March 16, 1965 B. D. FREDERICO 3,174,123

HIGH POWER HYBRID-L COAXIAL ATTENUATOR WITH T-FITTING FOR INNER CONDUCTORS

Filed Jan. 28, 1963

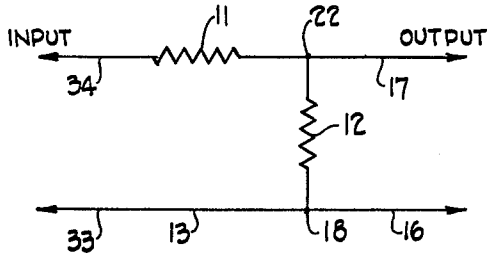
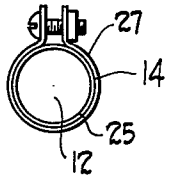


FIG. 3

FIG. 2



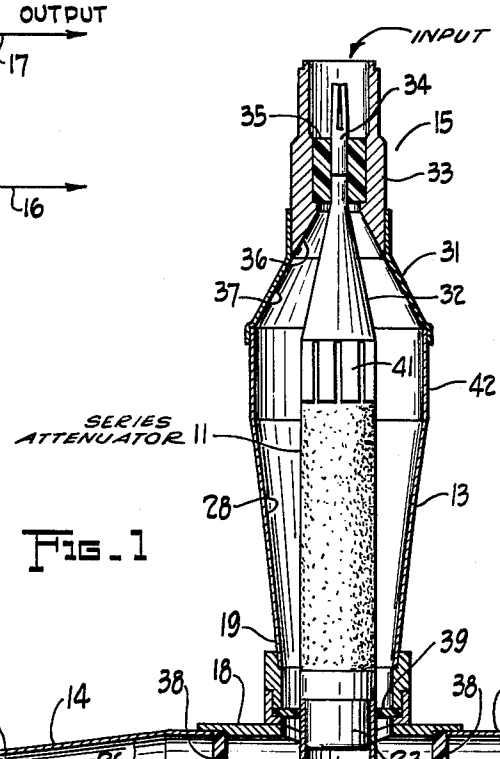
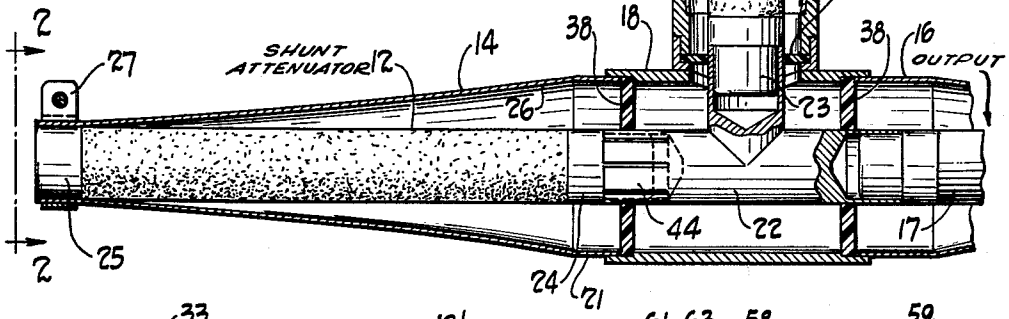


FIG. 1



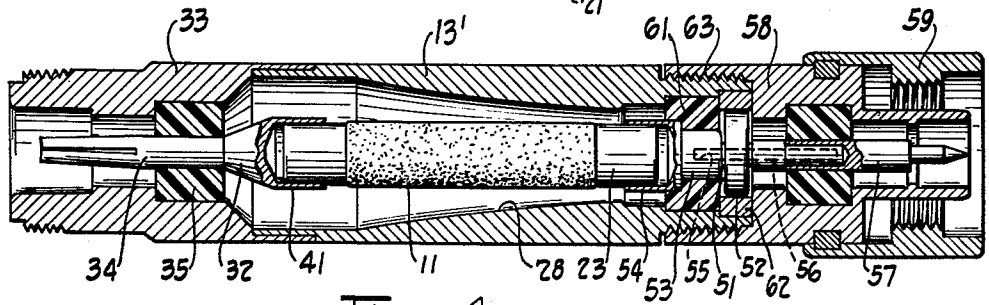


FIG. 4

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United States Patent Office 3,174,123 Patented Mar. 16, 1965

