

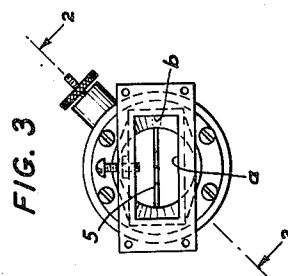
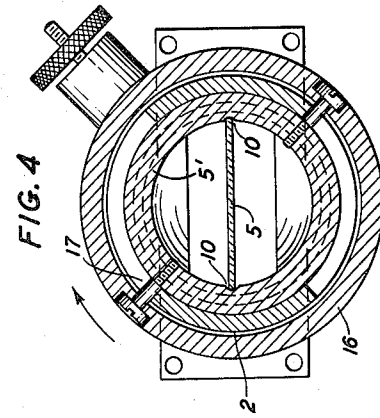
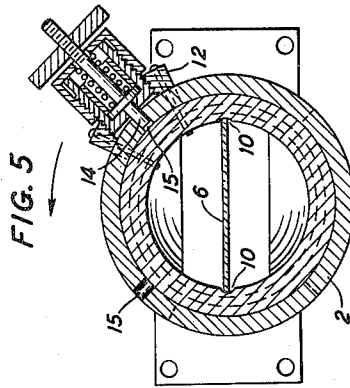
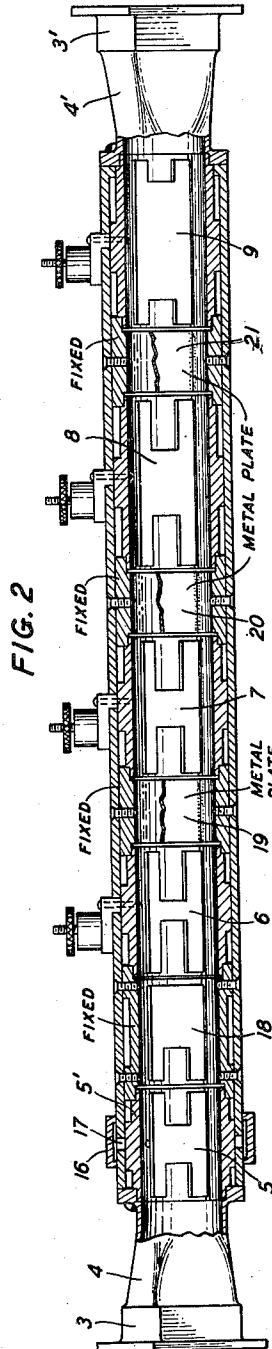
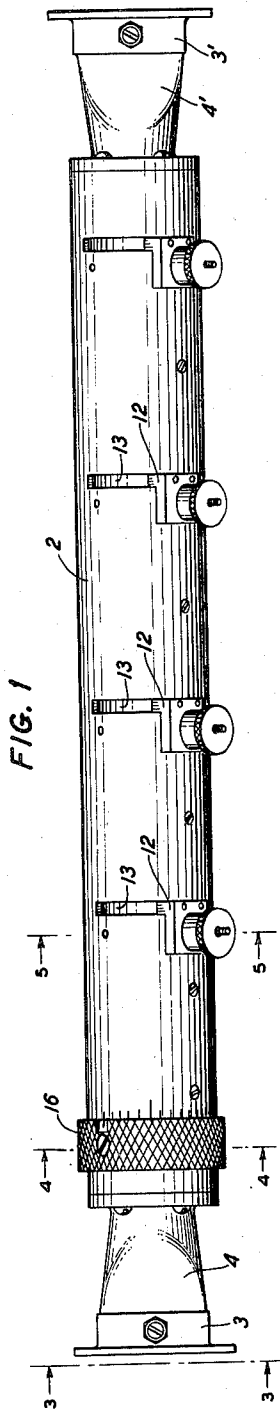
Nov. 21, 1950

