

May 31, 1938.

S. J. A. M. BAGNO

2,119,195

CONSTANT IMPEDANCE ATTENUATOR

Filed Nov. 5, 1935

2 Sheets-Sheet 1

Fig. 1.

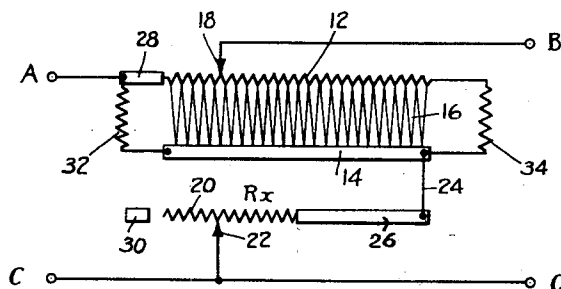


Fig. 2.

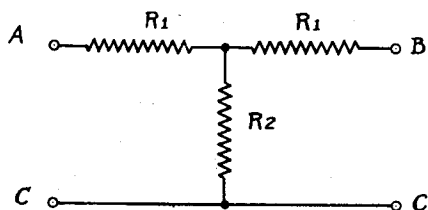


Fig. 3.

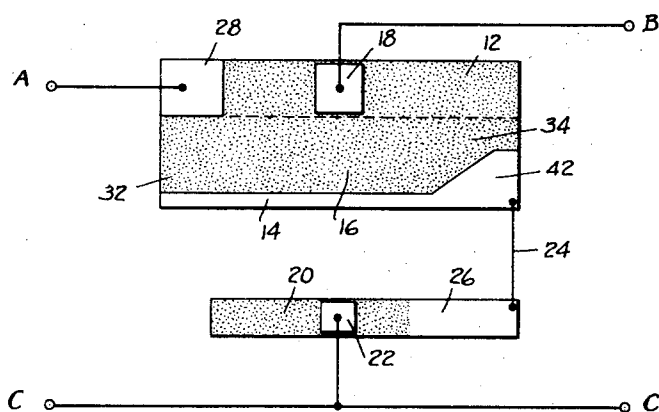
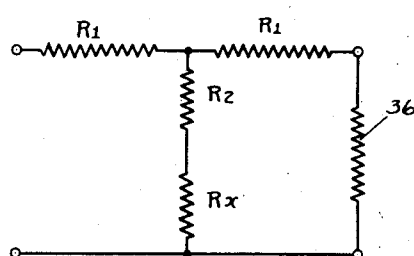


Fig. 4.

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2 Sheets-Sheet 2

Fig. 6.

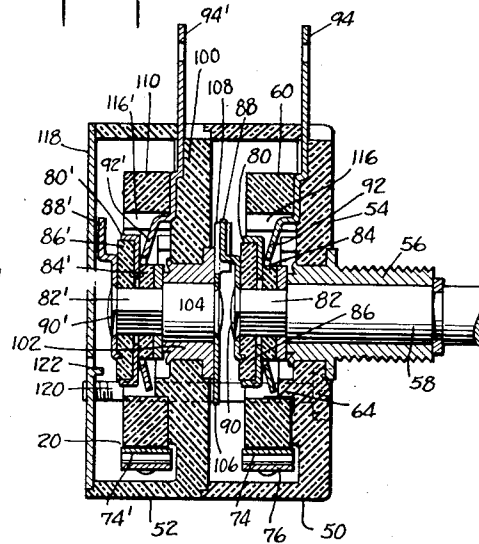
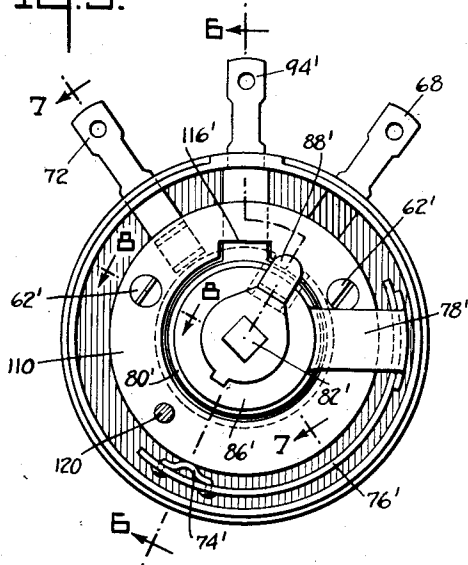


Fig. 7.

