Jan. 17, 1956 E. WEBER ET AL 2,731,603

MATCHED WAVE GUIDE ATTENUATORS

Original Filed Nov. 2, 1946

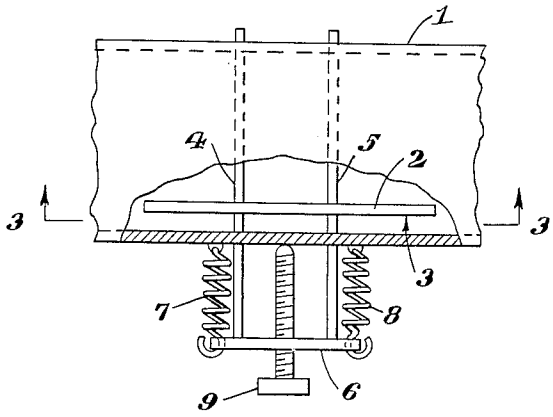


Fig. 1

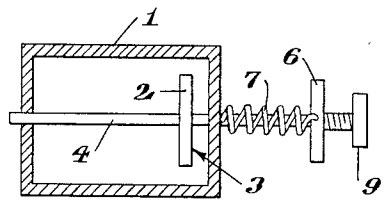


Fig. 2

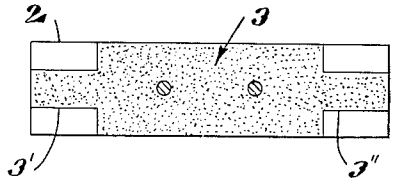


Fig. 6

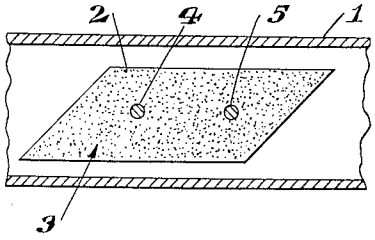


Fig. 3

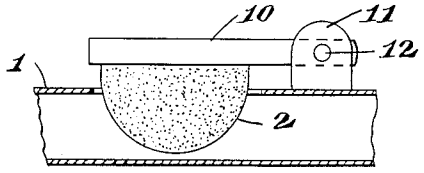


Fig. 7

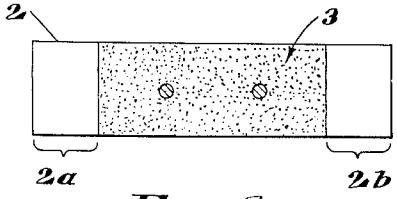


Fig. 4

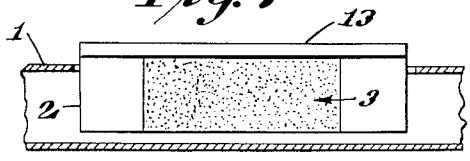


Fig. 8

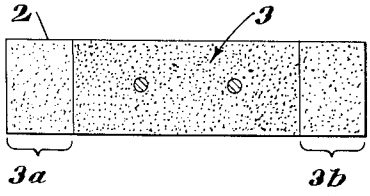


Fig. 5

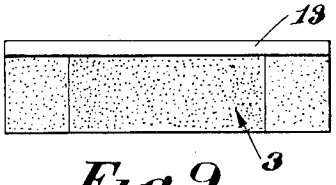


Fig. 9

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MATCHED WAVE GUIDE ATTENUATORS

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Original application November 2, 1946, Serial No. 707,468, now Patent No. 2,705,780, dated April 5, 1955. Divided and this application February 11, 1953, Serial No. 336,264

5 Claims. (Cl. 333—81)

This invention relates to attenuators for wave guides, and it is concerned especially with impedance matching of the attenuator with respect to the wave guide to eliminate or reduce wave reflections from the attenuator.

This application is a division of our co-pending application Serial No. 707,468, filed November 2, 1946, now Patent No. 2,705,780, April 5, 1955.

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

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

The present invention may be applied to wave guides generally, with or without a center conductor. The attenuator unit comprises a relatively thin, loss-producing, plate-like element mounted within the wave guide longitudinally thereof and with its plane parallel with the plane of the electric lines within the wave guide. 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 wave guide to vary the amount of attenuation, or it may be mounted to enter the wave guide through a slot formed in the wall of the guide.

Various forms of the invention are illustrated in the accompanying drawing in which

Figure 1 is a plan view, partly in section, showing one form of adjustable attenuator in which the attenuator plate moves transversely of the wave guide;

Figure 2 is an end view of Figure 1;

Figure 3 is a sectional view of Figure 1 taken along the line 3—3;

Figures 4, 5 and 6 are side elevational views of modified forms of attenuator units useful in Figure 1;

Figure 7 is a side view partly in section of a second form of variable attenuator in which the attenuator unit enters the wave guide through a slot in the broad face thereof;

Figure 8 is a side view, partly in section, showing a third form of attenuator; and

Figure 9 is a side elevational view of an attenuator unit useful in Figure 8.