3,174,123

HIGH POWER HYBRID-L COAXIAL ATTENUATOR WITH T-FITTING FOR INNER CONDUCTORS

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Filed Jan. 28, 1963, Ser. No. 254,125
4 Claims. (Cl. 333—81)

This invention relates to coaxial electrical power transmission systems and concerns particularly attenuators for such systems.

An object of the invention is to provide an attenuator capable of providing a relatively high loss in power transmitted from a coaxial transmission line system and which is effective for dissipating relatively high levels of power.

A further object of the invention is to provide an attenuator for a fixed decibel loss which is independent of frequency variations, functioning over a very wide range of frequencies from direct current to 4000 or more megacycles.

A further object of the invention is to provide an attenuator design which is very flexible and which is suitable for tapping off high frequency energy at different places.

A further object of the invention is to provide coaxial apparatus without abrupt changes in impedance which could cause reflection.

A further object of the invention is to provide an attenuator without limit in dissipation and which can, if necessary, use forced air cooling or a liquid, but which is self-cooling by air convection at power levels considerably in excess of attenuations heretofore available in wide-band, reflectionless, coaxial line operation.

A general object of the invention is to provide an economical self-contained portable attenuator which requires no primary power for operation, which has a substantially constant attenuation over a tremendous frequency range and produces negligible system reflection over a wide frequency range with a very small variation in standing wave ratio.

Other and further objects, features and advantages of the invention will become apparent as the description proceeds.

In carrying out the invention in accordance with a preferred form thereof an L type pad is employed with deposited-carbon, thin-film resistors in series and shunt elements enclosed in contoured horns with suitable means for connection to coaxial system such as type "N" input and output connectors.

A better understanding of the invention will be afforded by the following detailed description considered in conjunction with the accompanying drawings, in which

FIG. 1 is a view of a longitudinal section of one embodiment of the invention.

FIG. 2 is a fragmentary end view of the shunt element as seen looking in the direction of the arrows 2—2 of FIG. 1.

FIG. 3 is an equivalent circuit diagram of the L type connection formed by the apparatus of FIG. 1, and

FIG. 4 is a view of a longitudinal section of another embodiment of the invention for use in the intermediate power dissipation ranges where an even more compact device than that of FIG. 1 is desired.

Like reference characters are utilized throughout the drawing designating like parts.

Referring to FIG. 1, series and shunt, power-dissipating resistors or attenuators 11 and 12, respectively, are shown in the form of thin resistance coatings on insulating rods of ceramic or the like. In order to render the resistance value independent of variations in skin effect with variations in frequency the resistance coatings are in the form of very thin films such as accomplished by deposited carbon so that current conductivity must take place through the same depth of film at direct current and lower frequencies as well as ultra high frequencies. The resistor rod 11 is enclosed in a contoured horn 13 and the resistor rod 12 is enclosed in a contoured horn 14. Suitable means are provided for making an input connection, for example, by means of a conventional "N" type input connector 15. Suitable means are also provided for making an output connection through a fragmentarily shown output transmission line represented by an outer conductor 16 and an inner conductor rod 17.

A hollow conductor fitting shown in the form of a T 18 composed of brass or other suitable conductive metal is provided for interconnecting the output end 19 of the horn 13, the larger diameter input end 21 of the shunt horn 14 and the outer hollow conductor 16 of the output line. Likewise a conductive T fitting 22 is provided for interconnecting the end 23 of the resistor 11, the end 24 of the shunt resistor 12, and the center conductor rod 17 of the output transmission line.

The resistors 11 and 12 take the form of cylindrical rods or tubes of insulating material having a resistance carbon film deposited thereon with end portions 23, 24 and 25 coated with a suitable conductive material such as fired on silver paint or copper plating in order to enable connections to be made. The resistor 12 is terminated at the end 25 by connection to the outer conductor or horn surface 26. In order to insure good electrical connection, the end of the horn 14 around the conductive band 25 of the resistor 12 may be slitted and a clamp 27 may be provided for pressing the metal of the horn 14 against the silver band 25.