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ROTATABLE VANE TYPE ATTENUATOR WITH
PLUG IN OR OUT ELEMENTS

2,531,194

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2 Sheets-Sheet 1



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FIG. 6

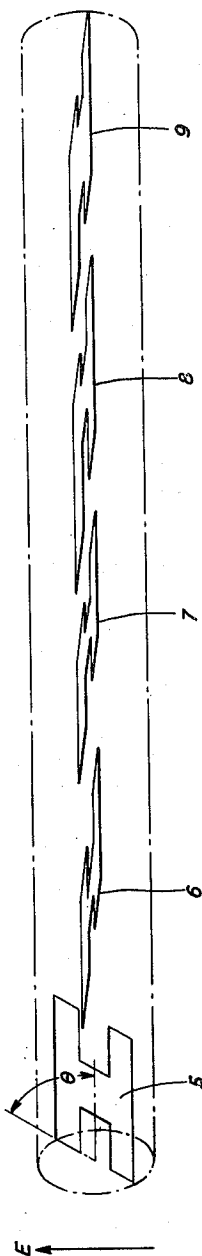
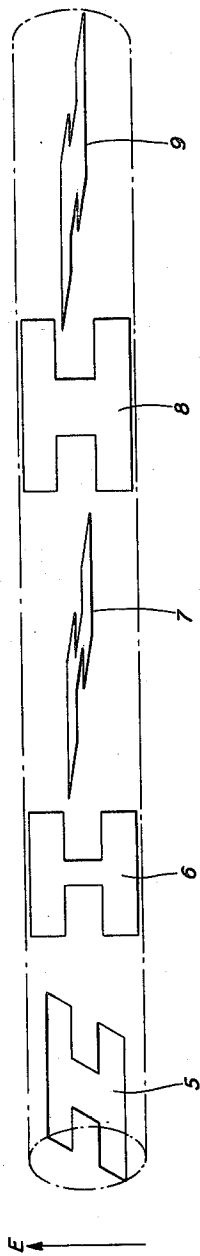


FIG. 7



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ROTATABLE VANE TYPE ATTENUATOR
WITH PLUG IN OR OUT ELEMENTS

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5 Claims. (Cl. 178-44)

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This invention relates to wave guide attenuators.

An object of the invention is to attenuate electromagnetic waves propagated in a wave guide in a series of discrete steps.

Another object of the invention is to provide in a wave guide the interpolation of a continuous series of attenuation values between a series of discrete attenuation values, the latter forming a geometrical progression.

A feature of the invention is a series of attenuation vanes having values in geometric progression adapted to be selectively brought into operative position by a 90-degree rotation with respect to the polarization of the dominant input wave.

Another feature of the invention is a rotatable attenuating vane with a $\cos^2 \theta$ characteristic adapted to introduce a continuous series of interpolated values of attenuation between a geometrically progressing series of attenuation values.

In accordance with an embodiment of the invention, there is provided an attenuator for wave guides, simulating in function a decade resistance box and comprising a cylindrical wave guide having a series of vane attenuators of fixed base values of attenuation, adapted to be selectively plugged into or out of operative position by a 90-degree rotation with respect to the polarization of the dominant wave. Certain ones of the attenuator vanes are thereby rendered active to form by their linear intercombination a set of discrete composite values of attenuation. To provide the intervening ranges of base values between successive composite values, a rotatable attenuator provides a continuous set of interpolated values according to a $\cos^2 \theta$ characteristic, where θ is the angle of rotation with respect to the input dominant wave.

Fig. 1 shows a side elevation of the wave guide attenuator;

Fig. 2 represents a longitudinal cross-section thereof;

Fig. 3 represents an end view taken along line 3-3;

Fig. 4 is a cross-sectional view taken along line 4-4;

Fig. 5 represents a cross-section along line 5-5 and shows the mechanism for rotating the attenuator vanes through 90 degrees;

Figs. 6 and 7 are explanatory diagrams of the operation of the device.

Continuous, rotatable attenuators having a $\cos^2 \theta$ law of variation heretofore are disclosed in my United States application Serial No. 715,587

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and Serial No. 715,589 filed concurrently herewith.

In accordance with the present invention a composite wave guide attenuator is disclosed which may be considered, in part, as the micro-wave analog of the well-known decade resistor box commonly used in electrical measurements. It is characterized by an attenuating vane adapted for continuous rotation which provides attenuation in decibels from 0 to a fixed base value a , in association with a series of plug-in or -out attenuating vanes which have discrete values of attenuation such as a , $2a$, $4a$, $8a$ forming a geometric series progression. All the attenuating vanes are spaced apart longitudinally in a cylindrical wave guide and are adapted to be selectively moved into or out of operative position, to thereby provide a linear intercombination of the base values a , $2a$, $4a$, $8a$, etc., with the continuous values $0-a$, whereby a wide continuum of attenuation values may be achieved.

