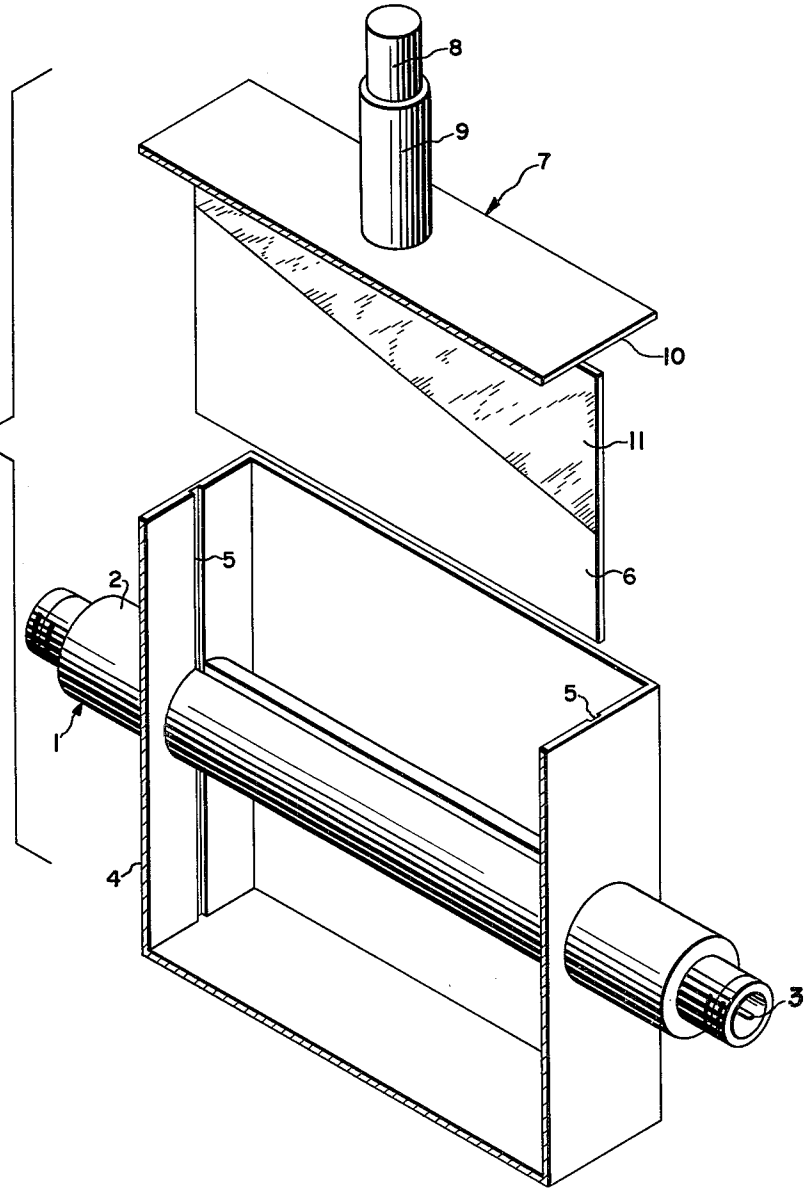
Nov. 16, 1965 C. Y. PON ETAL 3,218,583

HIGH FREQUENCY ATTENUATOR WITH CONSTANT PHASE SHIFT

Filed Aug. 30, 1963 2 Sheets-Sheet 1

FIG. 1



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Filed Aug. 30, 1963 2 Sheets-Sheet 2