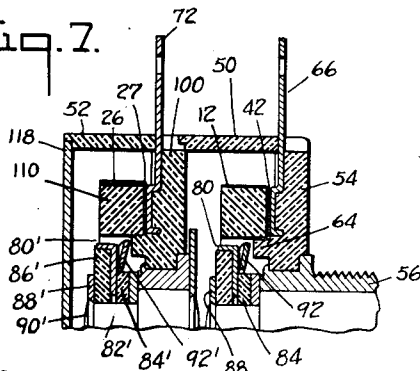


Fig. 8.

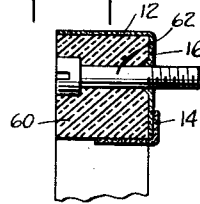


Fig. 9.

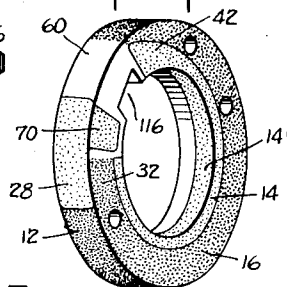


Fig. 11.

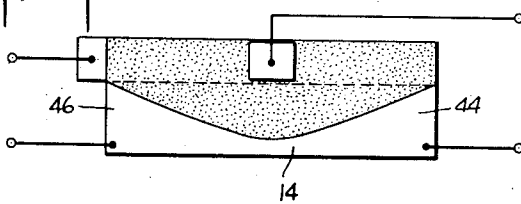
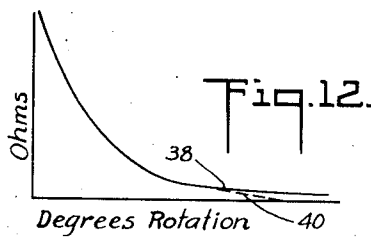
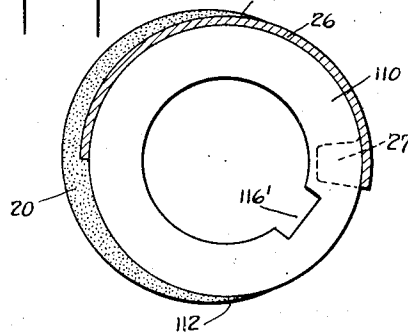


Fig.10.



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2,119,195

CONSTANT IMPEDANCE ATTENUATOR

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Application November 5, 1935, Serial No. 48,292

24 Claims. (Cl. 178—44)

This invention relates to attenuators, and more particularly to constant impedance attenuators.

In my Patent No. 2,081,572, patented May 25, 1937, entitled "Attenuator", I disclose an attenuator possessing special advantages, such as the possibility of obtaining logarithmic attenuation while using uniform resistances, and the further possibility of obtaining a substantially constant impedance during variation of the attenuator. I there explained that the impedance may be kept approximately constant, with a range of, say, 2 to 1, which was to be contrasted with conventional units, for example, a potentiometer, in which the variation is infinity.

The primary object of the present invention is to generally improve attenuators of the character shown in my aforesaid Patent No. 2,081,572. A more particular object is to give the attenuator a nearly perfectly constant impedance, that is, to eliminate even the 2 to 1 range of variation referred to, while retaining a structure which is practical and economical to manufacture.

A further and important object of my invention is to eliminate all loss in the attenuator when adjusted for zero attenuation, preferably by cutting the attenuator entirely out of circuit. Still another object of my invention is to so arrange the attenuator structure that the impedance at either end will be substantially the same as the impedance at the middle of the attenuator, while using the entire length of the attenuator.

To the accomplishment of the foregoing and other objects which will hereinafter appear, my invention consists in the attenuator elements, and their relation one to the other, as are hereinafter more particularly described in the specification and sought to be defined in the claims. The specification is accompanied by drawings in which:

Fig. 1 is a schematic wiring diagram illustrating one form of my invention;

Fig. 2 is a diagram explanatory thereof;

Fig. 3 is a diagram further explanatory thereof;

Fig. 4 is a schematic diagram of the invention as embodied with film type resistances;

Fig. 5 is a rear elevation of an attenuator using attenuator and auxiliary series resistance units arranged in tandem;

Fig. 6 is a section through the said tandem arrangement, taken in the plane of the line 6—6 of Fig. 5;

Fig. 7 is a section taken in the plane of the line 7—7 of Fig. 5;

Fig. 8 is a section through the attenuator ring, taken in the plane of the line 8—8 of Fig. 5;

Fig. 9 shows the attenuator ring in perspective;

Fig. 10 is a section through the auxiliary resistance ring;

Fig. 11 is a schematic diagram of a modification; and

Fig. 12 is a characteristic curve explanatory of the invention.

