

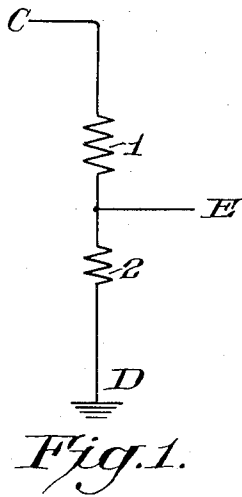
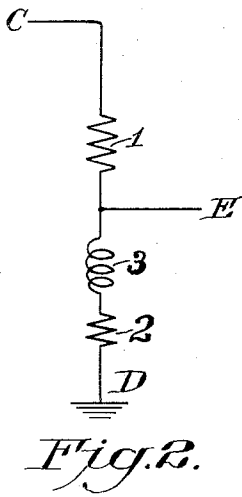
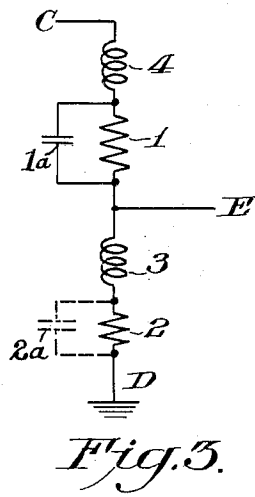
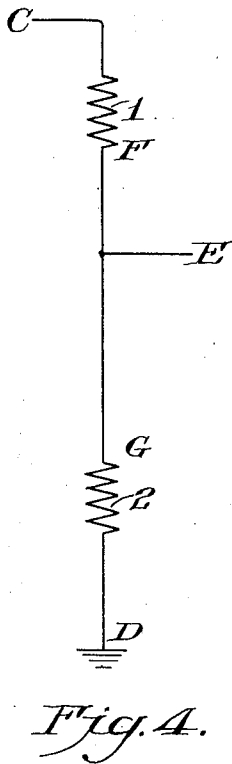
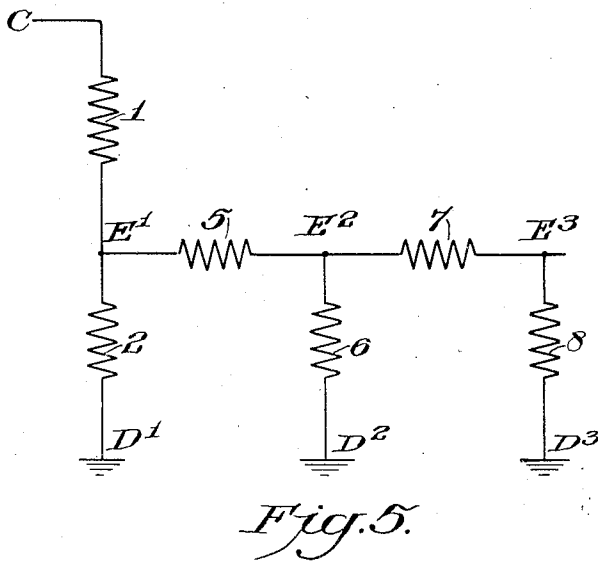
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RESISTANCE ATTENUATOR

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RESISTANCE ATTENUATOR

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12 Claims. (Cl. 178—44)

This invention relates to resistance attenuators, particularly those used for radio frequency measurements. Its object is to improve the accuracy of the attenuator and to permit its use at higher frequencies than can be normally used, by compensating for the effect of undesired reactance which may be inherently present in its various elements.

Resistance attenuators have been in general use in radio frequency measurements for several years. To obtain useful accuracy it is necessary to so design the resistors that inherent series inductance and inherent shunt capacity are reduced to very low values, and also to design the entire structure to reduce the effect of inherent inductive and capacitive couplings between different sections of the attenuator.

For resistors of the values frequently used, especially those of fifty ohms or less resistance, shunt capacity is of much less importance than series inductance. As already mentioned, the design of the resistors should be such as to reduce the inherent inductance to the lowest practical value. A bi-filar type of winding is frequently used for this purpose.

I have found that, after inherent inductance has been reduced as much as practical, a further improvement in accuracy may be obtained by introducing a small amount of inductance of the correct magnitude placed in the proper part of the circuit, and that such an arrangement will extend the upper frequency limit of the system for satisfactory operation.

Figure 1 shows a simple attenuator system consisting of two sections, one section containing resistance 1, the other section containing resistance 2, an input circuit C—D, and an output circuit E—D.

Figure 2 shows an attenuator system similar to that of Fig. 1 but containing additional element 3 indicating the undesired inherent inductance in the branch of the system in which it is located.

Figure 3 is similar to Fig. 2, but contains additional element 4 indicating inserted inductance to offset the inherent inductance effect indicated at 3.

