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E. WEBER ET AL
ATTENUATOR UNITS FOR WAVEGUIDES

2,705,779

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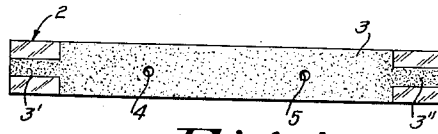


Fig. 1.

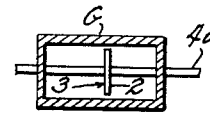


Fig. 1a.

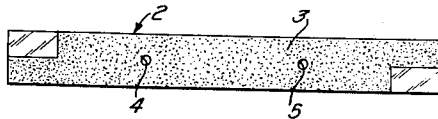


Fig. 2.

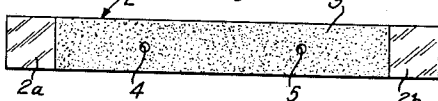


Fig. 3.

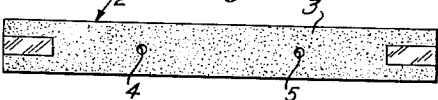


Fig. 4.

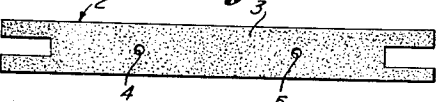
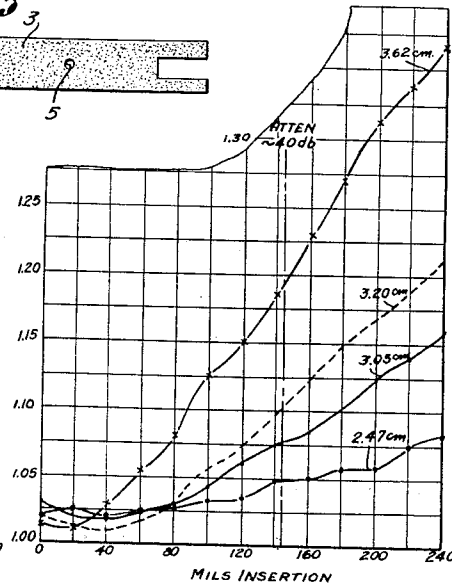
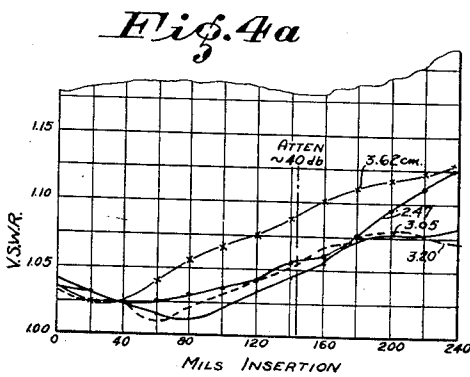


Fig. 5.

Fig. 5a.



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ATTENUATOR UNITS FOR WAVEGUIDES

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12 Claims. (Cl. 333—81)

This invention relates to attenuators for waveguides, and it is concerned especially with impedance matching of the attenuator with respect to the waveguide to eliminate or reduce wave reflections caused by the attenuator.

An object of the invention is to devise arrangements for matching the input impedance of the attenuator to the characteristic impedance of the waveguide.

A further object is to devise a matched attenuator having a broad-band transmission characteristic.

The present invention is applied to waveguides in which the attenuator unit comprises a relatively thin, loss-producing, plate-like element mounted within the waveguide longitudinally thereof and with its plane parallel with the plane of the electric lines within the waveguide. The attenuator unit is formed of a plate of dielectric material, such as glass, having a loss-producing coating or film on one or both faces thereof. The attenuator plate is provided at one or both ends with means to match the input impedance with the characteristic impedance of the guide. The plate may be mounted for movement transversely of the waveguide to vary the amount of attenuation.

The present application is a continuation-in-part of our application Serial No. 707,468, filed November 2, 1946. The claims in our earlier application are directed to a form of the attenuator plate in which reflection is reduced or prevented by tapering at least one end of the loss-producing plate in its broad dimension.

The present application is directed to attenuator plate forms in which the loss-producing coating or film is omitted from certain end portions of the dielectric plate, and the uncoated portions of the plate serve to reduce wave reflection.

Various forms of the attenuator unit are illustrated in the accompanying drawing in which:

Figures 1 to 4 illustrate different forms of attenuator units according to the present invention.

Figure 1a is a transverse sectional view of a waveguide showing an attenuator plate mounted therein.

Figure 5 illustrates a known form of attenuator unit.

Figures 4a and 5a are curves illustrating the operating characteristics of the attenuator units of Figures 4 and 5 respectively.