FIG. 2

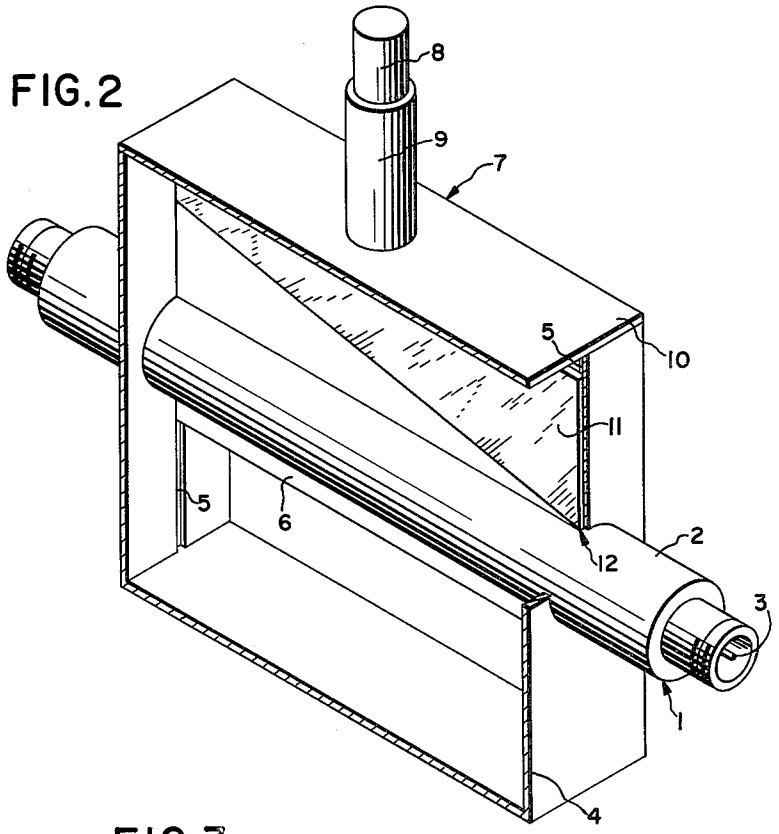
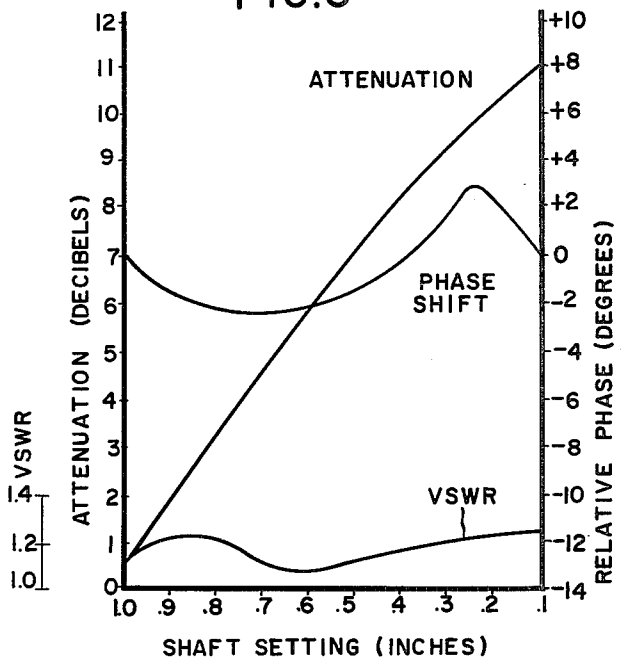


FIG. 3



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United States Patent Office 3,218,583 Patented Nov. 16, 1965

3,218,583

HIGH FREQUENCY ATTENUATOR WITH CONSTANT PHASE SHIFT

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Filed Aug. 30, 1963, Ser. No. 305,595
8 Claims. (Cl. 333—81)

The present invention relates to the variable attenuation of high frequency signals without an attendant variation in the phase of the signal. More particularly, the invention described below is directed to an improvement in the sliding-plate type of high frequency attenuator and provides a very substantial range of signal attenuation without introducing any substantial variation of phase shift into the transmitting signal.

Numerous types of attenuators are known in the art and attenuators for high frequency energy (wavelengths of one meter or less) often employ a coaxial transmission line provided with a slot therein parallel to the direction of energy transmission. A plate formed of resistive dielectric material is inserted a controlled distance into the transmission line through this slot to thereby attenuate signal transmission in proportion to the amount of plate area within the transmission line. One such type of attenuator is shown, for example, in U.S. Patent No. 2,515,228.

The general type of attenuator noted above varies the phase of the transmitted signal as it attenuates the signal. Commonly, the amount of phase shift introduced varies in proportion to the amount of attenuation. While this circumstance is tolerable in some applications, certain other applications are seriously limited thereby. Thus, for example, antenna feed systems and phase measuring systems are seriously impaired by the inadvertent introduction of variable phase shifts into the transmitted signal. For these above-noted applications, and many others, it is highly desirable to employ a sliding-plate attenuator which does not introduce a variable shift into the phase of signals transmitted therethrough. The present invention provides such an attenuator.