Referring to Fig. 1, a cylindrical wave guide 2, which contains attenuating vanes therein (Fig. 2), is smoothly connected to rectangular guide end sections 3, 3' by tapered transformation guide sections 4, 4', the latter providing a gradual and reflectionless transformation of impedance from the round pipe 2 to the rectangular pipes 3, 3'. The rectangular sections 3, 3' establish a linearly polarized wave as the input, the electrical wave vector E thereof being parallel to the small (b) side of the rectangle (a, b).

Within the cylindrical wave guide 2, there is positioned a continuously variable attenuator 5 and a series of plug-in or -out vane attenuators 6-9, inclusive. Each of the attenuators 5-9 is of the structural type more fully disclosed in the United States applications of A. E. Bowen Serial No. 486,013, filed May 7, 1943, and W. H. Hewitt, Jr., Serial No. 551,040, filed August 24, 1944 with impedance matching terminals of notched or tapered form.

The continuously variable attenuator 5 is a $\cos^2 \theta$ law attenuator capable of providing 0- a decibels of attenuation by rotation thereof through an angle θ , whose limiting value is defined by said base value a with respect to the input wave vector E aforementioned (see Fig. 5). The $\cos^2 \theta$ law of operation of said attenuator 5 is more fully described in the United States application of A. E. Bowen, Serial No. 715,589 filed concurrently herewith.

The series of plug-in or -out attenuators 6-9, inclusive, are characterized by respective, intrinsic attenuation values progressing in geometric

series and represented by a , $2a$, $4a$, $8a$, etc., respectively.

Structurally, the vane 5 is attached to a rotatable ferrule 5' contained in and forming the effective inner wall of the guide 2 for wave transmission and guidance. Rotation of the ferrule 5' and vane 5 as a unit is performed manually by the milled ring 16 fastened to the ferrule 5' by screws 17. If desired for convenience, a mechanical stop may be provided to limit the angle θ to a value corresponding to the predetermined base attenuation a .

The attenuation values a , $2a$, $4a$, $8a$ may be formed by depositing a uniform layer of resistive material, such as carbon and the like, on vanes of longitudinal extent substantially progressing according to such geometric series as shown in Fig. 2. Alternatively, the vanes may be of equal size but the deposited material may be built up in layers of thickness such that the attenuation values conform to a geometric series characteristic.

Structurally, the plug-in or -out vane attenuators 6-9, inclusive, are spaced longitudinally along the cylindrical wave guide 2, as shown in Fig. 2. Each vane thereof is situated in a diametrical plane as illustrated in Fig. 5 and fits into recesses 10 formed in the walls of a corresponding rotatable ferrule 11, similar in structure to ferrule 5'.

The ferrule 11 and its vane is adapted to be rotated as a unit through an angle of 90 degrees by an integral finger 12 thereon which rides in a 90-degree slot 13 cut in the outer wall of the guide 2 as shown in greater detail in Figs. 1 and 5. A spring pressed locking pin 14 is adapted to fit into holes 15 to lock the attenuator vanes 6-9 in position at the ends of slot 13.

In addition to the series of movable vanes 5-9 previously described, the attenuator has fixed sections, shown in Fig. 2, whose purpose is either to totally absorb or to dissipate by to and fro reflection, all cross-components, perpendicular to the direction of vector E . Any such cross-components, which are present in the incident wave or develop during the progress of the wave E through the attenuator, are extinguished by the action of the fixed sections.

The fixed section 18 comprises a ferrule fixedly attached to the guide with an attenuating vane therein, parallel to side a of the rectangular cross-section. Cross-component waves passing through section 18 in either direction of transmission are effectively absorbed and suppressed thereby. The fixed sections 19, 20, 21 each contain a cross-component suppressor in the form of a diametral, metal plate, fixed parallel to the a dimension of the rectangle and therefore perpendicular to E .

A more detailed explanation of the action of cross-component suppressors is disclosed in the United States application of A. E. Bowen Serial No. 715,589, filed concurrently herewith.

