TRANSMISSION SYSTEM

Filed Nov. 20, 1929

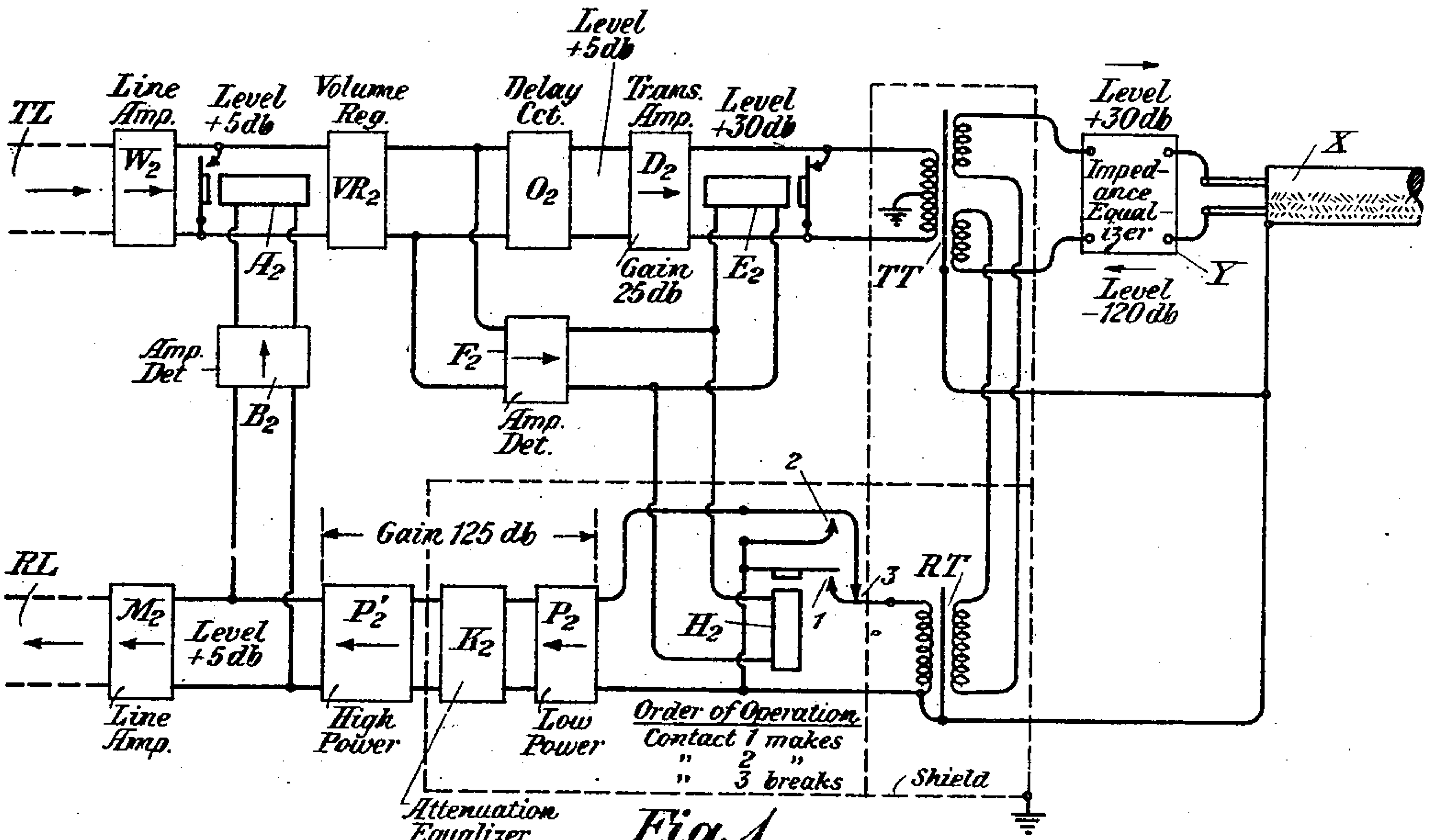

Fig. 1

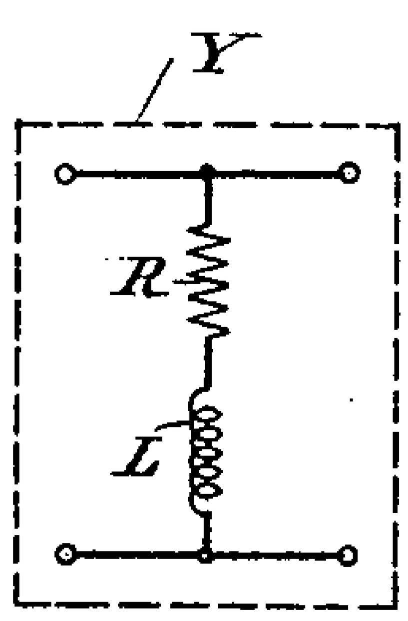

Fig. 2