In brief, the present invention comprises a substantially conventional section of coaxial transmission line having a longitudinal slot therein for the controlled insertion of an attenuating plate. In accordance herewith, this attenuating plate is formed of a dielectric material and extends entirely through the transmission line. Upon the plate there is disposed a pattern of resistive material so that variation in the position of the plate in the line produces a variation in the amount of resistive material disposed in the line. The attenuating plate is at all times disposed entirely through the transmission line, and consequently introduces a substantially constant phase shift in signals passing along the line. Attenuation is varied by control deposition of different amounts of resistive material in the line. As further noted below, the apparatus of this invention may be additionally modified to preclude even the slightest variation in phase shift with differing attenuations.

The invention is herein illustrated and described with respect to a single preferred embodiment thereof, which is illustrated in the accompaning drawings wherein:

FIGURE 1 is an exploded perspective view of a preferred embodiment of the invention;

FIGURE 2 is a perspective view partially in section of the embodiment of FIGURE 1; and

FIGURE 3 is a graph illustrating operating parameters of a preferred embodiment of the invention.

Considering now the present invention in more detail and referring to FIGURES 1 and 2 of the drawings, the

attenuator includes a short section of coaxial transmission line or cable **1**, which is conventional in including an outer conductor **2** and a coaxial inner conductor **3**. This cable extends longitudinally through an attenuator housing **4**, and in the housing is provided with a longitudinal slot axially thereof. The end walls of the housing **4** define internal vertical slots or grooves **5** aligned with the cable slot. An attenuator plate **6** is slidably disposed in the slots **5** within the housing in extension through the cable at the slot thereof, and is mounted for vertical movement within the housing, to thereby controllably dispose different portions of this attenuator plate within the cable. Vertical movement of the attenuator plate in the housing is provided by mounting and adjusting means **7**, including a shaft or solid cylinder **8** affixed to the top of the plate and extending upwardly therefrom. This shaft **8** has conventional micrometer threads formed on the outside thereof, in engagement with like internal threads on a surrounding hollow cylinder **9**. A top-mounting bar or plate **10** carries this hollow cylinder **9** in rotatable relation thereto, so that upon turning of the cylinder **9**, the mating threading shaft **8** and attached attenuator plate **6** move upwardly or downwardly with respect to the mounting bar. The housing **4** is closed by this mounting bar which rests atop same, with the attenuator plate depending into the housing. Suitable calibration markings may be provided upon the shaft **8**, and if desired this calibration may be provided directly in decibels.

The attenuator plate **6** is fabricated entirely from a dielectric material such as Bakelite. Upon the exterior surface of a predetermined portion of the attenuator plate there is provided a resistive coating **11**, and as illustrated in FIGURE 1, this coating is provided from the top portion of the plate downwardly, with the bottom edge of the resistive coating being disposed diagonally across the plate. It will thus be seen that vertical movement of the attenuator plate within the housing serves to dispose a predetermined and controllable amount of resistive material within the cable. As shown in FIGURE 2, the attenuator plate extends through the cable at all times, and in the position shown in this figure only the dielectric material of the plate is disposed with the cable, to provide thereby only a very small attenuation of high frequency signals transmitted by the cable.

The resistive coating **11** may be provided upon the attenuator plate in any conventional manner. Resistive coatings of the type herein employed are well known in the art and may be formed, for example, of Nichrome (a well-known nickel-chrome alloy) or other film-forming resistive substances. In one example of the present invention, a sheet resistance of about 200 ohms per square inch was employed for the resistive coating. Clearly, the sheet resistance of the coating may be varied for different applications inasmuch as the value of this resistance determines the amount of attenuation available. It is, in fact, possible to obtain dielectric plates having a resistive coating entirely covering same, as for example, from the Filmohm Corporation of New York city. Such plates may be utilized for the present invention by removal of a portion of the coating, as by sanding, so as to leave upon the dielectric plate a coating having an inclined lower surface, as clearly indicated in FIGURES 1 and 2.