Figure 4 is similar to Fig. 1, but provides for varying the position of output connection E along the conductor F—G with which it contacts.

Figure 5 indicates an attenuator system consisting of a number of sections, and provided with input terminals C—D1, and output terminals E3—D3.

Figure 1 shows an attenuator of the simplest

kind, made up of elements comprising a 45 ohm resistor 1 and a 5 ohm resistor 2. No inductance or capacity is shown in this figure, and if such an attenuator could be built, it would have an attenuation ratio of ten at all frequencies, that is, the voltage at the output terminals E and D would be exactly one tenth of that at the input terminals C and D.

In practice it is impractical to build such a unit without some inherent inductance and capacity. In most cases the capacity may be small enough to be unimportant, but the inductance may cause an error which will increase as the frequency of the current used is increased.

In Figure 2 an inductance 3 indicating inherent inductance is shown in series with resistor element 2 and between the output terminals E and D. At frequencies where the reactance of inductance 3 is small compared to resistance 2, the error is small, and may be neglected for most purposes. At higher frequencies the inductive reactance may become large enough to cause considerable error, making the output voltage greater than one tenth of the input voltage, and therefore making the attenuation less than ten.

It will be understood that the error in the above case will be caused by the inductance 3 (Fig. 2) changing the impedance of section E—D, so that it is no longer one tenth of the total impedance, or one ninth of the impedance of section C—E.

I have found that the attenuation ratio of such a circuit may be made independent of frequency by adding inductance of the proper magnitude in section C—E. This is indicated in Figure 3, where inductance 4 has been inserted in section C—E to offset the effect of inherent inductance 3. In order to maintain the attenuation ratio correct, independent of frequency, when there is inductance of appreciable magnitude in either section, the ratio of inductance 4 to inductance 3 should be the same as the ratio of resistance 1 to resistance 2. That is, in the attenuator section shown, the value of inductance 4 should be 9 times as great as that of inductance 3, since the resistance of resistor 1 is 9 times that of resistor 2.

Stated in another way, at any particular frequency the ratio of inductive reactance to resistance should be the same for both sections of the attenuator.

In practice, conditions such as shown in Figure 2, where inherent inductance was present in one section and entirely absent in another section, might be expected to be extremely rare. In most

cases some inductance will be found in each section, and to obtain an attenuation ratio independent of the frequency it is necessary to add inductance to one section, so that the ratio of inductive reactance to resistance will be the same for both sections. Obviously, the inductance should be added to the section which otherwise has the lowest ratio of inherent reactance to resistance.

The undesired inherent inductance present in attenuator sections is usually due partly to the necessary leads and connections, and partly to the fact that bi-filar or other "non-inductive" windings may not produce a unit entirely free from inductance. In correcting an attenuator, to make the reactance to resistance ratio of two sections the same, several methods may be used, among which the following may be specifically mentioned:

(1) A small concentrated inductance may be added to one section.

(2) The type of winding used in one section may be changed, to obtain a different ratio of reactance to resistance.

(3) The physical arrangement of the connections may be changed, thus distributing the inherent inductance of connecting leads between the two sections in the ratio desired. This is shown in Figure 4, where output lead E may be connected to any point between F and G, thus dividing the inductance of lead F—G between the two sections in whatever ratio may be desired.

Most attenuators in actual use are more complicated than the simple single section attenuators shown in Figures 1, 2, 3, and 4, and consist of networks of resistors making up numerous sections, but the same principle of compensation may be employed in these more complicated attenuators.

Figure 5 shows an attenuator made up of several sections, each arranged to give an attenuation of 10. Resistors 7 and 8, of 49.5 and 5.5 ohms respectively, constitute a simple section, similar to that shown in Figure 7, though of slightly different values. A second section is made up of resistor 5 of 49.5 ohms, and resistor 6 of 6.11 ohms, the latter shunted by resistors 7 and 8 in series, thus forming a network with 5.5 ohms resultant resistance, so that this section, as well as the preceding section, has an attenuation ratio of ten. Similarly, resistor 1 forms, with the combination of resistors 2, 5, 6, 7 and 8, another section which also has an attenuation ratio of ten. Resistor 2 is 5.5 ohms.

To properly compensate such an attenuator the ratio of reactance to resistance should be made the same for each section or element, and in general this would mean adding some inductance to every element except the one which already has the highest inherent reactance to resistance ratio. While this is the method of correction that should normally be used, it will occasionally be found desirable to make an approximate correction in which only one section has its inductance adjusted.

