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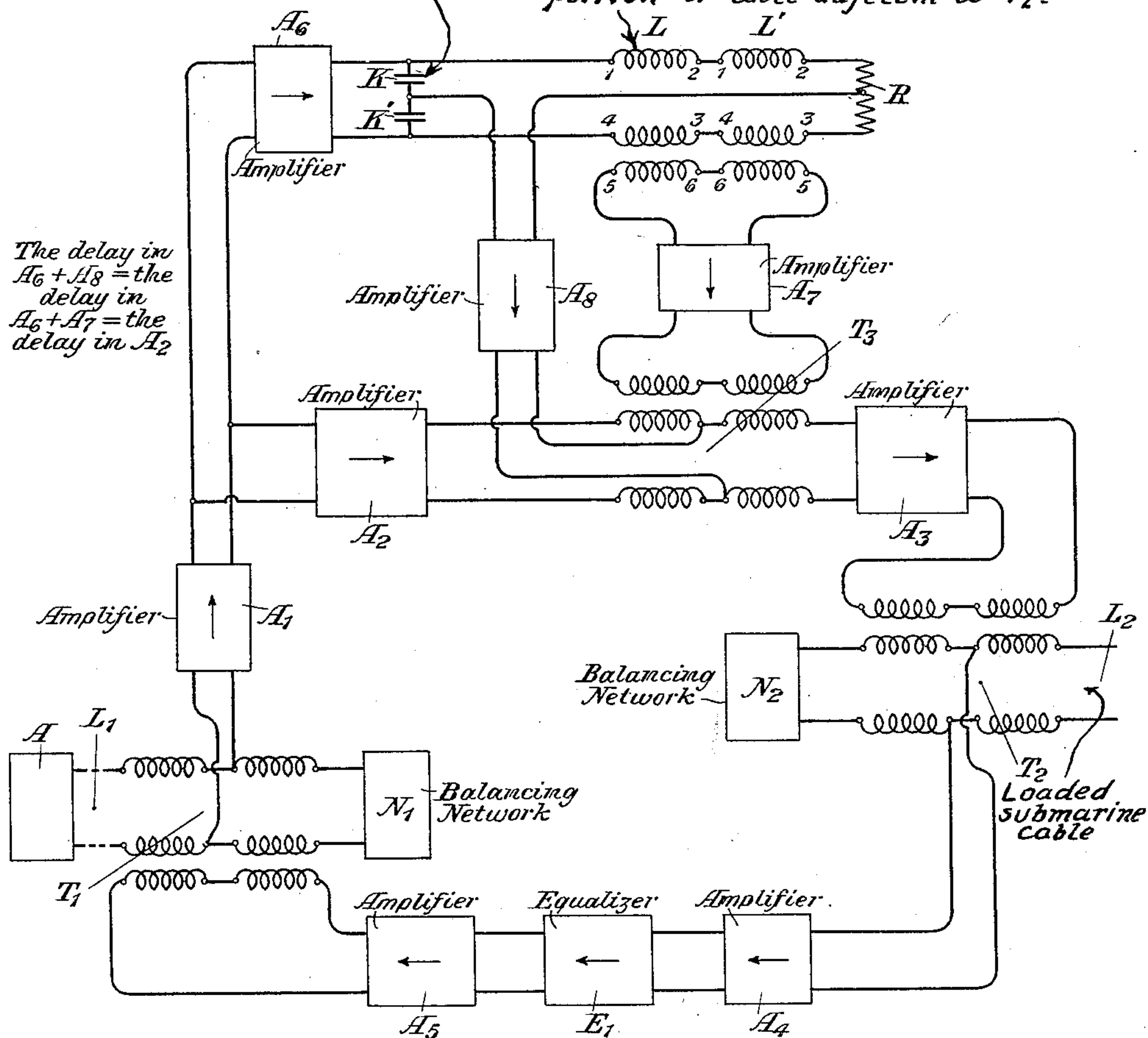
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MEANS FOR COMPENSATING FOR NONLINEAR DISTORTION IN TRANSMISSION CIRCUITS

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Preferably of the same dielectric as Cable L_2 and worked at the same point of its non-linear characteristic

Preferably of the same loading material as Cable L_2 , and worked on the same portion of its magnetic characteristic as the portion of cable adjacent to T_2 .



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MEANS FOR COMPENSATING FOR NONLINEAR DISTORTION IN TRANSMISSION CIRCUITS

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This invention relates to distortion compensating arrangements for signaling circuits, and particularly to a method and means for predistorting a signaling wave in order to compensate for the distortion that normally would be created in the signaling wave by the non-linear characteristics of the materials of the transmitting medium as the result of the transmission of the wave there-
over.

