Aug. 11, 1936. J. B. JOHNSON 2,050,703

TRANSMISSION SYSTEM REGULATION

Filed June 9, 1934

FIG. 1

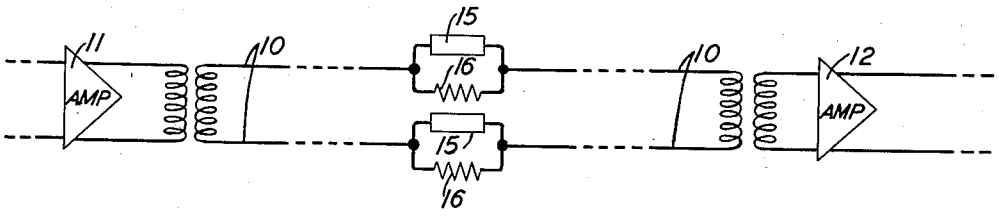
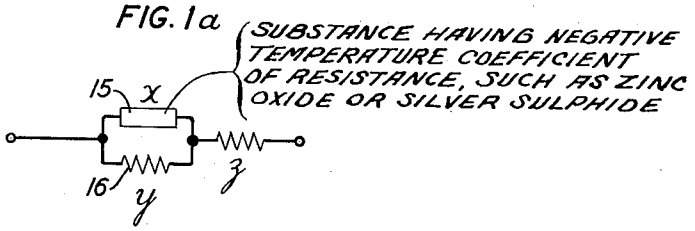


FIG. 1a



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TRANSMISSION SYSTEM REGULATION

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7 Claims. (Cl. 178—44)

The present invention relates to the compensation of variations in transmission characteristic of a circuit occasioned by variations in temperature. The circuit may, for example, be a telephone line strung on poles or included in a cable and subject to climatic or atmospheric temperature variations.

An object of the invention is to compensate for the effects of temperature variations in a simple and direct manner and without the necessity of using mechanically moving elements.

An ordinary telephone line has a positive and substantially linear variation of resistance with temperature over the limited range embraced by atmospheric temperatures. In accordance with the present invention an element having a negative coefficient of resistance is associated with a telephone line and is subjected to the same variations of temperature as is the line itself, such that the resistance changes in the line are compensated by the resistance changes in the element.

The nature of the invention and the manner of carrying out the invention in practice will now be made clear in the following detailed description, taken in connection with the accompanying drawing.

In the drawing:

Fig. 1 is a simplified diagrammatic showing of a telephone line including repeater stations and compensating means according to the invention; and

Fig. 1 is a diagram of impedance to be discussed.

In Fig. 1, the telephone line 10 may be a toll line included along with a large number of other similar lines inside a lead sheath (not shown). This toll line is shown as including one-way repeaters 11, 12 etc. at intervals, two such repeaters being shown with a length of line 10 comprising one repeater section between these repeaters. At some point along the line, for example, near the center of the repeater section, a compensating impedance combination 15, 16 is included, or, as shown, such a combination may be placed in each side of the line for symmetry. The compensating impedance combination may be placed at or near either end of the line section 10 so long as it is subjected to temperature variations similar to the temperature variations experienced by the line. For example, if the cable including line 10 is buried or placed in a conduit underground or suspended on a pole line, the compensating impedance combination is preferably included inside the lead sheath at a point along the cable where its temperature changes are representative of the temperature variations of the cable so far as possible. There may be several impedance combinations 15, 16 within a repeater section, spaced at intervals.

The compensating impedance combination comprises preferably an element 15 having a negative coefficient of resistance shunted by a resistance 16 of positive coefficient, and included in series in the line.

Referring to the diagram in Fig. 1*a*, let the element 15 have a resistance x, the element 16 a resistance y and the line 10 a resistance z, assuming now that but one such combination is used in the line section 10. In the following treatment, the symbols then have the following significance:

t=Temperature in centigrade degrees.
x=Resistance of the element 15.
y=Resistance of metallic shunt 16.
z=Resistance of line 10.
α=Temperature coefficient for x.
β=Temperature coefficient for y.
γ=Temperature coefficient for z.
r=Resistance of compensating combination, x and y.

$$R=z+r$$

$$p=\frac{r_0}{z_0}$$

The three resistances x, y, and z are assumed, over the temperature range —40° C., to vary with temperature as follows:

$$x=x_0\epsilon^{\alpha t} \tag{1}$$

$$y=y_0(1+\beta t) \tag{2}$$

$$z=z_0(1+\gamma t) \tag{3}$$

In (2), for purposes of simplicity, assume β to be so small that y may be considered constant. The resistance of the compensating combination is then

$$r=\frac{x_0y_0\epsilon^{\alpha t}}{x_0\epsilon^{\alpha t}+y_0} \tag{4}$$

The slope of the r, t curve at $t=0$ is given by

$$\frac{(\partial r)}{(\partial t)_0}=\frac{\alpha x_0y_0^2}{(x_0+y_0)^2} \tag{5}$$

The expression for the second derivative at $t=0$ is

$$\frac{(\partial^2 r)}{(\partial t^2)_0}=-\alpha^2x_0y_0^2\frac{x_0-y_0}{(x_0+y_0)^3} \tag{6}$$