Referring to the drawings and more particularly to Fig. 1, the attenuator resembles that shown in my prior application previously referred to, in comprising a series resistance 12, a highly conductive bus 14, and a shunt resistance 16 extending between and making continuous contact with the series resistance 12 and the bus 14. Connection is made to one end of the attenuator by means of a terminal A. Series resistance 12 may be varied by a slidable contact 18 to which connection may be made by a terminal B. In the present case, however, I add to the attenuator unit thus far described an auxiliary resistance 20 varied by a slidable contact 22. One end of resistance 20 is connected to bus 14 by means of a suitable connection 24. Slidable contact 22 is connected to the external circuits by means of terminals C. It will thus be seen that instead of terminals C being connected directly to the highly conductive bus 14, they are connected thereto through the auxiliary resistance 20. Slidable contact 22 is preferably moved simultaneously with slidable contact 18. The use of auxiliary resistance 20 is most important at the low attenuation end of the attenuator, and while the auxiliary resistance may be extended all the way to the connection 24, it is sufficient for all practical purposes to extend the same merely to approximately the center of the attenuator. For mechanical simplicity, however, the sliding contacts 22 and 18 are moved together throughout the range of the attenuator, and I therefore prolong auxiliary resistance 20 by a conductive bus 26 with which slider 22 contacts when slider 18 is at the high attenuation end of the unit.

It will be noted that while sliders 18 and 20 may be moved up to the points 28 and 30, the auxiliary resistance terminates ahead of the point 30, so that when slider 18 is moved to terminal 28 for zero attenuation, the slider 22 is disconnected entirely from auxiliary resistance 20. As a result, any input energy fed to the terminals A, C flows directly to the terminals B, C without loss in the attenuator, for there is no connection whatsoever between the line A—B and the line C—C.

The theory underlying this arrangement may be explained by a mathematical derivation for a series of values or curve defining the magnitude of auxiliary resistance 20, when fulfilling the condition that this auxiliary resistance in conjunction with the attenuator itself, is to provide both logarithmic attenuation and constant impedance throughout the range of attenuation control. In the following derivation the surge impedance of the attenuator will be represented by Z_0 , this being the surge impedance as calculated from the formula

$$\sqrt{\frac{R}{G}}$$

where R is the resistance per unit length of the series resistance, and G is the leakance per unit length of the shunt resistance. When the attenuator is adjusted to mid-position, two paths are provided in parallel, each having an impedance of Z_0 and consequently the resultant impedance is

$$\frac{Z_0}{2}$$

The external load which matches with this attenuator is also

$$\frac{Z_0}{2}$$

If the attenuator were made longer than the useful or variable portion thereof, thus providing tails or projections beyond the connection point of terminal A to series resistance 12 at the left-hand end of the attenuator network and similarly beyond the mechanically limited stopping point of slider 18 at the right-hand end of the network, the impedance of the attenuator would be, for all practical purposes,

$$\frac{Z_0}{2}$$

at the ends as well as at the middle.

However, for the sake of economy, the attenuator is made no longer than its useful or variable extent. When slider 18 moves from mid-position to end position, the effective impedance changes from

$$\frac{Z_0}{2}$$

to substantially Z_0 . If, however, the ends of the attenuator are loaded with a fixed shunt resistance having the value Z_0 as indicated by the resistances 32 and 34 in Fig. 1, the impedance at the ends of the attenuator will be substantially

$$\frac{Z_0}{2}$$

the same as at the middle of the attenuator. In accordance with one of the features of the present invention, the attenuator structure is refined by the addition of resistances 32 and 34, and structure for these is provided in a very simple manner subsequently described.

The value of the auxiliary resistor 20 at any point x may be designated by R_x in which x is the effective length from the beginning of the unit to the slider. For any single adjustment, the attenuator may be replaced by an equivalent T network such as that illustrated in Fig. 2. The input impedance, with the terminals B, C open-circuited, will always be a constant and equal to

$$\frac{Z_0}{2}$$

Therefore the sum of the series element R_1 and the shunting element R_2 is

$$(1) \quad R_1 + R_2 = \frac{Z_0}{2}$$

Since the attenuation of the attenuator proper is always

$$e^{-\alpha x}$$

in which α is the attenuation per unit length and x is the effective length from the beginning of the unit to the slider, it follows that with terminals B, C still open-circuited the attenuation of the equivalent T network must be