The curvature of the surface 26 and the resistance of the carbon film conductor 12 are so related, in accordance with known principles, that at each point along the length of the line so formed, the center conductor termination resistance between such point and the end of the line is equivalent to the characteristic impedance of the line measured at that point. This is accomplished, as is well known to those skilled in the art, by forming the surface 26 with a logarithmic taper in its diameter.

There is likewise a logarithmic taper in the portion 28 of the inner surface of the outer conductor 13. Thus the outer-to-inner diameter ratios vary logarithmically. However, the smaller diameter end 19 of the outer conductor 13 is not made so small as to make contact with the surface of the resistor 11 since the unit is merely an attenuator and a portion of the energy is to be transmitted on through the coaxial elements 16 and 17. The characteristic impedance at the output end 19 of the horn 13 is of suitable value to match the parallel impedances of the shunt 13, 14 and the output line 16, 17. The horn 13 is so contoured as to provide the requisite characteristic impedances at the input and output ends. This is accomplished by making the characteristic impedance of the enclosing horn 13 at any cross-section equal to the effective resistance beyond that cross-section looking toward the decreasing diameter end of the horn.

The relationship between the resistances of the elements 11 and 12 is determined by the attenuation desired. It will be understood that the apparatus is designed for connection to a load or to a transmission line at the points 16 and 17 which has a predetermined characteristic impedance. For example in the case of the apparatus illustrated it is designed for a nominal characteristic of 50 ohms.

It will be understood that changes of diameter and dielectric along the length of the output line 16, 17 are suitably proportioned to maintain the characteristic impedance of the line, here normally 50 ohms in accordance with well known considerations.

In order that the resistors 11 and 12 may be of suf-

ficient diameter to provide the requisite current-carrying capacity, although constituted by very thin films, the coaxial conductor diameters of the input connector 15 are increased in the elements 11 and 13. This may be accomplished by the use of a tapered union comprising a hollow conductor cone 31 and a center conductor 32 which may be either solid or hollow, as preferred, dimensioned in the manner described in Patent 2,453,759 Robinson in order to maintain constant characteristic impedance without discontinuities and to avoid reflection.

The input connector 15 comprises an outer conductor ferrule 33, a center pin 34 and an insulator bushing 35 for centering and supporting the pin 34 in the conductor 33. It will be understood that the internal conical surface portion 36 of the conductor body 33 forms a continuation of the conical surface of the interior 37 of the cone 31. The conical surfaces 32, 36 and 37 have the same apex, such that an arc drawn through the larger diameter ends of the surfaces 32 and 37 with said apex as a center fixes the length of the conical surface elements. Consequently, the conical surface 32 extends axially a slightly greater distance than the conical surface 37 toward the fittings 22 and 18.

Suitable insulator bushings or washers 38 and 39 are provided for supporting and centering the fitting 22 in the hollow T fitting 18.

In order to make electrical contact between the center pin 34 and the input end of the resistance surface 11, the end of the resistance surface is silvered and the cone 32 is formed with spring fingers 41 adapted to contact the silvered end surface of the resistor 11. The portion 42 of the outer conductor 13 surrounding the spring fingers 41 and extending slightly over the end of the resistance surface 11 is cylindrical. The axial length of the cylindrical portion 42 in relation to the length of the conductively coated end of the resistor 11 is such as to avoid reflections at the end of the resistor as will be understood by those skilled in the art.

The fitting 22 is also provided with spring fingers for making contact with the silvered ends 23 and 24 of the resistors 11 and 12 as well as with the end of the center conductor 17, spring fingers 44 being shown and remaining spring fingers being broken away in order to expose the entire section.

