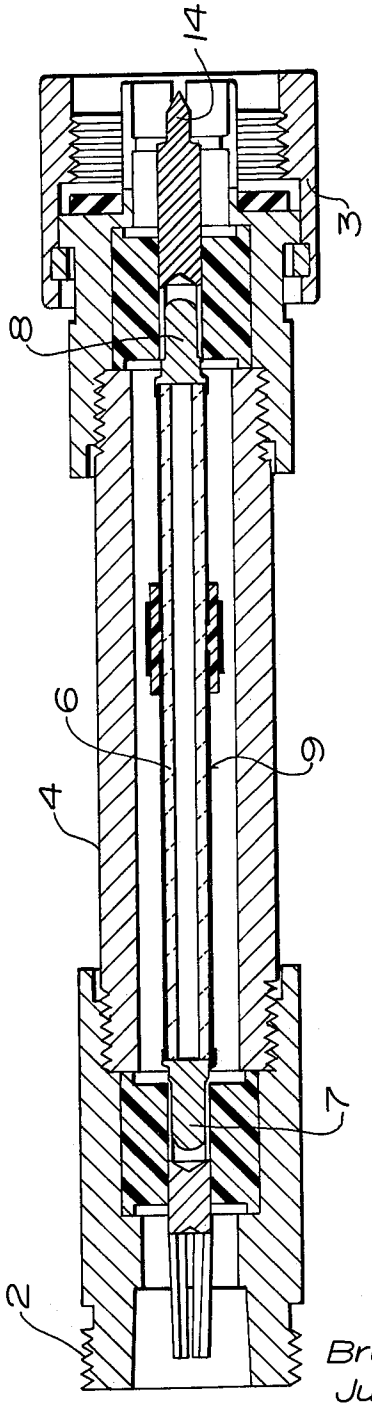
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FREQUENCY-COMPENSATED COAXIAL ATTENUATOR

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Fig. 1



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Fig. 2

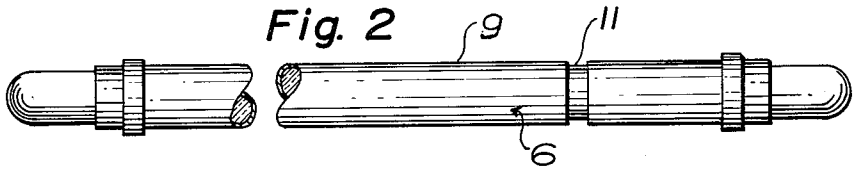


Fig. 3

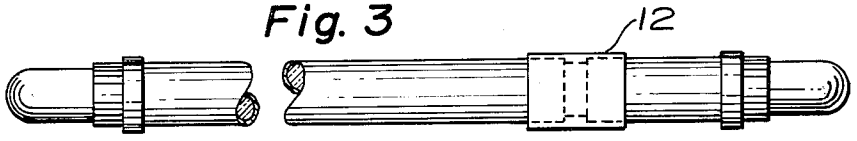
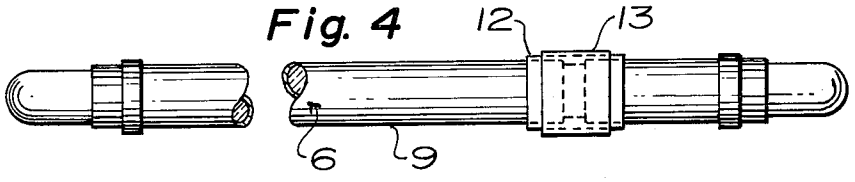


