May 23, 1933. L. L. LOCKROW 1,910,471

TRANSMISSION LINE

Filed Sept. 29, 1931

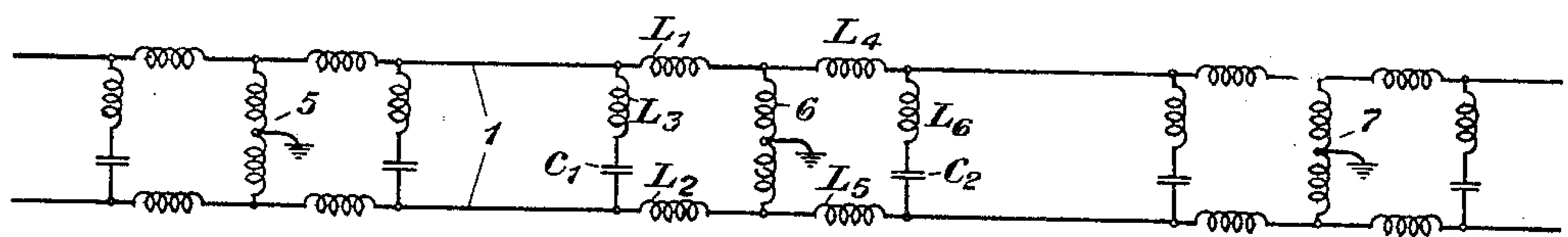

Fig. 1

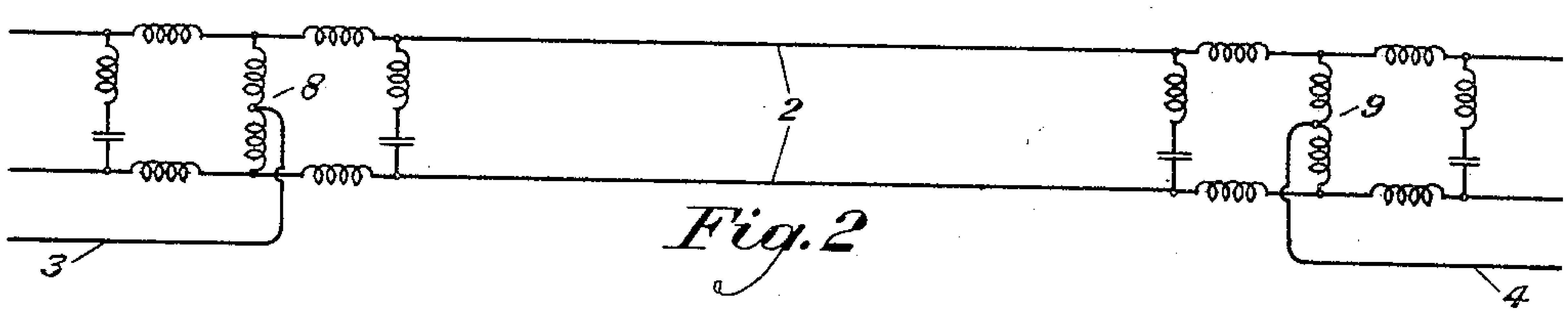

Fig. 2

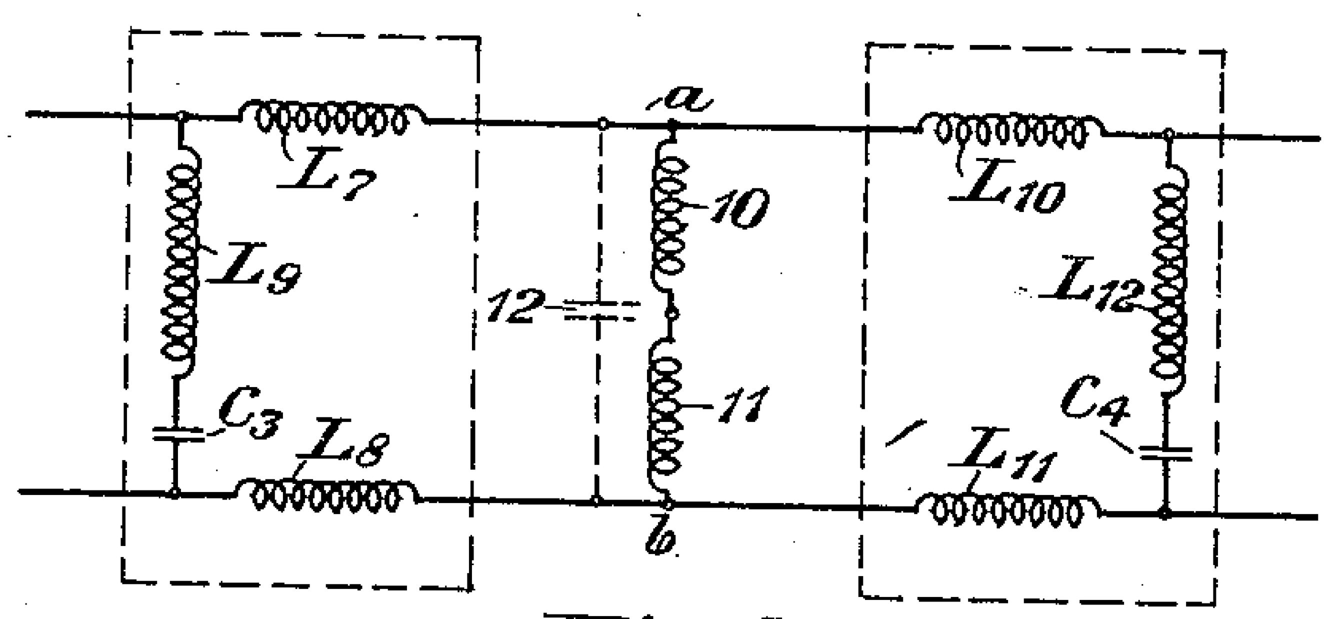

Fig. 3

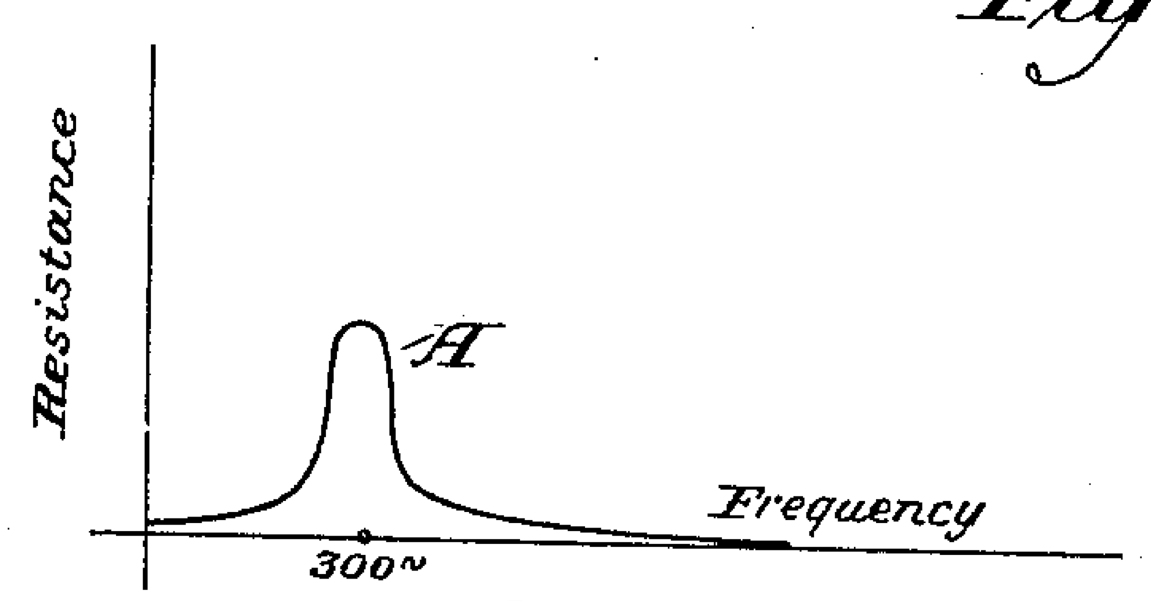

Fig. 4

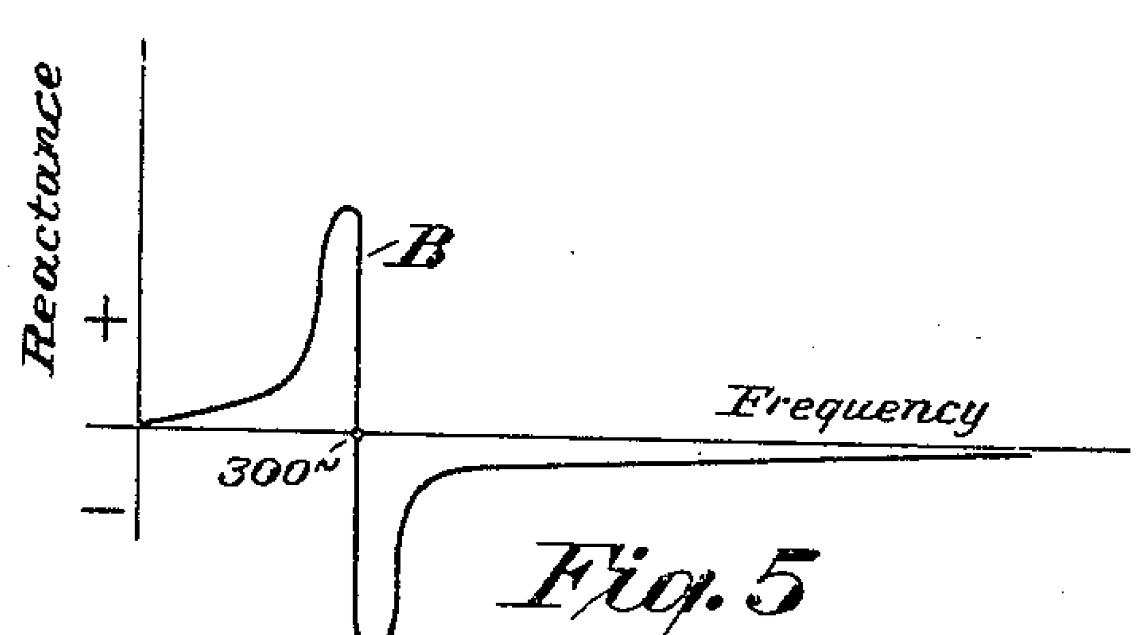

Fig. 5

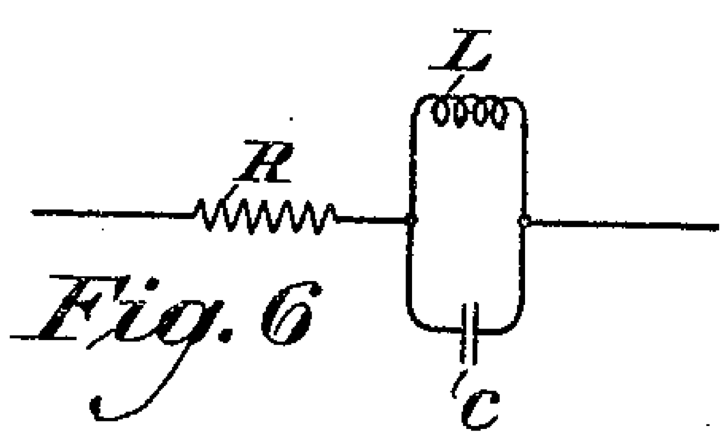

Fig. 6

Fig. 7

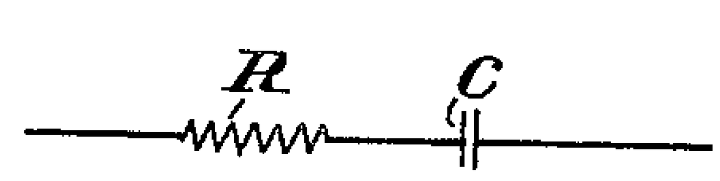

Fig. 8

INVENTOR
L. L. Lockrow
BY
G. E. Folk
ATTORNEY

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UNITED STATES PATENT OFFICE

LAURICE LAIRD LOCKROW, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

TRANSMISSION LINE

Application filed September 29, 1931. Serial No. 565,874.

This invention relates to transmission lines and more particularly to the use in said lines of networks in conjunction with circuit arrangements connected with said lines, such for example as retardation coils, so that said circuit arrangements will not impair the transmission capabilities of said line at the higher frequencies, such as those of carrier telephony or telegraphy.