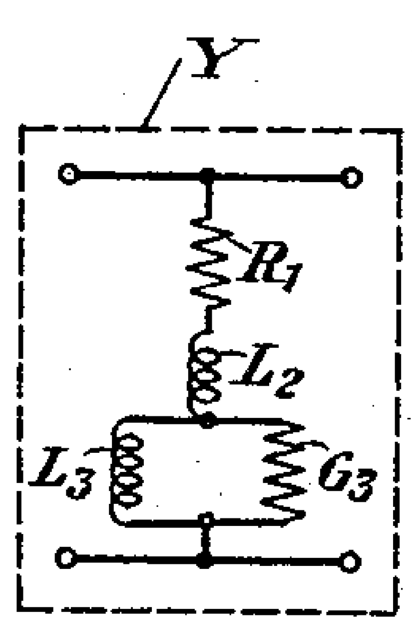

Fig. 3

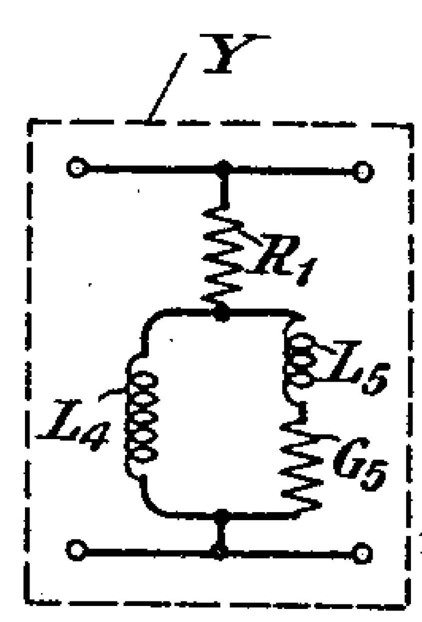

Fig. 4

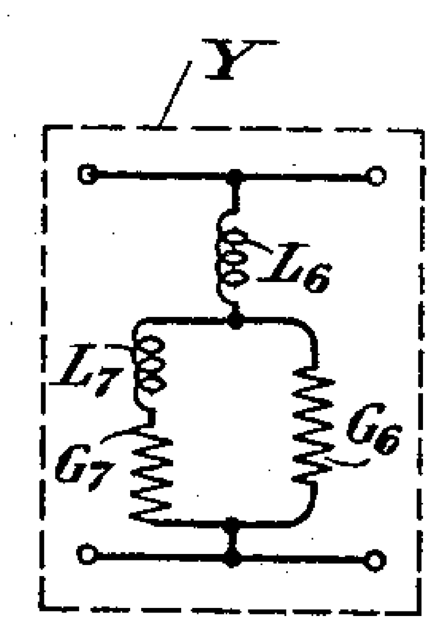

Fig. 5