Although the conventional symmetrical T- or pi-connected, disc-type attenuator is capable of dissipating only up to about 10 watts owing to the limitations of the disc power dissipation, the attenuator constructed in accordance with the invention may be employed for much greater dissipation. For example, in the case of an attenuator occupying 810 cubic inches (6 inches x 9 inches by 15 inches) and weighing less than 20 pounds designed for nominal impedance of 50 ohms, an average power dissipation of 500 watts and a peak power limited only by the voltage handling capacity of the connector 15 may be handled continuously over a frequency range from direct current to over 4000 megacycles with a variation in standing wave ratio of less than 1.2 in either pulse or continuous-wave operation, cooled by free air convection.

The attenuator may be designed for any attenuation desired without deteriorating or diminishing the power dissipation ratings mentioned. An attenuator of the same physical dimensions may be designed for any value of attenuation at still higher power inputs if forced cooling is employed. For example, the resistors 11 and 12 may be mounted on hollow rods cooled internally by forced air or circulating liquid in the manner described in Patent 2,894,219 Frederico.

Moreover, the type of attenuator illustrated is very flexible and can be designed to tap off power at different locations.

Where a smaller size and greater compactness are desired, a combination horn and disc type attenuator such as illustrated in FIG. 4 may be employed in the range

between approximately 5 and 20 watts dissipation with free air convection cooling and somewhat greater dissipation if forced cooling is employed. Within the power ranges specified this modified attenuator may be utilized at all ranges of attenuation and throughout the entire frequency range from direct current to 4000 megacycles or more.

The attenuator illustrated in FIG. 4 comprises a series resistor 11 similar in construction to that shown in FIG. 1 and a shunt resistor constituted by a resistance surface 51 on an insulating disc 52 of ceramic insulating material, or the like. The series resistor 11 is mounted within an outer conductor body 13' having the internal tapered horn surface 28. The left conductive surface end of the resistor 11 is supported by spring members 41 in a manner described in connection with FIG. 1; and for supporting the opposite conductive coated end 23, a fitting 53 is provided having spring fingers 54 for receiving the resistor end 23. The fitting 53 is composed of a suitable conductor such as brass, for example, and has a socket 55 for receiving and making contact with a tinned copper wire 56 passing through a center opening in the insulator disc 52 and electrically connecting the fitting 53 to the conventional center pin 57 of an output connector formed by the pin 57 and outer conductor fitting 58 and attaching nut 59.

An insulating bushing 61 is provided for centering and supporting the conductor 53 in a socket at the end of the horn body 13'. A conductor bushing or ring 62 of brass, copper or the like is provided for supporting and centering the insulator disc 52 in a counterbore at the end of the body 13' beyond the insulator 61.

The insulator disc 52 is coated on one surface with deposited carbon to form the shunt resistor corresponding to the resistor 12 of FIGS. 2 and 3. The center portion of this surface is coated with a suitable conductive paint such as silver paint for making electrical contact with the conductor fitting 53. The outer periphery of the resistance-coated surface as well as the cylindrical surface of the insulator disc 52 are likewise given a conductive coating of silver or the like in order to make electrical contact between the outer edge of the shunt resistor and the outer conductor body 13' through the conductor ring 62.

It will be understood that by suitable means such as a threaded connection 63, the conductor 58 is secured against the connector body 13' in order to hold the conductor ring 62, the insulator bushing 61, and the conductor fitting 53 in place after the apparatus is assembled.

The attenuator described may be used for any purpose for which an attenuator may be desired. For example in case it is desired to measure the output of a high power transmitter by means of a low power microwave watt meter, this may be done by connecting the transmitter to the input coupling 15 directly or through a transmission line of the proper characteristic impedance and the watt meter is connected by means of a suitable connector between the inner conductor 17 of the outer conductor 16 of the output of the unit. A power division then takes place. A major portion of the dissipation takes place in the resistor 11 for high attenuations and the remaining power continues to flow outward through the conductors 16 and 17.

Certain embodiments of the invention and certain methods of operation embraced therein have been shown and particularly described for the purpose of explaining the principle of operation of the invention and showing its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and it is intended therefore, to cover all such modifications and variations as fall within the scope of the invention.