The principles of the invention have various applications. Among these applications, for example, are the use of the arrangements of the invention in conjunction with circuit arrangements, such as retardation coils in drainage systems or in connection with circuit arrangements for utilizing the transmission line as a simplex telegraph circuit. A drainage system, for example, would employ retardation coils bridged across the transmission line at intervals with their center taps grounded for the purpose of reducing voltages due to a nearby power or railway conductor system. When the transmission line is utilized as a simplex telegraph circuit the telegraph circuit would be connected to the midpoints of a retardation coil bridged across the line. A retardation coil can be designed for a particular range of frequencies such as voice or carrier frequencies, but to design a coil which has favorable characteristics from the 20 cycle ringing frequency through the voice and carrier ranges to 30,000 cycles, is extremely difficult if not impossible. The use of circuit arrangements of this type, such for example as retardation coils designed to be effective at ringing and voice frequencies in connection with a transmission line will usually prevent the use on the line of the higher frequencies, such as those used for carrier purposes, due to the relatively low impedance of these coils between the points connected to the line at such frequencies. This invention relates to a network, which when used with a retardation coil having favorable impedance characteristics at ringing and voice frequencies reduces to a minimum the unfavorable reaction of the coil at carrier frequencies. In the arrangements of the invention there is connected in the line on each side of the retardation coil a compensating or terminating network and the use of the coil is thus prevented from impairing the transmission qualities of the line at the higher frequencies.

The compensating or terminating network to be utilized in the transmission line in conjunction with retardation coils of the type referred to consists of two inductance coils one connected in series with each side of the line and a shunt path consisting of an inductance and a condenser in series. The utilization of networks of this type for the purposes of the invention may be further understood from the detailed description hereinafter given.

The invention may be more fully understood from the following description together with the accompanying drawing in the Figures 1–8 of which the invention is illustrated. In Fig. 1 the arrangements of the invention are shown associated with a drainage system for a transmission line. In Fig. 2 the arrangements of the invention are shown associated with means for utilizing a transmission line for the simplex operation of telegraph. Fig. 3 is a detailed showing of the networks of the invention. Figs. 4 and 5 are curves showing certain transmission characteristics of the retardation coil. Figs. 6, 7 and 8 show equivalent circuits of the retardation coil under different conditions. Similar reference characters have been utilized to denote like parts in several of the figures.

In Fig. 1 is shown a transmission line 1. Bridged across the line at intervals with their center taps grounded are the retardation coils 5, 6 and 7. This would represent the conventional type of drainage system such as would be used to reduce harmful voltages on the line due to a nearby power or railway conductor system (not shown). The use of retardation coils which are effective in carrying current to ground in such a system and which do not interfere with the use of ringing and voice frequency currents will usually prevent the use on the line of the higher frequencies, such as carrier frequencies, due to the relatively low impedance of the coils between the points connected to the line at such frequencies. Accordingly the invention provides compensating or terminating networks connected in the line on both sides of each of the retardation coils. For example, on one side of retardation coil 6 is the network comprising the inductance coils L_1 and L_2 connected in series in each side of the line and the shunt path comprising the series inductance L_3 and the capacity C_1. On the other side of the retardation coil 6 is the network comprising the inductance coils L_4 and L_5 connected in series in each side of the line and the shunt path comprising the series inductance L_6 and the capacity C_2. Similar compensating or terminating networks are provided on each side of the retardation coils 5 and 7.

In Fig. 2 is shown a transmission line 2 arranged to be utilized for operation as a simplex telegraph circuit. The retardation coils 8 and 9 are bridged across the line and the telegraph circuits 3 and 4 would be connected to their midpoints as shown. In accordance with the arrangements of the invention compensating or terminating networks are connected in the line on each side of the retardation coils 8 and 9. Obviously the principles of the invention are capable of further applications in addition to those heretofore described.

The behavior of the circuit may be more readily understood from reference to the remaining figures. In Fig. 3 is shown a retardation coil bridged across a line together with terminating networks on each side thereof. The retardation coil is one constructed with parallel pair windings 10 and 11 of relatively low *d—c* resistance. It has a high impedance between points *a* and *b* at the ringing frequency of 20 cycles and at frequencies in the voice range and accordingly for these frequencies gives only a small bridging loss. Measurements of the impedance across the terminals *a—b* show that the coil exhibits resonance characteristics at frequencies around 300 cycles due to the distributed capacity between the windings. A detailed study of the phenomenon indicates that for practical purposes the behavior of the coil may be represented by the equivalent circuit of Fig. 6. At frequencies somewhat below 300 cycles, the retardation coil has the characteristics of an inductance and resistance in series, such as shown in Fig. 7. This will be apparent from the curves A and B of Figs. 4 and 5 respectively. The curve A shows the resistance-frequency characteristics of the coil and the curve B shows the reactance-frequency characteristics of the coil in which it appears that the reactance becomes zero at the critical frequency. At the critical frequency the coil appears to be a pure resistance and above and below the critical frequency the coil appears to be a resistance in series with a condenser and an inductance respectively as shown in Figs. 8 and 7 respectively. Well above the resonant frequency the retardation coil has the characteristic of a condenser with a resistance in series. It is also capable of being represented by a condenser of constant capacity with a resistance shunted across it. This would cause a large loss at carrier frequencies due to the low impedance shunt across the line.

