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COMPACT WAVEGUIDE ATTENUATOR
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This invention relates to apparatus for attenuating electromagnetic energy in a waveguide, and more specifically to such apparatus which provides variable attenuation and which is physically compact and operative over a broad band of frequencies.

Heretofore, electromagnetic wave attenuating apparatus comprised a strip of dissipative material disposed within a waveguide with its longitudinal dimension parallel to the longitudinal axis of the waveguide. To prevent reflection of energy from the ends of the strip toward the energy source, and thus eliminate mismatch, the ends have been shaped with a gradual taper. As a result of this practice, the strip was longer physically than desirable. The present invention involves the use of a conveniently short strip of dissipative material with square cut ends which is matched over a broadband of frequencies.

A particular object of the present invention is to provide electromagnetic wave attenuating apparatus which presents a matched impedance to the waveguide over a wide range of frequencies.

Another object is to provide wave attenuating apparatus which is physically compact and simple in construction.

Another object is to provide wave attenuating apparatus which provides simple and continuous attenuation control.

A further object is to provide wave attenuating apparatus which is fully operative with energy passing it in either direction.

These and other objects are made apparent in the following specification which is accompanied by a cut-away perspective view of one form of the present invention.

In the figure, a section of rectangular wave guide 10 is shown having a dissipative member 11 disposed therein. Two rods 12 are slidably mounted in openings in the narrow walls of the waveguide 10, and carry the member 11 which is fixedly attached thereto. The rods 12 are so oriented as to be perpendicular to the electric field intensity vectors within the guide 10, and are spaced a distance \( \frac{\lambda_4}{4} \) apart (\( \lambda_4 \) being the guide wavelength of the propagated fields) to cause energy reflected by one of the rods to be cancelled by that reflected by the other. The rods 12 thus do not appreciably affect the fields in the guide 10.

In accordance with the principles of the present invention, two strips 13 and 14 made of dissipative material and having unlike resistivities are mounted in adjacency to form the member 11. As shown, strip 13 is substantially longer than strip 14, and the two are symmetrically disposed with relation to one another, with the ends of strip 13 extending beyond the ends of strip 14 by a distance \( \frac{\lambda_4}{4} \).

The dissipative strips 13 and 14 are preferably made of a solid base of any convenient dielectric material coated with a dissipative substance such as polyiron, which is powdered iron dispersed in a phenolic or resinous binder, or aquadag, a powdered graphite suspension used as a surface coating. The resistivity between opposite edges of such a structure which offers solely a surface resistance is measured per square of material, the lateral dimensions of the square having no effect on the resistance thereof. As an example of representative values for the specific elements shown in the apparatus of Fig. 1, strip 13 has a resistivity of 800 ohms per square and strip 14, a resistivity of 200 ohms per square.

As shown, the dissipative member 11 essentially extends from one of the broad wave guide walls to the other with its surface parallel to the electric field intensity vectors within the guide. The impedance of this member 11 is thus effectively placed across the line in shunt with the usual infinite impedance between the central regions of opposite walls of a waveguide.

The structure of the present invention as just described can be seen to operate in the following manner. Consider electromagnetic energy passing through the waveguide section 10 of Fig. 1 from left to right. This energy first strikes the end 16 of strip 13 which presents an impedance of the waveguide being substantially reduced from infinity to 800 ohms. A small amount of the incident energy is reflected back to the source by this discontinuity and the remainder continues down the guide, being continuously attenuated by the 800 ohm strip 13.

At a distance \( \frac{\lambda_4}{4} \) from the end 16 of strip 13, the propagated energy strikes a second impedance discontinuity greater than the first. Here at the end 17 of strip 14, a 200 ohm impedance is placed in shunt across the waveguide and in parallel with the already existing 800 ohm shunt. A considerable amount of energy is reflected back to the source by this discontinuity and re-experiences attenuation in strip 13 before arriving at the end 16 of strip 13. At this interface, the energy reflected at the end 16 of strip 13 recombines with that reflected at the end 17 of strip 14, the two being 180° out of phase due to the additional path traversed by the latter.

It may now be seen that the design criterion for apparatus of the present invention to produce matched attenuation, in addition to involving the significant physical dimensions indicated, dictates that the impedances of the two strips be chosen so that the total energy reflected by the dissipative member 11 in the direction of the source be equal to zero. This, in turn, requires that the impedance of the strip 14 be such that it reflects a predetermined portion of the incident wave at its end 17.

This predetermined portion of the incident wave must be of sufficient magnitude to equal, after attenuation by a quarter wavelength section of strip 13, the amount of the unattenuated, incident wave reflected by the strip 13 along its face 16.

Practically all of the attenuation of the apparatus
3 shown in Fig. 1 is contributed by the center section of the member 11 where the strips 13 and 14 present their shunt impedance in parallel, and the amount of this attenuation increases with the length. Energy reflected back toward the source by the end 18 of strip 14 produces a negligible overall mismatch because of its nearly complete attenuation in re-traversing the dissipating member.

The attenuation introduced by the apparatus of this invention may be varied by sliding the dissipating member 11 across the waveguide 10 by means of rods 12. Maximum attenuation is had when the combination lies along the center line of the waveguide as the electric field within the guide has maximum intensity at this position. This motion across the waveguide is smooth, continuous, and easily adapted to calibration.