Fig. 4



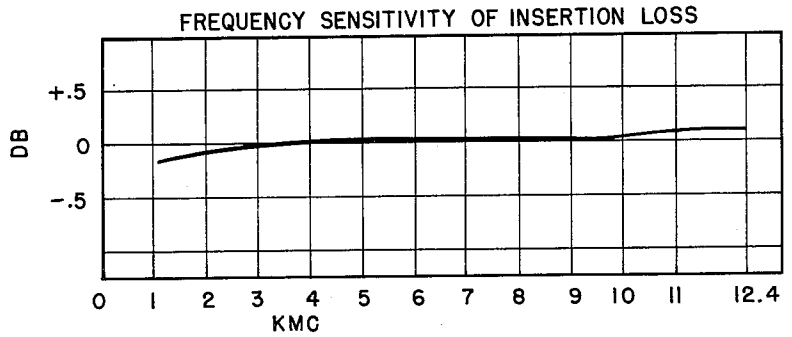


Fig.5A

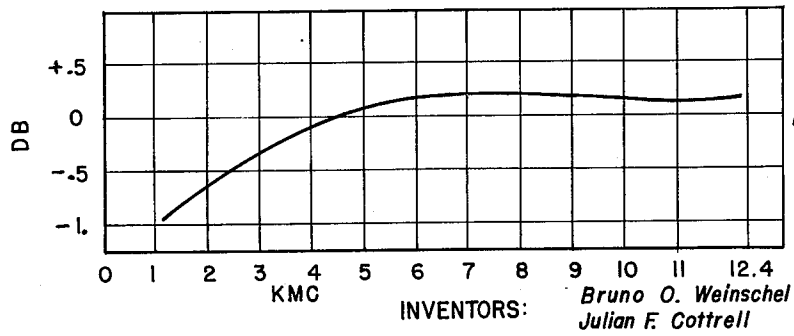


Fig 5B

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3,005,967
FREQUENCY-COMPENSATED COAXIAL ATTENUATOR

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Filed Apr. 27, 1960, Ser. No. 24,998
7 Claims. (Cl. 333—81)

This invention relates to a lossy-line type of coaxial attenuator such as is used in high-frequency and microwave coaxial line circuits, and has for its primary object the provision of a lossy-line type of attenuator which has a constant attenuation over a much wider frequency range than is possible with presently-used types of attenuators. The usual lossy-line attenuator is useful over a frequency range that is limited at the high end by problems due to the coaxial connectors which are necessarily used, or by higher modes generated in the lines, that is, by factors outside the attenuator itself. At the low end, the attenuator tends to fall off rather rapidly below a certain frequency, depending on the type and size of coaxial cable used, etc. One reason for this is that the attenuator must have a certain minimum length, expressed in terms of wavelengths, to function properly as an effective coaxial attenuator. If the resistive section is short compared to a wavelength, it is apparent that the attenuation will not be constant with respect to frequency; the major purpose of the present invention is to provide wide-band attenuation having substantially the same value of attenuation, expressed in decibels, for a wide band of frequencies.

A major object of the invention is to provide a lossy-line coaxial attenuator of the type using a very thin layer of resistive material as one of the elements of a section of coaxial line, with a series condenser which is structurally a part of the lossy-line and which functions in a novel way to offset the usual droop at the low end of the "insertion loss vs. frequency" curve. A further object is to provide such a construction without appreciably changing the bulk or physical configuration of the attenuator, and by means of a simple construction which adds little to the expense of fabrication or to the skill required to make the attenuator unit.

Another object is to provide a wide-band high-frequency coaxial attenuator of simple and rugged construction and having high stability and resistance to physical and thermal stresses and aging.

The invention is particularly applicable to attenuators of the type shown in U.S. patent to Weber, No. 2,689,294, for "Metal Film Attenuator," and also to attenuators of the type shown in the copending U.S. patent application of Bruno O. Weinschel, Serial No. 833,041, filed August 11, 1959, for "Inside-Out Attenuator," wherein the resistive coating is applied to the outer coaxial element of a coaxial section instead of to the inner coaxial element.

According to the invention, a circumferential gap is made in the thin resistive tubular coaxial element intermediate the ends thereof, and a short section of the element in the vicinity of this gap is coated with a thin layer of insulating material over which is placed a further coating of conducting material which extends across the gap axially for a suitable short distance on either side of the gap, forming, in effect, a series condenser arrangement, one plate of which is the conducting outer layer, the other plate (or plates) being formed by the portions of the resistive layer under the coating of the conductive material. This functions partly as a series condenser and partly as a construction which shorts out a portion of the resistive material at the higher frequencies and introduces more of the resistive material at the lower frequencies to level out the attenuation-frequency characteristic as will be explained in detail below.

The specific nature of the invention, as well as other objects and advantages thereof, will clearly appear from a description of a preferred embodiment as shown in the accompanying drawings in which:

FIG. 1 is a longitudinal cross-sectional view of one form of attenuator according to the invention;

FIGS. 2, 3 and 4 show the central resistive element of the attenuator of FIG. 1, in successive stages of preparation required to make the finished products; and

FIGS. 5A and 5B show a series of graphs used in explaining the characteristics of the invention in comparison with prior art devices.

The invention will be explained in connection with an attenuator in which the inner coaxial element is the resistive element, similar to that shown in the Weber patent previously referred to, but it will be understood that the same principle and construction are applicable to an attenuator of the type shown in the copending application of Bruno O. Weinschel, Serial No. 833,041, wherein the resistive coating is applied to the outer coaxial element.