It has been found that the material used for loading long transmission circuits such as a transatlantic cable, has a non-linear characteristic, and furthermore, that the dielectric used for the insulation of such cables also has a non-linear characteristic, the degree of which is perhaps less than that of the magnetic material. The effect of such non-linearity of the characteristic of a material employed in a submarine cable is to distort the wave that is being propagated over the cable, and while some distortion might not cause serious harm in the transmission of speech signals, it might prove detrimental if the cable were employed simultaneously for program transmission and telegraphy.

My invention resides in distorting the signal wave prior to its impression upon the cable, the degree and the character of the distortion being such as to compensate for that distortion that will be produced upon the wave as the result of the non-linearity of the characteristic of the materials employed in the cable.

This invention will be understood from the following description when read in connection with the attached drawing, showing schematically a form of embodiment of the invention.

In the drawing, L_1 represents a transmission circuit such as a land line over which two-way signals may be transmitted as in ordinary speech transmission, and L_2 represents another transmission circuit such as a loaded submarine cable. The loading material and the dielectric used in insulating the cable both possess non-linear characteristics and thereby tend to produce distortion in the signal waves being transmitted thereover, either those from the terminal shown in the

drawing or those transmitted from the terminal at the distant end not shown on the drawing. The lines L_1 and L_2 are connected by a two-way repeater comprising a sending path, by means of which signals are sent from the line L_1 into the cable L_2 and a receiving path by which the signals received from the cable L_2 are impressed upon the line L_1 . The sending path includes the amplifiers A_1 , A_2 , and A_3 and the receiving path includes the amplifiers A_4 and A_5 and the transmission equalizer E_1 . The line L_1 is balanced by the network N_1 , and similarly L_2 is balanced by the network N_2 . The line L_1 is connected with the sending and receiving paths by the hybrid coil or three-winding transformer T_1 which, as is well known, prevents the received signals from passing into the sending path when the line L_1 is properly balanced. In a similar manner the cable L_2 is connected with the sending and receiving paths by the hybrid coil or three-winding transformer T_2 . It is desirable to point out that while three amplifiers have been shown in the sending path and two in the receiving path, the number of amplifiers and their positions may be changed without departing from the scope of the invention.

The distortion compensating circuit is bridged across the sending path between the amplifiers A_1 and A_2 so as to take from the sending path a portion of the current of the transmitted signal to provide the basis for the predistortion of the transmitted wave. The circuit for building up the compensating distortion includes an amplifier A_6 , the condensers K and K' , inductances L and L' and the resistance R . The condenser K is preferably made of the same dielectric as is employed upon the cable L_2 and is worked at the same point of the non-linear characteristic. The condenser K' has the same capacity as K but a linear dielectric characteristic. Each of the inductances, L and L' , is made up of two coils, one for each side of the network, and those coils are coupled with the input of the amplifier A_7 by means of the secondary windings 5—6, which are connected in opposition. The output of amplifier A_7 is connected with one of the windings of

the hybrid coil T_3 . The mode of connection is such that the voltage produced by A_7 will be impressed across the windings of T_3 that are connected in series with the sending path between the amplifiers A_2 and A_3 . The amplifier A_8 has its input connected between the junction of the condensers K and K' and the midpoint of the resistance R and has its output connected with the windings of the coil T_3 so that it is connected in parallel with the sending path.

The elements forming the network in the output of the amplifier A_8 , namely, K , K' , L , L' , and R , are so chosen that the impedance of the condensers is large in comparison with the resistance while the impedance of the coils is small in comparison with the resistance. The coil L' is made of a material having a substantially linear characteristic, whereas the other coil L has a non-linear characteristic, being made, preferably, of the same magnetic material as is used in loading the cable. Moreover, the gain of the amplifier A_6 and the design of the coil L are so chosen that the coil works on the same portion of its magnetic characteristic as that portion of the cable L_2 near the end connected with the coil T_2 .

The manner in which the aforesaid circuit operates to compensate for the distortion created by the cable is as follows: Let it be assumed that a wave has been transmitted over the line L_1 and is impressed by the coil T_1 upon the sending path of the repeater shown in the drawing. The major portion of the current represented by that wave will pass over the sending path through the amplifier A_1 , A_2 , and A_3 and will be impressed by the coil T_2 upon the cable L_2 . A portion of the current will be impressed upon the amplifier A_6 in the distortion compensating circuit and the resultant voltage will be impressed across the network in the output of that amplifier. The resultant current will flow through the inductance coils L and L' . Since those coils differ only in their characteristics, one being linear and the other non-linear, the residual voltage impressed upon the input of the amplifier A_7 is simply that resulting from the distortion created by the inductance L . By adjusting the amplifier A_7 , the voltage that will be impressed upon the sending path by the output of the amplifier A_7 may be made to approximate the distortion that will be produced in the signal wave when transmitted over the line L_2 , which distortion arises from the non-linearity of the characteristic of the magnetic loading material. The distortion introduced by the non-linearity of the dielectric used in the manufacture of the cable is compensated for by the condensers K and K' and the amplifier A_8 . Since the capacities of the condensers are equal, the voltage that will be impressed upon A_8 will be simply that arising from the

non-linearity of the characteristic of condenser K , which, as pointed out, is made of the same dielectric material as is employed upon the cable L_2 , and, by adjustment of amplifier A_6 , is worked at the same point of the characteristic as the dielectric in the cable is worked.

