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REGULATION OF TRANSMISSION LINES

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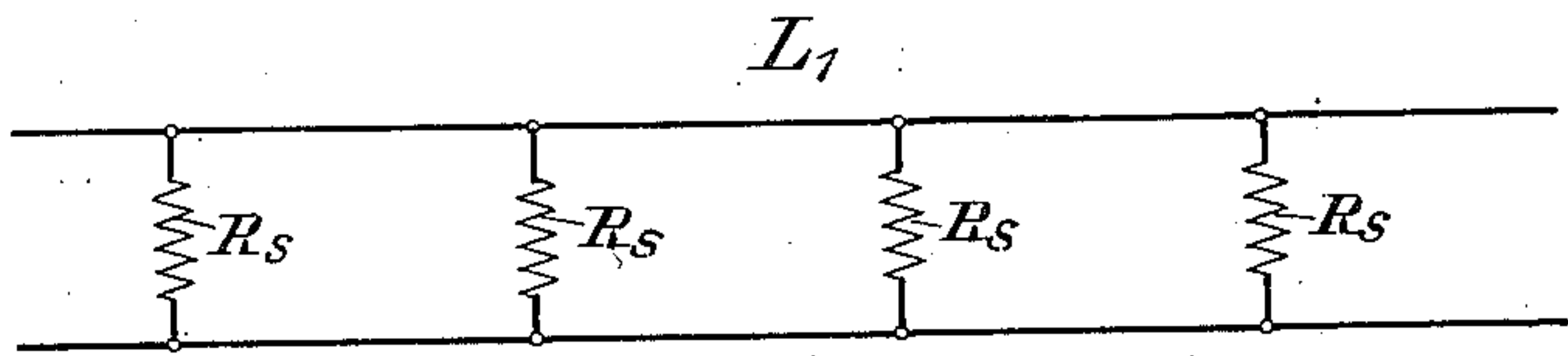