$$e^{-\alpha x}$$

or because of its known characteristics

$$(2) \quad \frac{R_2}{R_1 + R_2} = e^{-\alpha x}$$

From expressions (1) and (2) we obtain

$$(3) \quad R_1 = \frac{Z_0}{2}(1 - e^{-\alpha x})$$

and

$$(4) \quad R_2 = \frac{Z_0}{2}e^{-\alpha x}$$

When the auxiliary resistance R_x is added, the arrangement takes the form shown in Fig. 3, and with the attenuator properly terminated, as by the external load 36, equaling

$$\frac{Z_0}{2}$$

the input characteristic is still equal to

$$\frac{Z_0}{2}$$

so that the following condition obtains:

$$(5) \quad \frac{Z_0}{2} = R_1 + \frac{(R_2 + R_x)\left(R_1 + \frac{Z_0}{2}\right)}{R_2 + R_1 + \frac{Z_0}{2} + R_x}$$

which simplifies to

$$(6) \quad \frac{Z_0^2}{4} = 2R_1R_2 + R_1^2 + 2R_1R_x$$

which, solving for R_x , gives:

$$(7) \quad R_x = \frac{\frac{Z_0^2}{4} - 2R_1R_2 - R_1^2}{2R_1}$$

Now substituting the terminal impedance

$$\frac{Z_0}{2}$$

and the attenuation

$$e^{-\alpha x}$$

as determined in equations (3) and (4) above, for R_1 and R_2 we obtain:

$$(8) \quad R_x = \frac{Z_0[1 - 2e^{-\alpha x}(1 - e^{-\alpha x}) - (1 - e^{-\alpha x})^2]}{4(1 - e^{-\alpha x})}$$

which simplifies to

$$(9) \quad R_x = \frac{Z_0}{4} \left[\frac{e^{-2\alpha x}}{1 - e^{-\alpha x}} \right]$$

The quantity R_x defines the value of the auxiliary resistance employed in series with the conductive bus of the attenuator. The value of R_x may be computed for a series of values of x , and a curve may be plotted the general nature of which is indicated in Fig. 12 of the drawings. This curve shows the value of the auxiliary resistance in ohms plotted against degrees rotation of the dial,—a mode of expression which is convenient when dealing with a rotatable unit such

as is illustrated in Figs. 5 through 10. It will be noted that the curve is asymptotic and reaches the zero axis at infinity. It is because of this characteristic of the curve that it is both sufficient and practical to employ a conductive bus such as the bus 26 in Fig. 1 for part of the movement of slider 22. The auxiliary resistance then terminates at a point such as the point 38 in Fig. 12. However, by using a film type resistor and extending the resistance film over the metallic bus 26 (in a manner subsequently described in detail), the termination of the resistance curve may be given a form such as is indicated by the dotted line 40 in Fig. 12.

It will be noted in equation (9) that the parenthetic part of the expression defining the auxiliary resistance is applicable to various units regardless of the absolute dimension of the impedance. Some typical values for this expression in terms of decibels attenuation are as follows:—

DB	$\frac{e^{-\alpha x}}{1 - e^{-\alpha x}}$
0	7.3
1	1.71
3	.73
5	.36
7	.2
9	.084
12	.041
20	.011
25	.0034

The above quantities must, of course, be multiplied by

$$\frac{Z_0}{4}$$

to obtain the absolute value of the auxiliary resistance at any point.

In a practical embodiment of the invention, I prefer to use film type resistances, and the arrangement may then be explained with reference to the schematic illustration in Fig. 4. The series resistance 12 and the shunt resistance 16 may be one continuous film of resistance. Slider 18 moves over the upper part of this film which thus acts as the series resistance. Metallic bus 14 is preferably a strip of metallic paint, say, silver, applied over the lower edge of the resistance film. Auxiliary resistance 20 is a separate strip or band of resistance film, and the right-hand end portion thereof is preferably painted over a band of metallic paint 26. The resulting strip is slidably engaged by contact 22. It is important to note that auxiliary resistance 20 terminates short of the end terminal 28 so that when slider 18 is moved to terminal 28, slider 22 is moved off resistance 20, thus severing any connection through the attenuator network between the line A—B and the line C—C. It will also be noted that the shunt resistance 16 is projected beneath terminal 28 and extends between terminal 28 and the end of bus 14. This extension of the shunt resistance, marked 32, is so dimensioned as to act as a series resistance having the value Z_0 and connected between terminal 28 and bus 14. It corresponds to the resistance 32 shown in Fig. 1.