FIG. 1 is a longitudinal sectional view of an attenuator made according to the invention, in the usual form of an element which can be inserted directly into a coaxial line, and for this purpose is provided with standard coaxial male and female fittings 2 and 3 respectively. The outer coaxial conductor of the attenuator, 4, is of conventional construction. In this case, the actual attenuator element is the inner conductor 6, which is essentially a rod of insulating material, usually of ceramic material, provided with bullet connectors 7 and 8 at the ends thereof mating with the central terminal elements of the respective coaxial fittings 2 and 3. In a prior type of construction, such as shown in the copending application above referred to, the resistive element is formed of a very thin coating 9, which may be either an alloy of noble metals, or a thin layer of carbon suitably applied, by previously known methods and techniques which are not a part of the present invention. In the usual attenuator construction, this coating uniformly covers the ceramic rod 6 from end to end, and constitutes the resistive attenuator element. In this usual construction, however, the attenuator element typically has the characteristic shown in FIG. 5A, for a 3 db attenuator. It will be noted that while at 3 db the insertion loss is reasonably constant over range from 1–12.4 kilomegacycles, at 10 db, the insertion loss falls off very badly between 1 and 4 kmc. In making a 10 db attenuator, as shown in FIG. 5B, it is necessary to use a much higher resistance rod, and the ratio of resistance to wavelength goes up quite rapidly, and the attenuation correspondingly goes down for the lower frequencies, as explained above. This can be further understood by considering that if we assume a lossless line, the characteristic impedance is determined by the distributed inductance and capacitance of the line only, but in the case of an attenuator, it is necessary to make one of the conductors resistive, whereupon the characteristic impedance becomes frequency sensitive if the ratio of resistance to wavelength becomes too high, as it does for the lower frequencies. This will be apparent from consideration of the standard transmission line equations, which show that all of the parameters are expressed in terms of quantities which can be transformed into a ratio of wavelengths to the physical parameters of the line.

In order to minimize the drooping characteristic at the lower frequency range, the construction shown in the drawings is employed. For this purpose, the central conductor is prepared in the usual fashion, that is, the ceramic rod 6 is coated with the usual resistive layer 9 from end to end. A narrow circumferential groove, typically 30–60 mils wide, is then cut in the resistive film.

This can be conveniently done by grinding, the purpose being to remove the resistive film, but as little of the ceramic as possible. The resulting construction is as shown in FIG. 2. A coat of insulating material, for example, black "Glyptal," is now applied to the vicinity of the gap **11**, as shown at **12**. This may be done with a small camel-hair brush, or by any other convenient means, and should extend, in a typical case, at least one-half inch on either side of the groove **11**, as well as covering the groove. If "Glyptal" is used, the rod should then be baked at 150° C. for a minimum of eight hours, then a second coat of "Glyptal" should be applied and baked at the same temperature for an additional eight hours. A band of silver paint, **13**, should now be applied directly over the groove, but not extending as far as the "Glyptal," and baked for a minimum of four hours at 150° C. to provide, in effect, a tubular coating of conductive material over this portion of the rod. It will be understood that instead of silver, any other suitable conductive material may be similarly applied, and that band **13** may be of resistive material instead of highly conductive, depending on the characteristic required.

In order to determine the proper axial length of the conductive coating **13**, the attenuator may then be assembled, and the attenuation measured at both the high and low ends of the frequency spectrum desired, say for example, from 0.5 kmc. to 11.0 kmc. The attenuation should not differ by more than +0.1 db to −0.2 db at these two frequencies. If the attenuation is greater than this, the axial length of **13** should be increased, and vice versa.

As a final production step, the entire rod unit **6** may then be given an additional coat of black "Glyptal" from end to end, and baked again for a minimum of eight hours at 150° C. As indicated by the above procedure, it is normally expected that an attenuator so made will have a substantially flat frequency-attenuation characteristic, within the limits noted, over the entire frequency band from 0.5 to at least 11 kmc. This is in sharp contrast to the characteristic of an ordinary attenuator as noted in FIG. 5.

