are positioned for maximum constancy of attenuation, as the frequency is varied over the selected range. Furthermore, the

attenuation is a linear function of the angular rotation of the shaft 26.

Although a rigid theoretical analysis of wave guide attenuators employing resistive vanes is extremely difficult, a rough theory which at least partially explains the superiority in constancy of attenuation of the "non-equal insertion" double-vane attenuator of the present invention over either the single-vane or the "equal insertion" double-vane type is as follows:

The equal insertion double-vane attenuator is superior to the single-vane type because the added vane couples, by mutual inductance, a compensating reactance in series with the intrinsic self-reactance of each vane, thus reducing the net series reactance in the vane and thereby reducing frequency sensitivity of the attenuation by making each vane act more like a true shunt resistance across the wave guide. However, the intrinsic self-reactance of each vane probably varies with its insertion into the guide and, in order to compensate it exactly by mutual coupling from another vane, this coupling must be varied in a definite way as the main vane insertion increases. In accordance with the invention, this coupling is properly controlled by providing the required compensating vane insertion d_3 for each insertion d_2 of the main vane 2. According to this analysis the non-equal insertion double-vane attenuator may be regarded as a compensated single-vane attenuator where the function of the main vane 2 is to increase the attenuation by a continuous increase in its insertion d_2 , as shown by curve G of Fig. 5, while the action of the compensating vane 3 is that of a tuning adjustment which couples in the proper amount of cancelling reactance at each position of the vane 2.

As may be seen from curve H of Fig. 5, for low values of attenuation the compensating vane 3 has a rate of insertion only slightly lower than that of the main vane 2. However, the insertion d_3 of the vane 3 reaches a maximum value, in the vicinity of the point 31, and then actually decreases for higher attenuations. Furthermore, over a considerable range, between the points 32 and 33, the insertion d_3 of the vane 3 remains substantially constant.

A variable attenuator to cover the limited range between the points 32 and 33 may, therefore, have a main vane 2 which is continuously inserted and a fixed compensating vane 3 with its insertion d_3 equal to the mean value for the range. Such an attenuator is simpler in construction since one cam 23, one of the guide bars 18, one of the yokes 12, and other associated parts may be eliminated.

What is claimed is:

1. An attenuator comprising a section of wave guide having unequal cross-sectional dimensions and adapted to transmit a transverse electric wave with its electric vector parallel to the shorter of said dimensions and two thin, flat resistive elements longitudinally positioned within said section, said elements being opposite each other, parallel to said shorter dimension and at different distances from the respective sides of said section and said distances being so related that the attenuation has a minimum variation over a selected range of frequencies.

2. An attenuator comprising a section of wave guide of rectangular cross section and two resistive vanes positioned within said section beside each other, parallel to opposite sides thereof, and at different distances therefrom so related that

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the attenuation has a minimum variation over a selected range of frequencies.

3. An attenuator in accordance with claim 2 in which the attenuation is approximately equal at the limiting frequencies of said range.

4. An attenuator in accordance with claim 2 in which the attenuation has its maximum value at approximately the geometric mean frequency of said range.

5. An attenuator in accordance with claim 2 which includes means for moving said vanes laterally to vary the attenuation over a range while maintaining the condition of minimum attenuation variation with frequency.

6. An attenuator in accordance with claim 2 which includes unitary control means for moving said vanes laterally to vary the attenuation over a range while maintaining the condition of minimum attenuation variation with frequency.

7. An attenuator in accordance with claim 2 which includes means comprising a rotatable control shaft for moving said vanes laterally to vary the attenuation over a range while maintaining the condition of minimum attenuation variation with frequency, said attenuation being a linear function of the angular rotation of said shaft.

8. An attenuator in accordance with claim 2 which includes means comprising a rotatable control shaft and two cams for moving said vanes laterally to vary the attenuation over a range, said cams being shaped to make the attenuation

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a linear function of the angular rotation of said shaft while maintaining the condition of minimum attenuation variation with frequency.

9. An attenuator in accordance with claim 2 which includes unitary control means for moving said vanes laterally to vary the attenuation over a range while maintaining the condition of minimum attenuation variation with frequency, one of said vanes moving in one direction only throughout said range and the other of said vanes moving in opposite directions in different parts of said range.

10. An attenuator in accordance with claim 2 which includes means for moving one of said vanes laterally to vary the attenuation over a range, the other of said vanes having a fixed position such that the condition of minimum attenuation variation with frequency is substantially maintained throughout said attenuation range.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,180,950	Bowen -----	Nov. 21, 1939
2,197,123	King -----	Apr. 16, 1940
2,207,845	Wolff -----	July 16, 1940
2,425,345	Ring -----	Aug. 12, 1947