An effect equivalent to the effect of resistance 34 shown in Fig. 1 is obtained by narrowing the shunt resistance 16 at the right-hand end of the unit, this being most readily accomplished by widening the bus 14 to form an expanded metallic area 42. When slider 18 is moved to this end of the unit, the shunt resistance 16 acts in series between the slider and the bus, and inasmuch

as the series path is shortened, the series resistance is reduced and the parts may be dimensioned to obtain substantially the desired value

$$\frac{Z_0}{2}$$

instead of the value Z_0 .

In accordance with strict theory, the corrective effect obtained by widening bus 14 should manifest itself as soon as the slider 18 is moved to either side of mid-position. In such case the attenuator would take a form generally but not quantitatively illustrated in Fig. 11, in which it will be seen that the bus 14 tapers from a maximum width at the point 44 to a minimum width at the center of the unit, and then diverges to a maximum width at the point 46. In Fig. 11 the auxiliary resistance 20 has been omitted, for constant impedance is obtainable without the use of the auxiliary resistance. However, this unit cannot be made as readily as that previously described.

A specific structural embodiment of the invention is shown in Figs. 5 through 10 of the drawings, and will be described with reference thereto. The main attenuator network is housed in a first casing 50, while the auxiliary resistance is housed in a second casing 52 arranged in tandem relative to the first casing. These casings are in the form of shallow cylinders closed at the forward end and open at the rear end. The forward wall 54 of casing 50 is provided with a suitable threaded bushing 56 receiving a control shaft 58 passing therethrough. The series and shunt resistances are carried on an insulation ring 60 which is preferably rectangular in cross-section. This ring is shown in perspective in Fig. 9. The series resistance 12 is painted on the periphery of the ring. The shunt resistance 16 is painted on one face of the ring. The metallic bus 14 is painted near the inner edge of the face of the ring and may also be widened, if desired, onto the inner wall of the ring, as indicated at 14'. The metallic terminal 28 referred to in Fig. 4 is clearly indicated in Fig. 9, as well as the manner in which an extension 32 of the shunt resistance film is disposed between terminal 28 and bus 14. Similarly the widening of the bus 14 at the other end of the unit is indicated at 42, in correspondence with the use of this numeral in Fig. 4.

The ring 60 is secured against the front wall 54 of the casing, with the shunt resistance 16 toward wall 54 which, of course, is made of insulation. The ring is held in place by screws 62 one of which is clearly shown in Fig. 8, these screws being similar to the screws 62' shown in Fig. 5, although in Fig. 5 it is the tandem or auxiliary resistance rather than the attenuator resistance that is visible. The ring is concentrically located with respect to control shaft 58 as determined by a suitable locating ring 64 projecting inwardly on wall 54.

External connection to series resistance 12 and bus 14 is made by means of a soldering lug 66 (see Fig. 7) and a soldering lug 68 (see Fig. 5), these soldering lugs passing through the side wall of the casing and having their inner ends disposed between the adjacent faces of the ring and wall 54. Lug 68 is connected to terminal 28 through a metallic terminal 70 (see Fig. 9) which is carried from the peripheral to the face wall of the ring in order to bear directly against the inner end of the soldering lug. Soldering lug 66 is located in alignment with a soldering lug 72 shown in Fig. 5; hence soldering lug 66 is not visible in that figure. It is so disposed, however, that its

inner end bears against the enlarged portion 42 of bus 14, this being clearly evident upon inspection of Fig. 7.

The series resistance 12 is slidably engaged by a movable contact 74 shown in Fig. 6 and identical in construction with another movable contact 74' engaging the auxiliary resistance 20. The two tandem units are substantially similar in mechanical construction, and a description of the slidable contact mechanism of one will apply equally to the other. For simplicity, similar numbers will be employed, these being primed in the case of the auxiliary resistance, which will be described first. Contact 74' is rockably or self-adjustably carried at one end of a resiliently yieldable arcuate contact arm 76' (Fig. 5), the other end of which is secured to a radial contact arm 78' the inner enlarged end of which is circular and downwardly dished to form a hub 80'. Hub 80' is secured to the squared end 82' of the shaft, it being insulatedly mounted thereon by means of insulation washers 84' and 86'. A metallic stop arm 88' is also received by squared end 82', and the assembly is riveted in place, as is indicated at 90' (Fig. 6).

External connection to the contact arm is made by means of a bent or bowed metallic ring 92' (Fig. 6) which bears against the forward face of the hub 80'. Ring 92' is secured to and preferably formed integrally with a soldering lug 94' which passes radially through the casing wall like the other soldering lugs. Soldering lug 94' is so located as to come between the ends of the useful resistance surface, and does not contact with any metallic or resistance coating on the ring. It is aligned with and enters locating notch 116'.