Referring to the drawing, **1** indicates a rectangular wave guide in which is mounted a flat plate **2** of dielectric material, such as glass. This plate carries on one face thereof a thin metallic coating indicated at **3**, and the plate is mounted upon a pair of parallel rods **4** and **5** which pass through openings formed in opposite narrow walls of the wave guide. The rods **4** and **5** are bridged at one end by a plate **6** which is normally urged towards the wave guide by a pair of springs **7** and **8** secured to the plate at one end and secured to the wave guide at the other end. An adjusting screw **9** having threaded engagement with the plate **6** extends into contact with the adjacent wall of the wave guide and limits the amount of movement under the action of springs **7** and **8**. By adjusting the screw **9**, the position of the plate **2** within the

wave guide may be varied, the plate remaining parallel with the longitudinal axis of the wave guide in all positions.

In the plate **2** were of rectangular shape and the film **3** were uniform throughout, wave reflection would be set up by the attenuator unit. In order to eliminate or substantially reduce this reflection, the ends of plate **2** are tapered as shown in Figure 3 to constitute transition sections which serve to match the input impedance of the attenuator unit with the characteristic impedance of the wave guide. In this form of the invention the film **3** on the plate **2** is uniform throughout the area of the plate. The length of the taper 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 taper than high resistance films on a similar plate of glass. In general, the length of the taper will be of the order of ¼ to ½ of the center wavelength of the guide.

By way of example, a satisfactory attenuator unit according to Figures 1 to 3 for the free space band of 3.13 cm. to 3.53 cm. may be formed of soft window glass 1/16 inch thick and 0.375 inch wide with a 1½ inch taper at each end. With a film resistance of 80 ohms per square, the standing wave ratio is less than 1.1 over the entire band. The match was below 1.1 for all positions of the plate in the guide which measured 0.400" x 0.900" (inside). The length of the untapered section is dependent upon the amount of attenuation wanted. For narrow band applications, the length of the taper sections may be reduced.

Varying the position of the attenuator plate **2** within the wave guide causes variation in the amount of attenuation. The attenuation is very low when the plate is positioned closely adjacent the side wall of the wave guide, and it increases in value as the plate moves away from the wall. In the example given above the attenuation reaches a maximum value when the plate **2** is positioned about ¼ inch from the adjacent wall.

For any given length of attenuator plate, the attenuation increases as the width of the plate is increased, except where the gap between the edges of the plate and the wall of the guide becomes small.

Figure 4 illustrates a different arrangement for matching the attenuator. In this arrangement, 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 **2***a* and **2***b* 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 4, and useful in the above-mentioned band, may be formed of a rectangular glass plate having a length of 5.46 cm., a width of 0.375 inch and a thickness of 0.065 inch. The film **3** has a length of 4.52 cm., leaving blank sections at each end of a length of 0.47 cm. 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" x 0.900" inside.

For the unit shown in Figure 4, 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.

A modification of the arrangement of Figure 4 is illustrated in Figure 5. In this unit the plate **2** is rectangular in shape and the entire length of one face is provided with a metallic film, the central section **3** of the film being of greater thickness than the end sections **3***a* and **3***b*. This unit has a complex characteristic impedance. The high resistance film sections **3***a* and **3***b* act as complex impedance transformers in the same sense as the blank glass sections **2***a* and **2***b* of Figure 4, but with a pronounced loss effect. The loss produced in matching sections **3***a* and **3***b* makes the arrangement of Figure 5 less critical with respect to frequency than the arrangement of Figure 4. Both arrangements of Figures 4 and 5 have the advantage of being considerably shorter than Figure 3.

For use in the band mentioned above, it has been found that an arrangement according to Figure 5 is satisfactory where formed on thin "Pyrex" glass of a thickness of 0.038 inch where the main film **3** has a resistance of approximately 140 ohms per square and the transformer sections have a length of 0.30 inch with a film resistance of approximately 400 ohms per square.

Figure 6 shows still another arrangement of transition sections for the attenuator unit. In this arrangement, 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 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 and disclosed in U. S. patent to Weber et al., 2,586,752. The arrangement of Figure 6 has very good broad-band characteristics, and it also is 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. Figure 6 also gives a shorter arrangement than Figure 3.

For use in the above mentioned guide and band, a satisfactory attenuator unit according to Figure 6 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.