Fig. 1

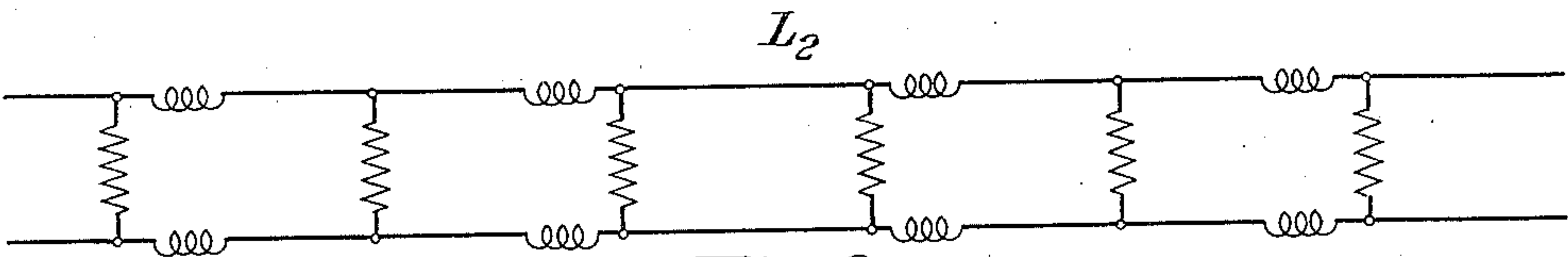


Fig. 2

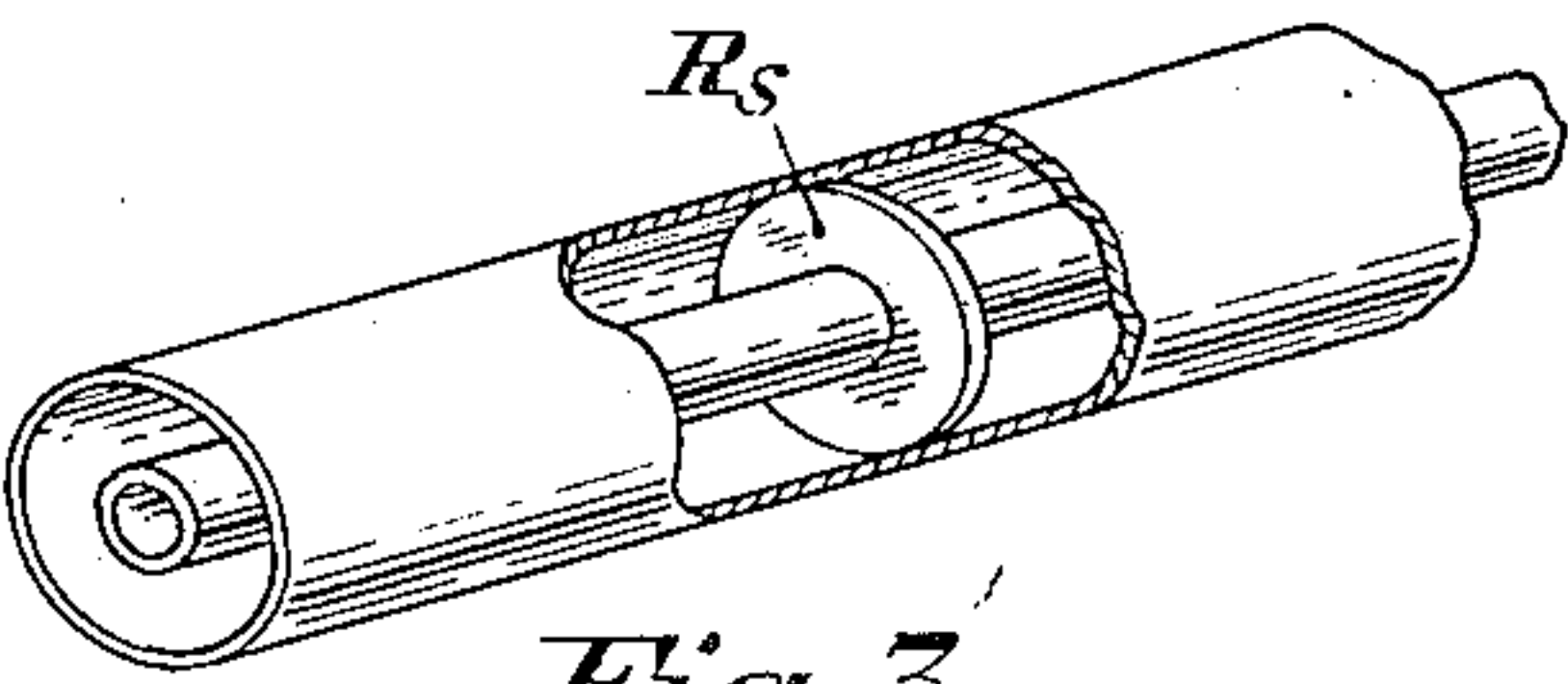


Fig. 3

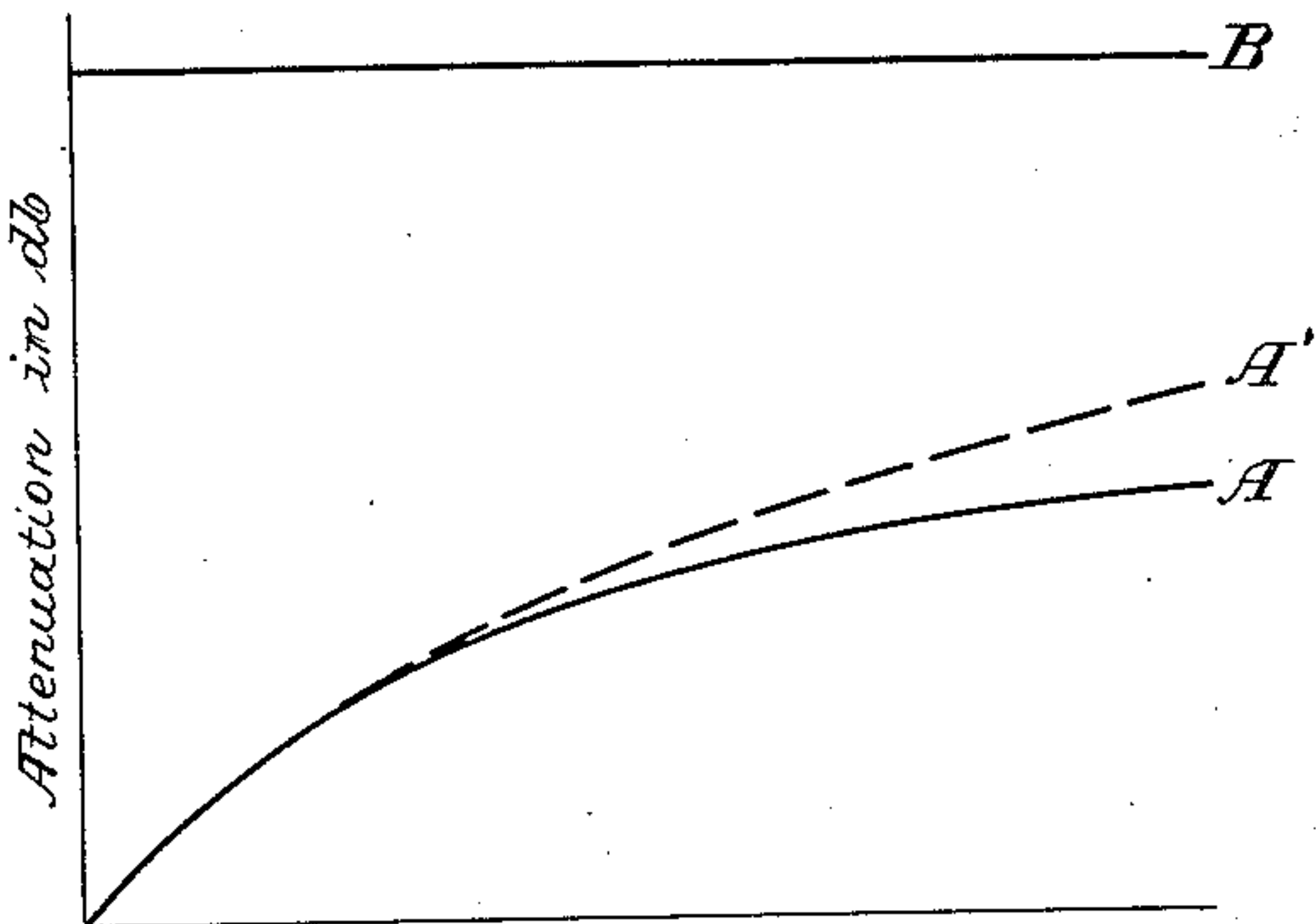


Fig. 4

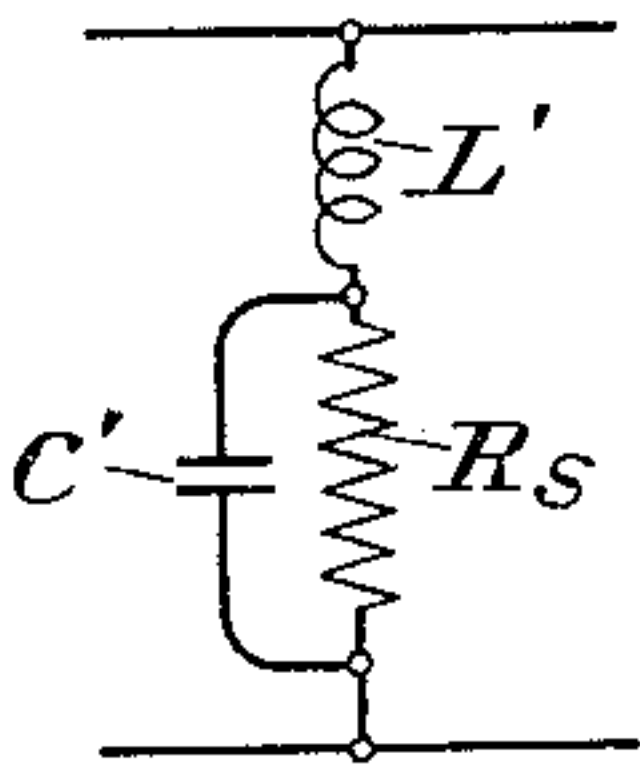


Fig. 5

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REGULATION OF TRANSMISSION LINES

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5 Claims. (Cl. 178—44)

This invention relates to regulation of transmission lines, and more particularly to compensation for changes in transmission equivalent in telephone circuits due to temperature changes in the line.