What is claimed is:

1. An attenuator comprising in combination a hollow outer conductor, a center rod concentric therewith having

a resistance coating, said rod and said conductor each have a first end and being adapted for receiving energy at said end and each having a second end serving as an output end, the said outer conductor having a portion extending toward said output end in the form of a logarithmically tapered horn, tapering to a smaller diameter toward the output end, an outer conductor fitting in the form of a hollow T, an inner conductor fitting in the form of a T, an outer conductor branch having a larger diameter end electrically connected to said outer conductor fitting and a smaller diameter end, the said branch outer conductor being a logarithmically tapered horn, a branch center rod having a resistive outer surface electrically connected at one end to the smaller diameter portion of the branch outer conductor and at the opposite end to said inner conductor fitting, the output ends of said first outer and inner conductors being electrically connected to the outer and inner conductor fittings, respectively, an output concentric transmission line comprising inner and outer conductors, said inner and outer conductor fittings being connected to the inner and outer conductors respectively of the output concentric transmission line for delivery of a fraction of the power supplied to the attenuator, the attenuation taking place in the resistive surfaces of said center rods, the branch and the output line extending in opposite directions perpendicular to the first mentioned outer conductor and center rod.

2. An attenuator comprising in combination a concentric transmission line with an input end for connection to a source of electrical energy to be attenuated and an output end, a branch transmission line, a hollow fitting in the form of a T, an inner fitting in the form of a T, each T having a pair of arms extending in opposite directions and an arm extending perpendicularly thereto, each transmission line comprising an outer hollow conductor and a concentric center rod, the latter possessing electrical resistance, the output end of the first mentioned concentric transmission line being connected to one arm of the T-fitting, the branch transmission line having a first end at which the outer conductor and the resistive center rod are electrically connected and having a second end connected to a second arm of the T-fitting, and the third arm of the T-fitting serving as a connector for an output transmission line, whereby the first resistive rod serves as a series dissipator and the branch resistive rod serves as a shunt dissipator to form an L-connected attenuator.

3. A wide, frequency band attenuator comprising in combination a concentric transmission line with inner and outer elements with a ratio of outer element diameter to inner element diameter tapering logarithmically to a smaller value from an input end to an output end, an output transmission line having a predetermined characteristic impedance, a shunt, a connection junction comprising a fitting in the form of a hollow T and an inner fitting therewithin in the form of a T, the connection junction thus having a pair of arms extending in opposite directions and an arm extending transverse thereto, one of said arms being connected to the output end of said concentric transmission line, the center element of

the concentric transmission line comprising a resistive center rod, the shunt comprising an outer conductor and an inner element with a resistive surface with first and second ends, the outer conductor having a first end connected to the first end of the resistance element and a second end, the second ends of the shunt being connected to a second arm of the connector junction, the output transmission line being connected to the third arm of the connection junction and having a predetermined characteristic impedance, the characteristic impedance of the first mentioned transmission line at its output end corresponding to the parallel characteristic impedances of the shunt and the output line.

4. An attenuator comprising in combination a first transmission line comprising an outer conductor with input and output ends, an inner element in the form of a resistive center rod with input and output ends, an input union with an inner element and a hollow outer element each with an input end and with an output end of greater diameter, the output ends being connected to the input end of the first mentioned transmission line, the first transmission line having a ratio of outer-to-inner diameter tapering to a smaller value from the input end to the output end, an output transmission line having a predetermined characteristic impedance, a shunt comprising a hollow outer conductor and a center element comprising a resistive center rod each having first and second ends with outer-to-inner diameter ratio diminishing from the first end to the second end, the diameters at the second end being the same to provide electrical contact between said second ends, a connection junction comprising a fitting in the form of a hollow T and therewithin a fitting in the form of a T whereby the connection junction has a pair of arms extending in opposite directions and a third arm extending transversely to the first and second arms, one of the arms being connected to the output end of the first transmission line, the second arm being connected to the first ends of the shunt and the third arm being connected to the output transmission line, the characteristic impedance at the output end of the first transmission line having a value equalling the parallel impedance of the shunt and the characteristic impedance of the output transmission line.

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HERMAN KARL SAALBACH, *Primary Examiner*.