Referring to the drawing, each attenuator unit is formed of a flat rectangular plate of dielectric material 2, such as glass. This plate carries on one face thereof a thin metallic coating indicated at 3, and a pair of spaced holes 4 and 5 are provided for mounting the plate upon a pair of parallel supporting rods passing through opposite narrow walls of a waveguide, as explained in our earlier-filed application. As shown in Figure 1a, the attenuator plate is mounted within the waveguide G parallel with the longitudinal axis and with the plane of the plate at right-angles to the broad walls of the waveguide. The plate is mounted upon a pair of rods 4a and 5a which pass through holes in the opposite narrow walls of the waveguide. By sliding the supporting rods, the position of the plate within the guide may be varied to vary the amount of attenuation, but the plate remains parallel with the longitudinal axis of the waveguide in all positions.

If the plate 2 were of rectangular shape and the film 3 were uniform throughout the entire area of the plate, wave reflection would be set up by the attenuator unit. In order to eliminate or substantially reduce this reflection, the end portions of the attenuator unit are designed to constitute transition sections which serve to match the input impedance of the attenuator section with the char-

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acteristic impedance of the waveguide. In the form of the invention claimed in our earlier application the film on the plate 2 is uniform throughout the entire area of the plate, but the ends of the plate are tapered in its broad dimension. In the present case the plates are of rectangular form. The length of the transition section required for best match will depend upon the center frequency and upon a number of things, including the film resistance, the dielectric constant of the plate, and the thickness of the plate. In general, a thick plate of window glass will require a shorter matching section than a thin plate of "Pyrex," since both the greater thickness of the window plate and its higher dielectric constant shorten the guide wave length. Low resistance films require a longer matching section than high resistance films on a similar plate of glass. In general, the length of the matching section will be of the order of $\frac{1}{4}$ to $\frac{1}{2}$ of the center wavelength of the guide.

In the arrangement of Figure 1, the plate 2 is of rectangular shape and the attenuator film 3 covers a central section of the plate and is provided at each end with narrow tongues shown at 3' and 3''. The film is of uniform thickness throughout, but the narrow tongues, together with the uncoated portions on the sides thereof, serve as matching sections. These tongues may be formed by suitably masking the four corners of the plate 2 while the metallic film is being deposited on the plate, preferably by a process of thermal evaporation disclosed in the copending application Serial No. 699,546, filed September 26, 1946, now Patent No. 2,586,752. The arrangement of Figure 1 has very good broad-band characteristics, and it is also satisfactory from a manufacturing standpoint, since the entire film may be formed in one coating operation. The tongue width and length are fixed to give the best match over the desired frequency range.

For use in a waveguide of inside transverse dimensions of 0.400" x 0.900", and for a free space wave band of 3.13 cm. to 3.53 cm., a satisfactory attenuator unit according to Figure 1 may be formed on a thin "Pyrex" plate of a thickness of 0.038 inch, a length of 5.1 cm. and a width of 0.363 inch. The length of the tongue is 0.242 inch, and the width is 0.160 inch. The resistance of the film is 140 ohms per square.

Instead of locating the matching tongue centrally of the width of the plate, as in Figure 1, the tongue may be located along one edge of the plate as shown in Figure 2. Preferably the tongue at one end of the plate is located along the opposite edge from the tongue at the other end of the plate. The tongue and the uncoated portion of the plate in each transition section may be of different widths, although they are shown equal in the drawing. The resistance film of Figure 2 is of uniform thickness throughout and may be applied in the same manner as the film of Figure 1.

In the arrangement of Figure 3, the plate 2 is of rectangular form and the attenuator film 3 covers a central portion of one face of the plate, leaving the end portions 2a and 2b blank, and these blank portions serve as matching or transition sections. The presence of the blank glass in the guide locally changes the characteristic impedance. This difference in characteristic impedance, together with the effective reactance provided by the shunt field distortion at the front edge of the glass, is capable of producing the necessary match.

A satisfactory attenuator unit according to Figure 3, and useful in the above-mentioned band, may be formed of a rectangular glass plate having a length of 2.14 inches, a width of 0.375 inch and a thickness of 0.065 inch. The film 3 has a length of 1.78 inches, with blank sections at each end of a length of 0.178 inch. The film has a resistance of 80 ohms per square. The input VSWR for this unit was in the neighborhood of 1.2 for all wave lengths within the band when used in a guide measuring 0.400 inch by 0.900 inch inside.

For the unit shown in Figure 3, the glass thickness and dielectric constant, the film resistance, and the length of the transformer section are the important factors. In practice, the glass thickness and the dielectric constant are usually fixed or variable over a very small range. Accordingly, the film resistance and the transformer length are the two quantities that must be determined.

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Figure 4 shows a "fork" type of matching section in which the uncoated portion of the plate is located between two coated portions extending along opposite edges of the plate. Except for this difference, the unit is constructed in the same manner as the previous units.

Figure 5 illustrates a known form of attenuator plate which corresponds to the unit of Figure 4 except that the uncoated portion of the plate is removed. This figure has been included for the purpose of showing applicants' discovery that the presence of the uncoated portions of the plate in Figure 4 produces an unobvious advantage over the notched-end unit of Figure 5.