Its object is to devise means by which, with no moving parts, the transmission loss of such a line is substantially independent of temperature changes.

Briefly, the invention consists in shunting the line with resistances so spaced and of such value as to bring about the desired results. I find that this can be accomplished by using shunt resistors of a material which has substantially the same resistance temperature coefficient as the material of the line itself. Since such lines are usually of copper, I prefer to use copper for the shunt material.

The invention will be better understood by reference to the following specification and the accompanying drawing in which Figure 1 illustrates an unloaded line equipped with my shunt resistors or leakages; Fig. 2 shows the application of these resistors to a loaded line; Fig. 3 shows a mode of application of the invention to coaxial cylindrical lines; Fig. 4 gives curves illustrating the changes in attenuation losses as a function of frequency between a line which is provided with my resistors and one which is not; and Fig. 5 shows a network including my shunt.

Referring more particularly to Fig. 1, there is shown a transmission line L_1 which may be the well known open-wire circuits in extensive telephone use, or cable telephone circuits. Shunted across this line at various points are resistances R_s of the kind which constitute the subject matter of this invention. It can be readily shown by circuit theory that the condition for distortionless transmission, i. e., transmission independent of frequency, is, at least approximately, that

$$\frac{R}{G} = \frac{L}{C}$$

where these quantities are, respectively, the resistance, leakance, inductance and capacitance of the line per unit length. It also follows that under these conditions

$$A = \sqrt{RG}$$

where A is the attenuation. These relationships may be substantially met by having frequent shunts of fairly high resistance, that is, low conductance, or by having them spaced farther apart but with a smaller resistance, that is, a larger conductance. For any given spacing this would

mean that the series resistance of the line for a section of length corresponding to this spacing, divided by the shunt conductance of the one resistor in that length, shall be equal to the inductance of that length, divided by the shunt capacity for that length. In order that the second relationship

$$(A = \sqrt{RG})$$

shall be independent of temperature, I would point out that it is necessary that the temperature coefficient of the series and the shunt resistances shall have the same value. Since the material of the line is usually copper, this condition may be most readily obtained by making the shunt resistor also of copper, although it is to be understood that any other resistor which has the same temperature coefficient would be equally good.

It will be understood that the explanation of the relation

$$\frac{R}{G} = \frac{L}{C}$$

given hereinabove holds strictly true only when the constants involved are continuously distributed over the line; however, the relation is approximately true if the shunt resistance or leakage is lumped at regular intervals.

Fig. 2 illustrates the application of the invention to a loaded line, and while from an engineering point of view it might be most convenient to have the shunt resistances located at the loading coils, this is not necessary, for a spacing of the resistors different from that of the loading coils is permissible upon suitable adjustment of the magnitude of the shunt resistances.

In Fig. 3 there is shown a transmission line of the form commonly spoken of as coaxial cylindrical conductors which are described in patent to Espenschied and Affel, No. 1,835,031, December 8, 1931. In such cylindrical conductors it is necessary to have spacers at various points to keep the two conductors coaxial, and while the shunt resistors may be inserted as separate resistances it is extremely convenient to make the spacers of such material that they are slightly conducting and in themselves furnish the leakage corresponding to the resistors. In any event, these spacers, if used as shunt resistors, should preferably be of a material and a design to have the same temperature coefficient as that of the conductors.

In Fig. 4 curve A shows the attenuation characteristic of a transmission line such as a cable circuit, the attenuation being plotted as a func-

tion of the frequency. Curve B shows the attenuation characteristic of the same line if supplied with shunt resistances of the correct value, and it will be noted that this characteristic is independent of frequency. According to my invention the resistors should preferably have such an ohmic value at a given temperature and for a given spacing as to yield a characteristic represented by curve B, and in order that this shall be independent of temperature it is necessary that the series resistance and the shunt resistance vary in the same way for temperature change.