Operation of the present invention is accomplished by vertical movement of the attenuator plate **6**. In the position shown in FIGURE 2, only dielectric material of the plate is disposed within the cable **1**. Increased attentuation is accomplished by turning the cylinder **9** to lower the attenuator plate within housing **4** and thus to dispose an increasing amount of resistive coating **11** within the

cable. By provision of a tapered pattern of resistive coating on the attenuator plate, as illustrated in FIGURES 1 and 2, it will be seen that an increasing amount of resistive material is disposed within the cable as the attenuator plate is lowered within the housing. This resistive coating attenuates high-frequency signals passed through the cable, and the greater the amount of resistive coating disposed within the cable, the greater the attenuation. It is to be particularly noted that under all operating conditions the same amount of dielectric material of the attenuator plate is disposed within the cable. While it is true that a certain amount of phase shift is introduced into signals transmitted through the cable by the presence of this dielectric material therein, it will be appreciated that movement of the attenuator plate does not vary this phase shift. The presence of the same amount of dielectric material within the cable at all times thus guarantees a constant phase shift of signals passed through the attenuator. There is thus provided by the present invention apparatus capable of producing variable attenuation without concomitant variation in phase shift of signals operated upon.

In the preferred embodiment of the invention, illustrated in FIGURES 1 and 2 of the drawing, the tapered edge of the resistive coating at the bottom thereof is shown as being straight. This lower edge of the resistive coating is aligned with respect to the direction of travel of energy through the cable, and the edge is disposed at an angle greater than 0° but less than 90° to this direction of energy travel. With the illustrated pattern of resistive coating on the attenuator plate, there is achieved an approximately linear variation of attenuation with depth of insertion of the attenuator plate into the cable. It will, of course, be appreciated that other relationships may also be employed, and thus the lower edge of the resistive coating may be formed in a curvilinear manner, if desired.

FIGURE 3 of the drawings graphically illustrates variations in attenuation, phase shift, and voltage standing wave ratio (VSWR) obtained with one particular preferred embodiment of the present invention, substantially as illustrated in FIGURES 1 and 2. A 50 ohm coaxial line was employed, and the shaft **8** was calibrated in inches, with such calibration being indicated as the abscissa of the graph of FIGURE 3. It will be noted that a one-inch movement of the attenuator plate is covered by the graph, and furthermore, that the one-inch setting of the shaft **8** corresponds to the physical position of the attenuator plate illustrated in FIGURE 2, wherein no resistive coating is disposed within the coaxial cable. In this position, only a very small attenuation of signals passed by the cable is realized, and in fact measurement showed an attenuation of 0.8 decibel. A substantially linear variation of attenuation with shaft setting (attenuator-plate lowering) is indicated by attenuation curve of FIGURE 3 and this type of attenuation is obtained from the resistive-coating pattern illustrated in FIGURES 1 and 2 hereof. An overall attenuation variation from 0.8 decibel to about 11 decibels was obtained, as indicated on the graph, and throughout this range of attenuation only a very minor phase shift was observed. This phase shift, as indicated on FIGURE 3, was determined by measurement to be no more than plus or minus 2 degrees. For most applications, this relatively negligible phase shift is quite tolerable. However, it is possible, with slight modification hereof, to reduce this phase shift even further. The attenuator plate, as described above, is stated to have a resistive coating applied upon the dielectric plate, and consequently, it will be appreciated that some slight variation in overall thickness of the plate does occur, by virtue of the added thickness of the coating on portions thereof. Further minimization of the phase shift is accomplished by insetting the coating so as to insure a uniform plate thickness over the entire area thereof, including that area covered by the resistive coating. A further measurement carried out upon this preferred embodiment of the present invention identified the constancy of the voltage standing wave ratio. It will be seen from FIGURE 3 that the VSWR varied only from about 1.1 to 1.25.

The present invention provides a substantially phase-shiftless attenuator, wherein a substantial range of attenuation is available without the introduction of a variable phase shift in signals being attenuated. It will, of course, be appreciated that the device as illustrated in the accompanying drawings is intended for insertion in a coaxial line, which would then extend from the right and left of FIGURE 2, for example.

Numerous modifications and variations are also possible within the scope of the present invention, and quite clearly, the pattern on the resistive material on the attenuator plate may be varied, and also the material of the resistive coating, and the length thereof available for insertion in the cable may also be changed in order to obtain desired ranges of attenuation. By provision of a substantially constant amount of attenuator plate disposed in the cable, the present invention overcomes prior difficulties of variable phase shift normally associated with variable attenuation. It has been found that the attenuator hereof is highly advantageous in the two-to-four megacycle region.

Inasmuch as various modifications and variations may be made in the present invention, it is not intended to limit the scope of this invention by the preceding description of a particular preferred embodiment hereof. Reference is made to the appended claims for a precise delineation of the true scope of this invention.