Varying the position of the attenuator plate 2 within the waveguide causes variation in the amount of attenuation. The attenuation is very low when the plate is positioned closely adjacent the side wall of the waveguide, and it increases in value as the plate moves away from the wall. The distance between the plate and the near side wall of the waveguide is commonly referred to as the "insertion" of the plate. For a waveguide of the size given above the attenuation reaches a maximum value when the plate 2 is positioned about $\frac{1}{4}$ inch from the adjacent wall.

For the purpose of demonstrating the difference between the unit of Figure 4 and that of Figure 5, units according to these figures were constructed from "Pyrex" glass plates of identical size of a length of 5.75", a width of 0.349" and a thickness of 0.038". The uncoated end portion in Figure 4 and the slot in Figure 5 had a length of 0.242" and a width of 0.160". A film of "nichrome" alloy of uniform thickness having a resistance of 158 ohms per square was used on both units.

Both units were tested in a waveguide of the size mentioned above, and the voltage standing wave ratio at four different wave lengths was observed for each unit, and the results of the tests for the two units are shown in Figures 4a and 5a respectively. The four wave lengths employed in the tests were 2.47 cm., 3.05 cm., 3.20 cm., and 3.62 cm., and the curves corresponding to these wave lengths have been marked with the respective wave length values. As shown by the curves, there is not much difference between the units up to an insertion of forty mils, but beyond this point the standing wave ratios of the two units depart considerably. As the insertion increases towards maximum value, the standing wave ratios of Figure 5 at the different wave lengths scatter or diverge considerably, whereas the ratios for the unit of Figure 4 increase substantially at the same rate. Thus, the unit of Figure 4 produces a considerably better broad-band characteristic than the unit of Figure 5.

We claim:

1. An attenuator unit for use in a waveguide comprising an elongated glass plate having a loss-producing resistive coating applied on one broad face thereof and means for reducing wave reflection from said unit comprising an uncoated portion of said glass plate located at one end thereof.

2. An attenuator unit according to claim 1 wherein said uncoated portion extends entirely across the width of said plate.

3. An attenuator unit according to claim 1 wherein said uncoated portion comprises a relatively narrow portion extending longitudinally of said plate and bounded by one longitudinal edge of said plate, and a second relatively narrow uncoated portion of said plate bounded by the opposite longitudinal edge and the intervening longitudinal portion of said plate being covered by said resistive coating.

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4. An attenuator unit according to claim 1 wherein said uncoated portion comprises a centrally located, relatively narrow, longitudinally extending portion positioned between two narrow longitudinally extending coated portions.

5. An attenuator unit according to claim 1 wherein said uncoated portion comprises a relatively narrow portion extending longitudinally of said plate along one edge of said plate.

6. An attenuator unit according to claim 5 wherein an uncoated portion is provided at each end of said plate, the two uncoated portions being located along opposite longitudinal edges of said plate.

7. A waveguide attenuator, including a rectangular waveguide and plural rectangular bodies of different lengths and of different energy absorbing characteristics disposed side by side in said waveguide so that a portion of each body occupies part of a given transverse cross-section of the waveguide, one of said bodies being of high-loss material.

8. An attenuator unit for use in a waveguide comprising an elongated plate of low-loss material having a loss-producing resistive coating on one broad face thereof and means for reducing wave reflection from said unit comprising an uncoated portion of said plate located at one end of the unit.

9. An attenuator unit for use in a waveguide comprising an elongated plate of low-loss material, an elongated body of high-loss material arranged in parallel overlapping relation with said low-loss plate, and means for reducing wave reflection from said unit comprising a portion of said low-loss plate extending at one end thereof beyond the adjacent end of said high-loss body.

10. In combination with a hollow rectangular waveguide for electromagnetic waves, an attenuator pad in the channel of said waveguide, said pad being composed of a plurality of superposed sections of energy-absorbing material having different energy-absorbing characteristics said sections extending lengthwise of said channel at least two of said sections having the adjacent ends thereof terminating in different transverse planes of the waveguide channel spaced apart and said section of lower absorbing characteristic being longer than the other section.

11. In combination with a hollow rectangular waveguide for electromagnetic waves, an attenuator pad mounted in the guide channel said pad comprising a plurality of superposed sections having different energy-absorbing characteristics and of rectangular form in which the ends thereof terminate in planes extending transversely of said channel, an end of the one of said sections of lower energy-absorbing characteristic being advanced with respect to the others whereby the phase shifted components of power reflected from said ends are cancelled.

12. A waveguide attenuator including a length of waveguide, and plural bodies of different energy-absorbing properties and of different lengths disposed side by side in said waveguide with a portion of each one of said bodies extending through a transverse cross-section of the waveguide, at least one of said bodies being of high-loss material.

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