While series resistances with a suitable negative temperature coefficient have been proposed heretofore for temperature compensation of transmission equivalent, such an arrangement has the disadvantage that in order to maintain balance of the line it is necessary to have such a series resistance in both sides of the line and considerable difficulty arises in making and keeping these resistors on the two sides of equal value. My invention has an advantage, however, in that no such difficulty arises. A second advantage of the shunt arrangement shown in my invention is that the transmission frequency characteristics of the line would be more nearly uniform and less equalization would be required. A third advantage is that with my arrangement there are avoided the hazards introduced by the use of series elements which may have unknown characteristics.

While it is apparent, of course, that the introduction of such shunt resistances increases the attenuation of the line, this increase in attenuation may readily be made up by an increase in the number of amplifiers which would ordinarily be associated with such lines.

As an illustration of the magnitudes which may be involved, it may be stated that in a typical cable pair in which $R=100$ ohms, $L=1.1$ millihenries and $C=.07$ microfarads per 6000 feet of line, resistors with a spacing of 6000 feet should have a resistance of approximately 160 ohms, and under these circumstances the attenuation would be approximately doubled.

In the discussion and relations given above, ideal conditions have been assumed for simplicity. Actually, conditions are not ideal. Thus, the value of the series resistance is somewhat dependent on frequency, due to skin effect. Also, the values of G , L and C are slightly dependent on temperature and even slightly on frequency because of changes in dielectric constant and changes in current distribution, etc. As a result of such slight effects the attenuation curve is more nearly like that shown in the dotted curve A' , and for this reason it would, in practice, be desirable to make a small adjustment in the value of the shunt resistances to yield best results at some chosen intermediate frequency. It is also to be noted that the relationships above, assume uniform distribution of the leakance G , whereas, actually, in this invention it is proposed to have these shunts or leakances "lumped". This calls for a modification of the value of the shunt resistance. The modification of the resistance units due to this "lumpiness" can be readily calculated from appropriate formulae given in connection

with circuit theory. The value of 160 ohms for the illustrative cable pair above, is on the basis of uniformly distributed leakance, and this particular value then should be modified, the extent of modification depending upon the spacing between the individual resistances.

In view of the fact that the values of L and C are not quite independent of frequency and temperature a closer approximation to the condition of distortionless transmission is made possible by including inductance and capacity in some suitable network arrangement with the shunt resistor. Such a combination is shown in Fig. 5, in which a small inductance is connected in series with the resistance and a small capacity in parallel to the resistance. Suitable choice of the values of the inductance and the capacity would largely correct for the departure from the ideal conditions. Closer correction can obviously be obtained by increasing the complexity of the shunt network as a whole.

What is claimed is:

1. In a transmission line, means for compensating for temperature changes which consists of shunt resistances, said resistances having the same temperature coefficient as the line material and having such values that under conditions of distortionless transmission the transmission loss shall be substantially independent of temperature.

2. In a transmission line, means for compensating for temperature changes which consists of shunts comprising resistance and inductance in series, and a condenser in parallel to the resistance, said resistance having the same temperature coefficient as the line material and having such values that under conditions of distortionless transmission the transmission loss shall be substantially independent of temperature.

3. The method of compensating for variations of distributed attenuation due to temperature variations in a signal transmission line which consists in shunting across the line an impedance device including an element of the same temperature coefficient as the line material, exposing said element to similar variations and thereby oppositely varying the attenuation by said lumped impedance device shunted across the line.

4. In the transmission of signaling currents over conductors, the method of compensating for variation of attenuation due to temperature changes in the conductors which consists in shunting resistance of the same temperature coefficient as the material of the conductors across the conductors subjecting it to the same temperature changes as the conductors and thereby varying the shunted resistance by the same percentage amount as the conductors to yield the required compensation.

5. In a transmission line, means for compensating for temperature changes which consists of shunt resistances, said resistances having the same temperature coefficient as the line material and being of such magnitude that the ratio of series resistance of the line and the shunt conductances shall be substantially equal to the ratio of the series inductance to the shunt capacity of the line over the operating temperature range of the line.

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