From the above, applicant has discovered, that in the frequency range extending upward from 300 cycles and in the carrier frequency range, the retardation coil above discussed has characteristics which closely approximate those of a loading section of cable. As is well known in the art in loading cable the line is divided into sections which, in the case of one type of carrier loading, are approximately 930 feet long. The retardation coil above discussed resembles in its characteristics just such a section of cable.

In United States Patent 1,475,997 to R. S. Hoyt it was discovered and pointed out that such a section of cable could be given a terminal impedance characteristic equivalent to a pure resistance over a wide range of frequencies by terminating the cable in a proper network. This network may, as pointed out in the Hoyt patent, comprise a loading coil having .80 of its normal value across the terminals of which is bridged a series combination of inductance and capacity suitably related to the inductance and capacity of the cable section. The principle underlying this terminating network is as follows: When the cable section is terminated in a loading coil of either .8 or .2 the normal value, the resistance component of the impedance of the cable section as seen through the fractional loading coil will be constant with frequency up to a cut off point dependent on the characteristics of the loading coil and the cable section. The reactance component of the impedance of course varies with frequency. If, however, the reactance component could be neutralized without changing the resistance component, the terminal impedance of the system could be made to look like a pure and constant resistance. Hoyt discovered, as pointed out in his patent, that shunting the terminals of the fractional load coil by a series combination of inductance and capacity bearing suitable relations to the inductance and capacity of the cable section would neutralize the reactance component of the impedance of the partially loaded cable section, with the result that the terminal impedance of the entire combination would be reduced to a pure and constant resistance.

Having discovered that a retardation coil bridged across the line has approximately the same characteristics as a loading section of cable, applicant's invention consists in connecting in the line on each side of the retardation coil a terminating network similar to that disclosed in the Hoyt patent. For example in Fig. 3 the inductances L_7 and L_8 are equivalent of .80 of a normal loading coil. The inductance L_9 and condenser C_3 are similar to the Hoyt structure. Accordingly applicant's terminating network is substantially the same as that of Hoyt. This will cause the impedance of the retardation coil when seen from either end to be that of a pure and constant resistance. Under these conditions the retardation coil may be used without adversely affecting the transmission of the higher frequencies. The combination of the coil and networks behave just as a short length of cable with its networks at carrier frequencies, this analogy being so close that it is found that the capacity of the coil can be "built out" to the proper amount, if necessary, just as a section of cable can be "built out", by placing a condenser across points *a* and *b* of Fig. 3, such as condenser 12 shown in dotted lines in said figure.

While the invention has been disclosed as embodied in certain specific arrangements which are deemed desirable it is understood that it is capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined by the appended claims.

What is claimed is:

1. A transmission line, a retardation coil bridged across said line, said retardation coil having characteristics approximating those of a loaded section of cable and terminating networks on each side of said retardation coil, each of said networks comprising inductance coils connected in series with each side of said line and an inductance and capacity connected in series with each other and in shunt across said line.

2. A transmission line, a retardation coil bridged across said line, said retardation coil having characteristics approximating those of a loaded section of cable, and terminating networks on each side of said retardation coil, each of said networks comprising inductance coils connected in series with each side of said line and an inductance and capacity connected in series with each other and in shunt across said line, said networks having their elements so designed that the impedance of the retardation coil when seen from either end will be that of a pure and constant resistance at all frequencies.

3. A transmission line, a retardation coil bridged across said line, said retardation coil having characteristics approximating those of a loaded section of cable, and terminating networks on each side of said retardation coil, each of said networks comprising inductance coils connected in series with each side of the line and designed to be equivalent to a loading coil having .80 of the normal value of the loading coil of a section of cable and an inductance and capacity connected in series with each other and in shunt across said line, said last mentioned inductance and capacity having values proportional to the inductance and capacity of the equivalent section of cable.

In testimony whereof, I have signed my name to this specification this 25th day of September 1931.

LAURICE L. LOCKROW.