Figs. 6 and 7 illustrate the mode of operation of the attenuator as a microwave analog of a decade resistor. Initially, the attenuator is adjusted to align all the attenuating vanes 5-9 and the cross-component suppressing vanes in one common plane perpendicular to vector E . This initial position may be considered the reference or zero attenuation position, for a linearly polarized wave having its electric vector E perpendicular to the common plane. To introduce attenuation, the vane 5 is first rotated through an angle θ , to provide an attenuation between 0 and a . For example, in a decimal system a may

represent an attenuation in decibels from 0-10. The zero attenuating position of vane 5 is perpendicular to E , and the a position is at an angle θ with respect to vector E , as illustrated in Fig. 6.

All the plug-in vanes 6-9 inclusive, remain in their initial position perpendicular to E . These vanes 6-9 are plugged in when an attenuation greater than a is required.

To obtain an attenuation between a and $2a$, for example, between 10 and 20 decibels, the plug-in attenuator 6 is brought into position parallel to E in one jump, by rotating the finger 12 in slot 13 through the quadrantal angle. This provides 10 decibels of attenuation in one discrete jump. Therefore, by combining consecutively the attenuations furnished by vane 5 and vane 6, a continuum of attenuations from 0-20 decibels is provided.

In similar manner, a continuum of attenuations from 0-40 decibels may be provided by adding vane 5 to the effect of plugging in vanes 6 and 7 selectively:

Intercombinations	Vane 5	Vane 6	Vane 7
	0-10	10	20

Thus for the range between 20 and 30 decibels, vane 7 would be plugged in, but vane 6 would be out. For the range between 30 and 40 decibels, both vanes 6 and 7 would be plugged in.

Fig. 7 illustrates the operative positions of the vanes 5-9 for producing an attenuation of between 50 and 60 decibels; vanes 6 and 8 being active, together provide 50 decibels.

What is claimed is:

1. An adjustable wave guide attenuator comprising a section of wave guide containing an attenuator unit continuously variable over a range of attenuation values followed by a plurality of other attenuator units, said variable attenuator unit comprising a rotatable vane of lossy material, said other attenuator units each comprising a lossy planar element having two operative positions corresponding to minimum and maximum attenuation, respectively, each said element in its position of maximum attenuation having its plane aligned with the electric vector of incident guided waves of predetermined polarization, individual stop means for maintaining the several said other elements in one or the other of said operative positions, the maximum attenuation values of each of said other units differing substantially from each other, and polarization selective means for suppressing transmission of wave components produced at said variable attenuator unit and differing in polarization from said predetermined polarization.

2. A wave guide attenuator comprising a section of wave guide having a longitudinal axis, means connected thereto for linearly polarizing a wave perpendicularly to the guide's axis, a series of spaced longitudinal attenuating vanes having a rectangular body portion of resistive material disposed along said longitudinal axis in said guide, each of said vanes providing a discrete amount of attenuation, related to each other as the successive terms of a progression series, and selective means for rotating any of said vanes in one jump through 90 degrees, whereby said rotated vane is parallel to the electric field vector of said polarized wave and provides its maximum

attenuation and a stop for holding each vane in its parallel relation.

3. The structure of claim 2, and a separate attenuating vane continuously rotatable from a region of zero field strength to a region of maximum field strength to provide interpolating values of attenuation in said series.

4. An attenuator simulating a decade resistance box for the microwave range of wavelengths comprising a hollow pipe wave guide excited by linearly polarized waves and having a principal longitudinal axis, a plurality of reflectionless vane attenuators spaced apart longitudinally, in said guide, each vane having a rectangular body portion with impedance matching terminals, said attenuators having different fixed base values of attenuation related consecutively to each other as the terms of a geometric series progression, means for rotating each of said vanes through an angle of 90 degrees into a plane parallel to the input polarization, a separate vane attenuator located in said wave guide adjacent its input end and means for continuously rotating the said vane to provide a continuous range of attenuation up to a maximum equal to the first vane of

said series progression attenuators, and linear polarization selective means at opposite ends of said wave guide.

5. The structure of claim 4, and fixed absorbers adjacent said vanes for eliminating undesired polarizations.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,129,712	Southworth	Sept. 13, 1938
2,197,122	Bowen	Apr. 16, 1940
2,257,783	Bowen	Oct. 7, 1941
2,411,534	Fox	Nov. 26, 1946
2,425,345	Ring	Aug. 12, 1947
2,427,100	Kihn	Sept. 9, 1947
2,433,368	Johnson	Dec. 30, 1947

OTHER REFERENCES

Proceedings of the I. R. E. October 1946, page 783.