The condition that compensation be attained at $t=0$ is that

$$\frac{(\partial r)}{(\partial t)_0}=-\frac{(\delta z)}{(\delta t)_0} \tag{7}$$

For compensation over a range of temperatures it is also well to have the second derivative small, say

$$\frac{(\partial^2 r)}{(\partial t^2)_0}=0 \tag{8}$$

From (7) we find that the first condition is fulfilled if

$$\gamma z_0 = \frac{-\alpha x_0 y_0^2}{(x_0+y_0)^2} \tag{9}$$

From (8) we find that the second condition is fulfilled if $x_0=y_0$, so that substituting in (9) we have

$$x_0 = -\frac{(4\gamma)}{(\alpha)} z_0 = y_0 \tag{10}$$

Substituting for x_0 and y_0 in (4),

$$r = -\frac{(4\gamma z_0)}{(\alpha)} \frac{\epsilon^{at}}{\epsilon^{at}+1} \tag{11}$$

The ratio,

$$p = \frac{r_0}{z_0}$$

can now be calculated.

$$p = \frac{r_0}{z_0} = \frac{x_0}{2z_0} = -\frac{2\gamma}{\alpha} \tag{12}$$

Assuming reasonable values as follows,

$$\frac{\alpha}{\gamma} = -4 \quad \gamma = .004$$

and z=1,000 ohms we have $p=\frac{1}{2}$, and calculations indicate the degree of compensation possible with this arrangement, viz:

Temperature	R	R−R₀	Percent deviation
−40	1495	−5	−0.335
−30	1498	−2	−0.134
−20	1499	−1	−0.067
−10	1500	0	0.0
0	1500	0	0.0
10	1500	0	0.0
20	1501	+1	+0.064
30	1502	+2	+0.134
40	1505	+5	+0.335

If y were placed in series with x and z, and were constant at such a value that

$$\frac{x_0+y_0}{z_0} = \frac{1}{2},$$

with the same values of

$$z_0 \text{ and } \frac{\alpha}{\gamma}$$

as above, the results would be as follows:

Temperature	R	R−R₀	Percent deviation
−40	1564	+64	+4.09
−30	1533	+33	+2.15
−20	1513	+13	+0.86
−10	1503	+ 3	+0.20
0	1500	0	0.0
10	1503	+ 3	+0.20
20	1512	+12	+0.79
30	1524	+24	+1.57
40	1542	+42	+2.72

In the shunt example, since $p=\frac{1}{2}$, the resistance added to that of the line is 50 per cent of the line resistance. The comparison is made with the series case on the same basis, but if, in the latter case, y_0 were zero so that the added resistance would be 25 per cent of the line resistance, the deviations would be changed very little.

As examples of materials that are suitable for use in practice and that behave in the general manner assumed in the above calculations, the element **15** may comprise a resistance made of one of the metallic oxides or sulphides such as zinc oxide or silver sulphide. The element **16** may be a resistance of very small temperature coefficient (β) such as advance wire.

It is to be understood that the invention is not to be limited to the numerical values or relations that have been given but its scope is indicated by the claims.

What is claimed is:

1. The combination of a circuit subject to variable temperature, said circuit having a positive temperature coefficient of resistance, and an impedance combination connected in series in said circuit, subjected to similar variable temperature and including elements of different temperature coefficients connected in parallel with each other, one of them having a negative temperature coefficient of resistance, the resistance relations of said one element, impedance combination and circuit, and the relation of temperature coefficients of said circuit and said one element, being such that the combination of circuit and impedance combination has an overall resistance substantially constant throughout a range of temperatures.

2. The combination of a telephone line subjected to variable temperature and an impedance combination serially inserted in the line and subjected to similar variable temperature, said impedance combination comprising two elements in parallel, one an element having a temperature coefficient of resistance opposite to that of the line, and the other an element of very small temperature coefficient of resistance, said two elements having substantially the same resistance at reference temperature, and in parallel presenting an impedance (r_0) in the line which bears to the line resistance (Z_0) substantially the same numerical relation as twice the temperature coefficient of resistance of the line bears to that of the first mentioned element.

3. The combination of a transmission line subjected to variable temperature and an element serially included in said line and subjected to the same variable temperature as said line, said element having a temperature coefficient of resistance opposite to that of the line whereby resistance changes of said line and element in response to temperature variations tend to compensate one another, and a resistance of small temperature coefficient connected in parallel to said element and proportioned with respect to said element such that the parallel combination of element and resistance causes the resistance variations to be more completely compensated than they would be by said element alone.

4. A combination according to claim 1 in which said one element having a negative temperature coefficient of resistance comprises zinc oxide.

5. A combination according to claim 1 in which said one element having a negative temperature coefficient of resistance comprises silver sulphide.

6. The combination with a transmission line whose attenuation is variable with line-temperature, of a plurality of physically small elements of a material having a negative temperature coefficient of resistance included serially in said line at frequent intervals and subjected to the same temperature variations as the line, for counteracting the overall variation of attenuation of the line, and a resistance shunting each such element for rendering the compensation more exact.

7. The combination recited in claim 6 in which said elements are comprised of silver sulphide.

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