What is claimed is:

1. In an attenuating apparatus for varying the attenuation of high frequency energy passing therethrough, wherein the apparatus includes a coaxial transmission line with a slot axially completely through both inner and outer conductors of the line, the improvement comprising:

an attenuator plate of uniform cross-section and formed of dielectric material,

means mounting the attenuator plate extending entirely through the slot in both inner and outer conductors of the transmission line for movement to dispose different portions of the plate in the slot,

and a resistive coating upon the attenuator plate in a pattern to provide a controllable amount of resistive coating within the transmission line while always maintaining a constant portion of said plate within said line, said amount varying in one direction continuously as said plate is moved in one direction through said line, to thereby provide for causing a varying amount of attenuation of said energy without substantially changing the phase of transmitted energy with changes in attenuation.

2. Attenuating apparatus for attenuating high-frequency energy comprising a short section of coaxial transmission line having a longitudinal slot passing completely through said line parallel to the direction of energy transmission through said line,

a dielectric plate extending completely through said slot and having disposed thereupon a pattern of resistive material, said pattern having a lower edge lying at an angle greater than 0° and less than 90° to the direction of energy transmission along said line, and

means mounting said plate for controlled reciprocal movement in the slot to dispose a controlled amount of resistive material in the slot for controlling attenuation of signals transmitted through the line while maintaining a constant amount of plate through the line,

whereby the phase shift of signals transmitted through the line is maintained substantially constant at all levels of attenuation.

3. The improvement of claim **2** where the resistive

coating has a straight inclined edge on the plate, to thereby provide a linearly varying attenuation with plate insertion through the line.

4. The improvement of claim 2 where the uncoated portion of the plate and the coated portion of the plate has a constant equal thickness to minimize phase change of said energy as the position of said plate within said slot varies.

5. In a variable attenuator having an axially slotted transmission line with a dielectric attenuator plate adapted to fit into said slot, the improvement comprising:

a housing about the slotted portion of the transmission line,

means slidably mounting said attenuator plate in said housing in position to extend at all times entirely through the slot in said transmission line,

drive means engaging the attenuator plate for sliding same in said housing to dispose different portions of the plate within the transmission line,

and a resistive material forming a part of said attenuator plate in a pattern varying in resistance from one end of the plate to the other in the direction of plate movement,

whereby a controllable amount of resistive material is disposable in the transmission line for controlled attenuation while maintaining a substantially constant amount of plate in the transmission line for constancy of phase shift in signals transmitted through the line.

6. In an attenuating apparatus for varying the attenuation of high-frequency energy passing therethrough, wherein the apparatus includes a coaxial transmission line with an axial slot completely through both inner and outer conductors of the line, the improvement comprising:

an attenuator plate of uniform cross-section and formed of dielectric material,

means mounting the attenuator plate extending entirely through the slot in both inner and outer conductors of the transmission line for movement to dispose different portions of the plate in the slot, and

a resistive coating upon the attenuator plate in a pattern to provide a controlled amount of resistive coating within the transmission line while always maintaining a constant portion of said plate within said line, said

amount of resistive coating in said line continuously varying linearly as the plate is moved in one direction through said line, to thereby provide for causing a varying amount of attenuation of said energy without substantially changing the phase of transmitted energy which changes in attenuation.

7. In an attenuating apparatus for varying the attenuation of high-frequency energy passing therethrough, wherein the apparatus includes a coaxial transmission line with a slot axially completely through both inner and outer conductors of the line, the improvement comprising:

an attenuator plate of uniform cross-section and formed of dielectric material,

means mounting the attenuator plate extending entirely through the slot in both inner and outer conductors of the transmission line for movement to dispose different portions of the plate in the slot, and a resistive coating upon the attenuator plate in a pattern to provide a controlled amount of resistive coating within the transmission line while always maintaining a constant portion of said plate within said line, said pattern having a straight leading edge disposed askew to the direction of energy transmission through the transmission line whereby the amount of resistance in the line varies continuously in one direction as the plate is moved in a single direction through the line to thereby produce a varying amount of attenuation of transmitted energy without a substantial change in the phase of transmitted energy.

8. The improvement of claim 7 further defined by the straight leading edge of said pattern of resistive material being displaced from an edge of said plate in the direction of plate motion.

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HERMAN KARL SAALBACH, *Primary Examiner.*