Reverting now to the attenuator unit and keeping in mind that the parts of the control arm are identical with those just described, it will be readily understood that on oscillation of the control shaft 58, the slidable contact 74 is caused to move over the series resistance 12, and that connection to the contact, equivalent to terminal B in Fig. 4, is made by means of the soldering lug 94.

The casing of tandem unit 52 is so shaped at its forward edge as to be received in and mate with the open rear edge of casing 50. The forward wall 100 of casing 52 is provided with a short bushing 102 carrying a stub shaft 104 to the forward end of which there is riveted a disc 106 having a pair of forwardly bent ears 108 thereon. Ears 108 are so disposed as to receive the stop arm 88 therebetween, and stop arm 88 thus operates to oscillate stub shaft 104 in unison with control shaft 58.

The auxiliary resistance film 20 is painted on an insulation ring 110 which structurally resembles the insulation ring 60 previously referred to. However, the ring 110 is coated only on its peripheral edge, the face being left blank. The coating is preferably made as described in connection with Fig. 4, with a resistance film 20 overlapping a metallic film 26. The arrangement is shown to exaggerated thickness in Fig. 10 in which it will be seen that a metallic film 26 of uniform thickness is first applied to a portion of the periphery of the ring, after which a resistance film 20 of variable thickness is applied to the ring, the point of maximum thickness being located approximately at one end of the metallic film, so that the resistance film tapers in thickness toward a high resistance end 112 pointed away from the metallic film, and an opposite end

114 superposed on the metallic film. The desired variation in thickness is readily obtained by positioning the ring as shown in Fig. 10 and spraying the same horizontally from the left, the thickness thereby becoming minimized at the top and bottom of the ring or the points of tangency.

The high resistance end 112 of the film is so located with respect to the locating notch 116' of the ring (which, of course, is registered with similar notch 116 of ring 60) that the slidable contact 74' leaves the resistance film and open-circuits the unit when contact 74 reaches the end of metallic terminal 28. This operation has heretofore been described in connection with Figs. 1 and 4 of the drawings. As contact 74' moves away from end 112 in the other direction, the resistance decreases, because the film thickness increases and the film length decreases. The variation preferably follows the curve previously described and shown in Fig. 12. If desired, the resistance value may be adjusted by means of the general character described in copending application for Letters Patent of Henry G. Richter, Ser. No. 8,433, filed February 27, 1935. When the contact reaches the bare metallic film 26, the resistance is, of course, brought to zero, and when the contact is on the part of the resistance film located over the metallic film, the resistance value is very low. The overlap serves to gradually rather than abruptly lower the resistance to zero, as is indicated by the dotted line 40 in Fig. 12.

Connection to the metallic film 26 is obtained by means of soldering lug 72. The inner end of this lug bears against the front face of insulation ring 110, and an extension of the metal film 26 is painted around the edge of the ring and over the forward face, as is indicated at 27 in Figs. 7 and 10. Soldering lugs 66 and 72 are connected by a suitable short lead which is preferably soldered to the lugs, this lead corresponding to the connection 24 shown in Figs. 1 and 4. The connection has been omitted in Figs. 5 and 7 but is very simply made at the time the unit is being installed, particularly so inasmuch as lugs 66 and 72 are in alignment.

I prefer to use standard soldering lugs and to make the connection 24 externally of the unit, as above described, because it is then possible to add the auxiliary resistance to an otherwise standardized attenuator unit. In other words, the forward unit in casing 50 may be made and sold alone without the refinement of the tandem auxiliary resistance. For special uses in which the refinement is desired, the manufacturer need merely add the tandem unit, the forward end of casing 52 then replacing the metal back or closure plate of casing 50, and the said closure plate being used at the back of tandem casing 52.

Specifically, in the present case the metallic closure plate is marked 118 and is shown in Figs. 6 and 7 although it has been omitted in Fig. 5 in order to expose the interior of the tandem unit. The assembly of casing 50, casing 52, and closure plate 118, is held together by a single long screw 120 which passes entirely through the unit and is threadedly received in plate 118. Plate 118 has struck inwardly therefrom a stop lug 122 (Fig. 6), this lug being so located as to cooperate with stop arm 88' in order to limit the movement of the control shaft.