For instance, referring to Figure 5, suppose it should be found that section E1—D1, including resistor 2, has a reactance to resistance ratio considerably greater than that of any other section. An approximate correction could be made by adjusting the section C—E1 (including resistor 1) to have the same reactance to resistance ratio as that of section E1—D1. This would be only an approximate correction, but if the network in

parallel with section E1—D1 is of high resistance, comparative to resistor 2, it may be sufficiently accurate for many practical purposes.

While the above description applies to a resistance attenuator in which inductive reactance is the main source of error, the same principle may be employed in compensating such an attenuator if inherent capacitive reactance, in parallel with the resistors, should be the main source of error. In this case it would be necessary to add capacity in parallel with some of the resistors, to make the ratio of reactance to resistance the same for all sections of the attenuator. This is illustrated in Fig. 3, where inherent capacity is indicated in dotted lines by capacitance 2a, and compensating added capacity is indicated by capacitance 1a. This requirement is usually of less practical importance, but might be expected to occur in attenuators using high values of resistors.

In some cases both added inductance and capacitance may be necessary to offset the inherent inductance and capacitance present in the attenuator system.

The exact circuit arrangements and values shown and described herein are for example only but the same principles may be employed in attenuators of much more elaborate construction, and with different values of resistance and different attenuation ratios, but the description should enable anyone skilled in the art to apply the invention to various kinds of resistance attenuators.

What I consider as new and desire to protect by Letters Patent is contained in the following claims:

1. The method of correcting for inherent capacity and inductance in a resistance attenuator composed of a plurality of sections, consisting in applying additional inductance and capacity to one of its sections to render the reactance to resistance ratio substantially the same for a plurality of its sections.

2. The method of correcting for inherent capacity in a resistance attenuator composed of a plurality of sections, consisting in adding additional capacity in parallel in one of its sections to render the reactance to resistance ratio substantially the same for a plurality of its sections.

3. The method of correcting for inherent inductance in a resistance attenuator composed of a plurality of sections, consisting in adding additional inductance in series in one of its sections to render the reactance to resistance ratio substantially the same for a plurality of its sections.

4. A resistance attenuator comprising a plurality of sections, one of said sections containing undesired inherent inductance and another of said sections in which additional inductance has been added to make the ratio of reactance to resistance substantially the same for both of said sections.

5. A resistance attenuator comprising a plurality of sections containing resistors, one of said sections having undesired inherent inductance, and a second of said sections in which inductance has been added to make the ratio of reactance to resistance substantially the same for a plurality of said sections.

6. A resistance attenuator comprising two resistors connected in series, an input circuit connected to the outer ends of said series connected resistors, one terminal of an output circuit connected between said resistors, the other terminal of said output circuit connected to an outer

end of said series, and an inductance in series with one of said resistors to compensate for the inherent inductance of said other resistor.

5 7. A resistance attenuator comprising two resistors connected in series, an input circuit connected to the outer ends of said series connected resistors, one terminal of an output circuit connected between said resistors, the other terminal of said output circuit connected to an outer end
10 of said series, and a condenser in shunt with one of said resistors to compensate for the inherent capacity of said other resistor.

15 8. A resistance attenuator comprising a plurality of sections containing resistors and provided with input and output circuits, one of said sections containing undesired inherent inductance, and additional inductance added to the other of said sections to render the reactance to resistance ratio of said sections substantially the same.
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25 9. A resistance attenuator comprising a plurality of sections containing resistors and provided with input and output circuits, one of said sections containing undesired inherent capacitance, and additional capacitance added to said sections to render the reactance to resistance ratio of said sections substantially the same.

30 10. A resistance attenuator comprising sections containing resistors, one of said sections containing undesired inherent inductance and capacitance, an input and output circuit connected to said system, and additional capacitance and inductance added to said system to render the reactance to resistance ratio of said sections substantially the same.
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11. A resistance attenuator system containing undesired inherent capacitance comprising two resistors connected in series, an input circuit connected to the outer ends of said resistors, an output connection containing two resistors in series made at a point between said first mentioned two resistors, a resistor connected at a point between said second mentioned two resistors and having its opposite end connected to the other connection of the output circuit, a resistor connected at the outer end of said second mentioned two resistors and having its opposite end connected to the other connection of the output circuit, and additional capacitance added to said system to render the reactance to resistance ratio of two portions of said system substantially the same.

12. A resistance attenuator system containing undesired inherent inductance comprising two resistors connected in series, an input circuit connected to the outer ends of said series, an output connection containing two resistors in series made at a point between said first mentioned two resistors, a resistor connected at a point between said second mentioned two resistors and having its opposite end connected to the other connection of the output circuit, a resistor connected at the outer end of said second mentioned two resistors and having its opposite end connected to the other connection of the output circuit, and additional inductance added to said system to render the reactance to resistance ratio of two portions of said system substantially the same.

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