The resultant voltage as amplified by A_8 will be impressed across the sending path. It is important to point out that the compensating distortion impressed upon the signal wave that passes from the amplifier A_2 to A_3 through the windings of the coil T_3 must be in phase opposition to the distortion set up in the cable L_2 . Moreover, the amplifiers A_7 and A_8 should be so designed that there is no considerable difference in delay between the various frequencies transmitted there-through. Furthermore, the total delay in amplifier A_8 should equal that in amplifier A_6 and A_7 should equal the delay in amplifier A_2 .

Inasmuch as the wave is attenuated as it proceeds along the cable, different portions of the loading material are worked to different points on its characteristic. Accordingly, the coil L may be worked to an average point upon its characteristic, or the cross-section of the core of the inductance coil may be varied so that different portions of it are worked at different points of the characteristic. A similar refinement could be introduced in the construction of condenser K by making the dielectric of non-uniform thickness in order to correspond to the effect of the dielectric upon the wave as it is attenuated during transmission.

While the invention has been described as embodied in a particular form, it is to be understood that it is capable of embodiment in different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a system in which the distortion of a signal wave is created by the non-linearity of the characteristics of materials employed in the transmitting medium, the method for reducing the tendency to distort which consists in selecting a part of the signal wave being transmitted, distorting the selected portion in the same manner and to the same degree as the signal wave will be distorted by the non-linearity of the materials of the transmitting medium, and impressing the said selected portion, as thus distorted, upon the transmitting circuit in phase opposition to the distortion produced in the signal wave by the transmitting medium.

2. In a system in which the distortion of a signal wave is created by the non-linearity of the characteristics of materials employed in the transmitting medium, the method which consists in predistorting the signal wave in an opposite sense electrically to that distortion which will be produced in the sig-

nal wave by the non-linear characteristics of the materials of the transmitting medium.

3. In a system in which the distortion of a signal wave is created by the non-linearity of the characteristics of materials employed in the transmitting medium, the method which consists in selecting a portion of the wave, creating distortion effects like those produced by the non-linear characteristics of the capacity and the inductance elements of the transmitting medium, and impressing said distortion effects upon the signal wave in phase opposition to the distortion produced during propagation of the wave over the transmitting medium, as the result of the non-linear characteristics of the materials employed.

4. In a system in which the distortion of a signal wave is created by the non-linearity of the characteristics of materials employed in the transmitting medium, the method for reducing the tendency to distort which consists in selecting a part of the signal wave being transmitted, amplifying the selected part and impressing it upon a network comprising capacity, inductance and resistance elements, the said elements being so chosen as to cause a predetermined distortion of the selected part of the signal wave, and combining the distortion products of the said selected part with the remaining part of the said wave as transmitted over the said medium, where distortion may be neutralized.

5. In a system in which the distortion of a signal wave is created by the non-linearity of the characteristics of materials employed in the transmitting medium, the combination with a transmission circuit the materials of which have non-linear characteristics thereby tending to produce distortion, of a source of signaling waves to be sent over the said transmission circuit, amplifying means connected between said source and said circuit, a path around all or a part of said amplifying means and containing means to distort to a predetermined degree and in a predetermined manner a portion of the wave from the said source and to effectively impress said distorted portion upon said transmission circuit in phase opposition to the distortion produced in the transmitted wave by the non-linear characteristics of the materials of the transmission circuit.

6. In a system for reducing the effect upon signal waves of distortion arising from the non-linear characteristics of the materials used in the transmitting medium, the combination with a transmission line the materials of which have non-linear characteristics, of a source of signal waves connected with the said transmission line, and means connected with the said source to predistort the signal waves in the same manner as is produced by the non-linearity of the transmission line, but in phase opposition to the line distortion.

7. In a system for reducing the effect upon signal waves of distortion arising from the non-linear characteristics of the materials used in the transmitting medium, the combination with a transmission line the materials of which have non-linear characteristics, of a source of signal waves connected with the said transmission line, and a network comprising inductance and capacity elements, the inductance elements creating a distortion effect similar to that produced by the inductance of the said line and the capacity elements creating a distortion effect similar to that produced by the dielectric of the said line, means to control the magnitude of the distortion effects, and means to combinedly apply said distortion effects to the said signaling waves in phase opposition to the distortion created therein by the said transmission line.

In testimony whereof, I have signed my name to this specification this 26th day of June, 1930.

HARRY NYQUIST.

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