The dissipating member 11, shown in Fig. 1, is designed to offer identical physical and electrical appearances to energy passing it in either direction, causing incident as well as reflected propagation in the waveguide 10 to be affected equally. By eliminating the long tapered ends usually focusing on waveguide dissipative inserts, desired compactness is gained.

Because of this compactness, physical dimensions of the apparatus described suffer negligible relative change with variation in frequency, and frequency insensitivity over a broad frequency band is thereby achieved.

The features described in the foregoing specification need not be limited to the details shown, which are considered to be illustrative of one form the invention may take.

What is claimed is:

1. Apparatus for attenuating electromagnetic energy in a waveguide, said apparatus comprising a member of dissipative material disposed within said waveguide, said member being formed by a first strip of material having a predetermined resistivity, said first strip being oriented with its longitudinal dimension parallel to the longitudinal axis of said waveguide, and its wide dimension parallel to the electric field intensity vectors within said guide, and a second strip of material having a predetermined value of resistivity smaller than that of said first strip, said second strip being disposed in said waveguide in manner similar to said first strip and held laterally adjacent thereto, said first strip being greater in length than said second strip, with each end of said first strip extending out beyond an end of said second strip by a distance equal to an odd number of quarter wavelengths of the energy propagated in said waveguide, means being provided to support said member within said waveguide, said means including two rods slidably engaged in the narrow walls of said waveguide with their longitudinal axes perpendicular to the electric field intensity vectors within said guide, said member being fixedly attached to said rods, and the distance between said rods measured along the longitudinal axis of said waveguide being an odd number of quarter wavelengths of the energy propagated in said guide.

2. Apparatus for attenuating energy in a waveguide comprising, a first dissipative strip having a first resistivity, a second dissipative strip having a second resistivity, said first strip being rigidly joined to said second strip and extending beyond each end of said second strip by a distance equal to an odd number of quarter wave lengths measured at the frequency of energy to be propagated in said waveguide, and means for movably supporting said strips so that said strips are at all times oriented in said waveguide with their longitudinal dimensions in the plane of the electric field intensity vectors of said energy propagated in said waveguide and so that said strips are movable transversely of said wave guide, said last-mentioned means including two rods slidably engaged in at least one wall of said wave guide with their longitudinal axes perpendicular to the electric field intensity vectors of said energy propagated in said waveguide, the distance between said rods measured along the longitudinal axis of said waveguide being an odd number of quarter wave lengths of said propagated energy in said waveguide.

3. Apparatus as in claim 2 wherein said first resistivity is larger than said second resistivity.

4. Apparatus for attenuating energy in a wave guide, said apparatus comprising, an attenuating member disposed within said waveguide, said member being formed by a first strip of material having a first predetermined value of resistivity, said strip being oriented with its longitudinal dimension parallel to the longitudinal axis of said waveguide, and its wide dimension parallel to the electric field intensity vectors of the energy to be propagated within said waveguide, and a second strip of material having a second predetermined value of resistivity, said second strip being disposed in said waveguide in a manner similar to said first strip and held adjacent thereto, said first strip being greater in length than said second strip, with each end of said first strip extending out beyond an end of said second strip by a distance equal to an odd number of quarter wave lengths of said energy to be propagated in said waveguide.

5. Apparatus as in claim 4 and means for movably supporting said attenuating member in said waveguide so that said strips are at all times oriented in said waveguide with their longitudinal dimensions parallel to the electric field intensity vectors of the energy to be propagated in said waveguide and so that said strips are movable transversely of said waveguide.

6. Apparatus for attenuating energy in a wave guide, said apparatus comprising, an attenuating member disposed within said waveguide, said member comprising, a first strip of a first dissipative material having a first resistivity and a second strip of dissipative material having a second resistivity, said first strip being joined to said second strip and extending beyond each end of said second strip a distance equal to a quarter wave length of the energy adapted to be propagated in said waveguide.

7. Apparatus as in claim 6 wherein said first resistivity is greater than said second resistivity and wherein said strips are oriented with their longitudinal dimensions parallel to the longitudinal axis of said waveguide and with their wide dimensions parallel to the electric field intensity vectors of said energy adapted to be propagated in said waveguide.

8. Apparatus for attenuating energy in a wave guide, said apparatus comprising an attenuating member disposed longitudinally within said waveguide, said member comprising a first strip of a first resistive material and a second strip of a second resistive material, said first and second strips being joined together and having their longitudinal dimensions parallel to the longitudinal axis of said waveguide, each end of said first strip extending out beyond a corresponding end of said second strip by a distance equal to an odd number of quarter wave lengths of the energy adapted to be propagated in said waveguide.

9. Apparatus as in claim 6 wherein the ends of both said strips are squared and lie in parallel planes perpendicular to the direction of energy propagation within said waveguide.

10. A microwave attenuator comprising, in combination, a section of hollow rectangular waveguide, a first rectangular strip of dielectric material having a width approximately equal to the distance between a pair of opposite walls of said waveguide, said strip being coated with an electromagnetic energy dissipative substance having a first resistivity per unit area of said strip, and a second strip of dielectric material having a width equal to that of said first strip and coated with an electromagnetic energy dissipative substance having a second resistivity per unit area, said strips differing in length by one-half the wave length of the electromagnetic energy being propagated within said waveguide and being joined intimately together so that equal portions of the longer strip extend beyond.
in an electrically parallel relationship across said waveguide.

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