It is believed that the mode of constructing and using, as well as the many advantages of my improved attenuator, will be apparent from the foregoing detailed description thereof. The pres-

ent unit is particularly valuable in situations where it is necessary to maintain input and output impedances which are equal and constant to a degree higher than that obtainable in the more elementary unit described in my copending Patent No. 2,081,572 previously alluded to. The tandem unit is simple and practical in construction, and does not introduce mechanical complexities in the way of a movable metallic bus or like structure. The auxiliary resistance element is itself simple in nature and may be constructed at slight cost. A very important advantage incidental to the use of the auxiliary resistance, but one which may be obtained even without the use of an auxiliary resistance, is the complete open-circuiting of the attenuator with respect to the terminal C when in zero attenuation position. The tandem auxiliary resistance may be added to a standard attenuator unit.

The theory underlying the attenuator is based on the assumption of a long line having leakage; and if an attenuator substantially longer at both ends than the useful portion is used, the theory is properly applied. However, when the unit is limited in length to its useful portion, the impedance is greater at the ends than at the middle, and in accordance with the present disclosure the ends of the attenuator may be loaded to adjust the end values to match the middle value.

This desired adjustment is obtained in a very simple and economical manner by varying the shunt resistance film which is anyway provided as a part of the unit.

It will be apparent that while I have shown and described my invention in a preferred form, many changes and modifications may be made in the structure disclosed, without departing from the spirit of the invention, defined in the following claims.

I claim:

1. An attenuator comprising a continuous series resistance, a contact movably related thereto, a highly conductive bus, a continuous shunt resistance extending between and continuously connected to said series resistance and said bus, a terminal normally connected to said bus, and means for automatically disconnecting said terminal from the bus when the attenuator is in its zero attenuation position.

2. An attenuator comprising a continuous series resistance, a contact movably related thereto, a highly conductive bus, a continuous shunt resistance extending between and continuously connected to said series resistance and said bus, an auxiliary variable resistance including a movable contact and having one terminal connected to said bus, and means for simultaneously moving both of said contacts.

3. An attenuator comprising a continuous series resistance, a contact movably related thereto, a highly conductive bus, a continuous shunt resistance extending between and continuously connected to said series resistance and said bus, an auxiliary resistance including a movable contact and having one terminal connected to said bus, and means for simultaneously moving both of said contacts, the auxiliary resistance being varied toward zero at the same time that the contact of the series resistance is moved from low toward high attenuation.

4. An attenuator comprising a continuous series resistance, a contact movably related thereto, a highly conductive bus, a continuous shunt resistance extending between and continuously connected to said series resistance and said bus,

an auxiliary resistance including a movable contact and having one terminal connected to said bus, and means for simultaneously moving both of said contacts, the auxiliary resistance being varied toward zero at the same time that the contact of the series resistance is moved from low toward high attenuation, and the value of the auxiliary resistance being approximately defined by the equation

$$R_x = \frac{Z_0}{4} \left(\frac{e^{-2\alpha x}}{1 - e^{-\alpha x}} \right)$$

5. An attenuator comprising a continuous series resistance, a contact movably related thereto, a highly conductive bus, a continuous shunt resistance extending between and continuously connected to said series resistance and said bus, an auxiliary resistance including a movable contact and having one terminal connected to said bus, means for simultaneously moving both of said contacts, the contact of the auxiliary resistance being moved toward zero at the same time that the contact of the series resistance is moved from low toward high attenuation, the auxiliary resistance so terminating at its open end relative to the series resistance that the auxiliary resistance is open-circuited when the attenuator is in zero attenuation position.

6. An attenuator comprising a continuous series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally to and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series resistance being uniform, and said shunt resistance being non-uniform.

7. An attenuator comprising a uniform continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally to and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, said series resistance being uniform in width, and said shunt resistance being non-uniform in width.

8. An attenuator comprising a uniform continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally to and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, said shunt resistance being uniform in resistivity but variable in width, the width being reduced at the ends relative to the middle.

9. An attenuator comprising a continuous series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a continuous shunt resistance extending between and connected to said series resistance and said bus, a terminal at the low attenuation end of the series resistance, and a terminal resistance forming a part of the attenuator and connected between said terminal and said bus and being so designed as to tend to equalize the impedance of the attenuator at the end and at the middle thereof.

10. An attenuator comprising a continuous series resistance, a contact slidably related there-

to, a highly conductive bus extending collaterally with and spaced from said series resistance, and a continuous shunt resistance extending between and connected to said series resistance and said bus, a terminal at the low attenuation end of the series resistance, and a terminal resistance forming a part of the attenuator and connected between said terminal and said bus and having a value substantially equal to the surge impedance of the attenuator.

11. An attenuator comprising a continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, a metallic terminal at the low attenuation end of the series resistance, and a terminal resistance connected between said terminal and said bus, said terminal resistance being formed by an extension of the shunt resistance film connected between the metallic terminal of the series resistance and the bus.