In the case of Figure 5, each matching section may have different linear sections formed with different resistance values, and in the case of Figure 6, each matching tongue may have different widths in different linear sections thereof.

The arrangement illustrated in Figure 7 involves a variation of the taper match shown in Figure 3. In this case the attenuator plate is formed of generally semi-circular shape, and the rounded ends of the plate located within the guide serve to match the input impedance of the attenuator unit with the characteristic impedance of the guide. The film on the plate **2** in Figure 7 is of uniform thickness throughout.

Figure 7 also illustrates another way of mounting the attenuator unit for obtaining adjustment of the amount of attenuation. In this arrangement the plate **2** is secured in a slot formed in a bar **10**, as by cementing, and the bar **10** is pivotally supported between a pair of brackets **11** on a pivot pin **12**. Any suitable means may be employed for adjustably moving and holding the bar **12** in different angular positions about the pin **12**, to thereby vary the extent to which the plate **2** enters the wave guide. It will be understood that the plate **2** is positioned to enter a longitudinal slot formed in the broad face of the wave guide **1**.

Figure 8 illustrates another variable attenuator of the same general type as Figure 7 in which the attenuator unit has the same construction as shown in Figure 4 but is mounted within a longitudinal slot formed in the wave guide. The attenuator unit in Figure 8 is supported from a bar **13** which may be moved vertically by any suitable means to vary the amount of penetration of the attenuator plate into the wave guide.

Figure 9 illustrates an attenuator unit provided with matching sections like that shown in Figure 5 and mounted upon a bar **13** to be used in the arrangement of Figure 8.

In the foregoing discussion of Figures 1 to 3 it was pointed out that the amount of attenuation is dependent upon the width of the attenuator film. The arrangements illustrated in Figures 7 and 8 are designed to vary the effective width of the film within the wave guide and thereby vary the amount of attenuation.

The preferred method of forming the metallic film on the attenuator units embodied in this invention is by thermal evaporation as disclosed in U. S. patent to Weber et al. 2,586,752, since this process produces highly stable films, although other processes may be used if desired. Also, it is obvious that instead of using a film on a dielectric plate, the plate itself may be formed of loss-producing material, and this would apply especially to units like those shown in Figures 3, 5, 6 and 7. In the case of Figure 5, the matching sections **3***a* and **3***b* would be formed of gradually decreasing thickness.

While the invention has been illustrated herein as applied to a rectangular wave guide, it is obvious that it may be applied to guides of other shapes where the electric field lines are essentially parallel over a certain region. The attenuators may be used in wave guides of the coaxial type and they need not be variable.

We claim:

1. A variable attenuator for a wave guide comprising an elongated loss-producing plate-like element positioned within a longitudinal slot formed in the wall of said guide with the plane of said plate parallel with the electric field in said guide and with its major axis substantially parallel with the longitudinal axis of said guide, and means mounting said plate for movement in its own plane transversely of said guide, whereby the amount of penetration of said plate into said guide may be varied, said plate having a main attenuating section and a matching end portion of the same width as said attenuating section and presenting a higher impedance than said attenuating section, said matching end portion being of uniform construction throughout its width.

2. A variable attenuator according to claim 1 wherein said loss-producing plate-like element is formed of a rectangular plate of dielectric material having a high-resistance film formed on one face thereof throughout said attenuating section, and said matching end portion comprises an end portion of said dielectric plate having a resistance film thereon of a higher resistance value per square than the film in said attenuating section.

3. A variable attenuator according to claim 1 wherein said loss-producing element comprises a rectangular plate of dielectric material having a high resistance film coating on one face thereof and forming said main attenuating section, and said matching section comprises an uncoated end portion of said dielectric plate.

4. A variable attenuator for a wave guide comprising an elongated loss-producing plate-like element positioned within a longitudinal slot formed in the wall of said guide, with the plane of said plate parallel with the electric field in said guide and with its major axis substantially parallel with the longitudinal axis of said guide, and means mounting said plate for movement in its own plane transversely of said guide, whereby the amount of penetration of said plate into said guide may be varied, said plate having a main attenuating section and a matching end portion of the same width as said attenuating section but of a higher resistance value per square than said attenuating section, said matching end portion being of uniform construction throughout its width.

5. An attenuator element for wave guides comprising a rectangular plate of dielectric material carrying on one broad face thereof a thin metallic film of uniform resistance value per square throughout the width and length of a main section of said plate, and an end section of said plate adjacent said main section carrying a thin metallic film of uniform resistance value throughout the width and length of said end section and having a higher resistance value than the film in said main section.

References Cited in the file of this patent

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