It will be noted that the improved result is not due simply to the effect expected by placing a capacitor in series with a resistive line, since a pure capacitive element is not dissipative and does not produce the same effect as a lossy-line resistance type of attenuator. In the above construction, the groove **11** provides, together with the adjacent ends of the resistance material **9** and the conductive layer **13**, a structure corresponding to two capacitors in series. However, this is obviously not a lumped capacity, but the capacity is also distributed along a portion of the line adjacent the groove. Due to this construction, the current in the resistive film at very high frequencies will mostly be bypassed right into the silver from the resistive films, tending to go directly from the resistive film to one end of the conductive band **13**, and then to return into the resistive film at or very near the other end. In this case, only a small part of the capacity will be effective; furthermore, since there is a larger effective length of the outer silver coating acting in this case, there is correspondingly a shorter effective length of the resistive element being utilized. Conversely, at the lower frequencies more and more of the inner surface of the silver coating **13** is effective as an ordinary condenser, and more and more of the resistive material enters into the action. Therefore, at the lower frequencies, the attenuation does not fall off as shown in FIG. 5, but tends to remain substantially uniform throughout the entire range. It will be apparent from the foregoing that the distribution of current along the length of the capacitor-resistor section is different at different frequencies in a manner which tends to compensate for the usual low-frequency droop.

While exact calculation of the effect at each frequency is difficult, as previously noted, approximate calculations can be easily made with simplifying assumptions, which give sufficiently good results so that it is not difficult to compute the approximate dimensions for any given set of practical conditions, using as a basis the capacitive reactance of a condenser of the dimensions which are determined by the size of coaxial cable and other parameters employed.

The above construction is of particular utility where a flat characteristic is essential, but adds so little to the cost of the attenuator, that it may be used in any situation where a general-purpose wide spectrum attenuator is required. It does not adversely affect the operation of the attenuator in any way, and the stability, aging, shock resistance, etc. are fully equal to those of an ordinary attenuator of this general type. The units are easily reproducible as to electrical characteristics in manufacture by the use of ordinary production control methods, and do not require more highly skilled labor than the ordinary attenuators.

While the band **13** has been shown as of conductive material, it will be understood that this could also be of resistive material, which may be desirable in some cases to produce a particular characteristic.

In FIG. 2, the gap **11** has been shown as being further from one end of the rod **6** than from the other. This is the preferred construction in the case of a unilateral attenuator, that is, one which is always to be fed from one end. In this case, it is desirable to put the discontinuity fairly close to the other end, so as to provide the maximum attenuation path for any slight reflections which may occur due to the unavoidable effects of the discontinuity. In the case of a bilateral attenuator, that is, one which is intended for use in both directions of transmission, then the gap **11** should obviously be placed at the center of the rod **6**.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of our invention as defined in the appended claims. For example, the resistive coating could be on the inner surface of the outer coaxial conductor, as in the copending Weinschel application previously referred to, in which case the circumferential slit would be made as before, but on the inside surface of a hollow cylinder, and the respective bands of insulation and silver would be respectively nearer the central axis than the main resistive coating instead of being further away from the central axis, but otherwise the construction and principle of operation will be the same.

We claim:

1. A high-frequency coaxial attenuator having opposed conductive surfaces lying between coaxial terminals, one of said surfaces being constituted by a thin layer of resistive material adhered to the surface of an insulating member to constitute a lossy-attenuator surface, and extending continuously between said coaxial terminals, except for a narrow circumferential gap; a thin layer of insulating material covering said layer of resistive material on both sides of said gap; and a further layer of conductive material covering said layer of insulating material for a portion of the axial extent of said resistive material on both sides of said gap, said further layer being electrically separated from said layer of resistive material by said layer of insulating material.

2. The invention according to claim 1, said opposed surfaces being concentric cylindrical surfaces.

3. The invention according to claim 2, said further layer of conductive material being a layer of highly conductive material of negligible resistance.

4. The invention according to claim 3, said highly conductive material being silver.

5. A wide-band high-frequency coaxial attenuator comprising an elongated inner insulator having a cylindrical outer surface, a very thin resistive layer of electrically

conductive material adhered to the outer surface of said insulator and constituting a lossy-attenuator surface, a tubular outer conductor coaxially spaced from said resistive layer, there being a circumferential gap in the length of said resistive layer intermediate its ends, a thin layer of insulating material covering said resistive layer in the vicinity of said gap, and a further layer of conductive material covering said layer of insulating material for a portion of the axial extent of said resistive material on both sides of said gap, said further layer being insulated from said layer of resistive material by said layer of insulating material.

6. The invention according to claim 5, said further layer of conductive material being a layer of highly conductive material of negligible resistance.

7. The invention according to claim 6, said highly conductive material being silver.

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