12. An attenuator comprising a uniform continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, a metallic terminal at the low attenuation end of the series resistance, and a terminal resistance connected between said terminal and said bus and having a value substantially equal to the surge impedance of the attenuator, said terminal resistance being formed by an extension of the shunt resistance film connected between the metallic terminal of the series resistance and the bus.

13. An attenuator comprising a series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, a continuous shunt resistance extending between and connected to said series resistance and said bus, said shunt resistance being so decreased in value at the high attenuation end as to tend to equalize the surge impedance of the attenuator at the end and at the middle.

14. An attenuator unit comprising a continuous series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a continuous shunt resistance extending between and connected to said series resistance and said bus, and means at the high attenuation end of the unit connected between the series resistance and the bus and acting like a load substantially equal to the surge impedance of the unit.

15. An attenuator unit comprising a continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, said bus being displaced toward the series resistance at one end of the unit in order to so narrow the shunt resistance film as to approximately halve the surge impedance of the unit at the said end.

16. An attenuator unit comprising a uniform continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, and an equivalent terminal resistance at the high attenuation end of the unit connected between the series resistance and the bus and having a value substantially equal to the surge impedance of the unit, said equivalent terminal resistance being formed by widening the bus at the high attenuation end in order to narrow the shunt resistance and thereby decrease the value of the shunt resistance considered in series between the series resistance and the bus.

17. An attenuator comprising a continuous series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a continuous shunt resistance extending between and connected to said series resistance and said bus, and means forming a part of the attenuator and connected between the series resistance and the bus at the ends of the series resistance, said means being so designed as to tend to equalize the impedance of the attenuator at the ends and at the middle.

18. An attenuator comprising a continuous series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a continuous shunt resistance extending between and connected to said series resistance and said bus, said shunt resistance being changed from uniformity at its ends in such direction as to tend to equalize the impedance of the attenuator at the ends and the middle.

19. An attenuator comprising a uniform continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, said shunt film being shaped and dimensioned to so reduce the resistance at its ends as to tend to equalize the impedance of the attenuator at the ends and the middle.

20. An attenuator comprising a series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a shunt resistance extending between and connected to said series resistance and said bus, said shunt resistance being so designed at its ends as to tend to equalize the impedance of the attenuator at the ends and the middle, a terminal normally connected to said bus, and means for automatically disconnecting said terminal from the bus when the contact is in zero attenuation position.

21. An attenuator comprising a series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a shunt resistance extending between and connected to said series resistance and said bus, said shunt resistance being so designed at its ends as to tend to equalize the impedance of the attenuator at the ends and the middle, an auxiliary variable re-

sistance including a movable contact and having one terminal connected to said bus, and means for simultaneously moving both of said contacts.

22. An attenuator comprising a uniform continuous series resistance film, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance film, and a continuous shunt resistance film extending between and connected to said series resistance film and said bus, said series and shunt films being made of the same material and constituting structurally a single film, said shunt film being so shaped and dimensioned at its ends as to tend to equalize the impedance of the attenuator at the ends and the middle, an auxiliary variable resistance including a movable contact and having one terminal connected to said bus, means for simultaneously moving both of said contacts, the contact of the auxiliary resistance being moved toward its zero resistance end at the same time that the contact of the series resistance is moved from low toward high attenuation.

23. An attenuator comprising a series resistance, a contact slidably related thereto, a highly conductive bus, a shunt resistance extending between and connected to said series resistance and said bus, an auxiliary variable resistance including a movable contact and a resistance film

and having one terminal connected to the bus, means for simultaneously moving both of the aforesaid contacts, the contact of the auxiliary resistance being moved toward zero resistance when the contact of the series resistance is moved from low toward high attenuation, said auxiliary resistance comprising a metallic film and a resistance film which overlaps the metallic film for substantial distance, the resistance film having a maximum thickness at the middle and tapering in thickness toward both ends.

24. An attenuator comprising a series resistance, a contact slidably related thereto, a highly conductive bus extending collaterally with and spaced from said series resistance, a shunt resistance extending between and connected to said series resistance and said bus, said shunt resistance being so designed at its ends as to tend to equalize the impedance of the attenuator at the ends and the middle, an auxiliary variable resistance including a movable contact and having one terminal connected to said bus, means for simultaneously moving both of said contacts, the auxiliary resistance so terminating at its open end relative to the series resistance that the auxiliary resistance is open-circuited when the attenuator is in zero attenuation position.

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