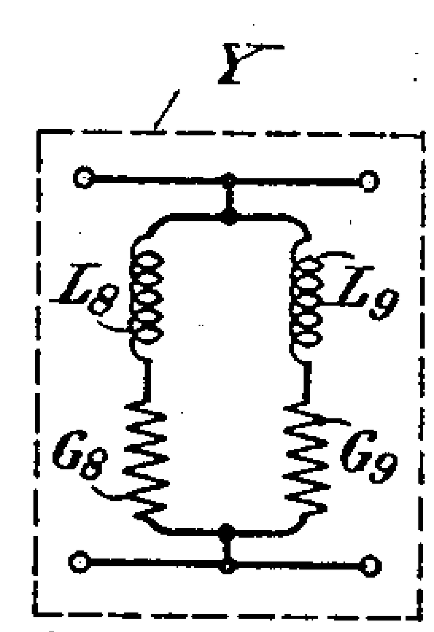

Fig. 6

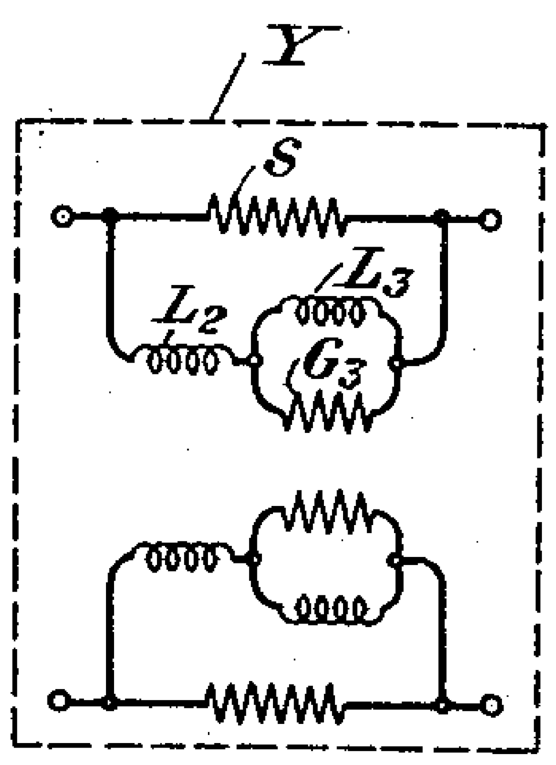

Fig. 7

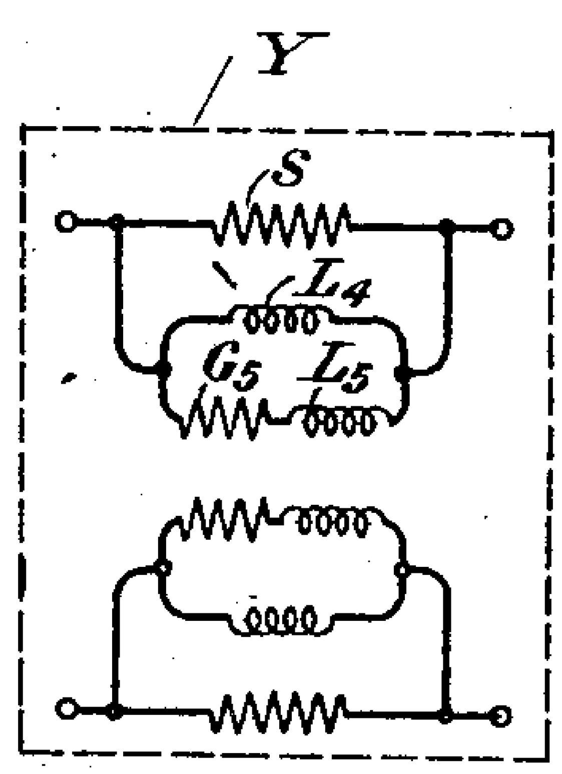

Fig. 8

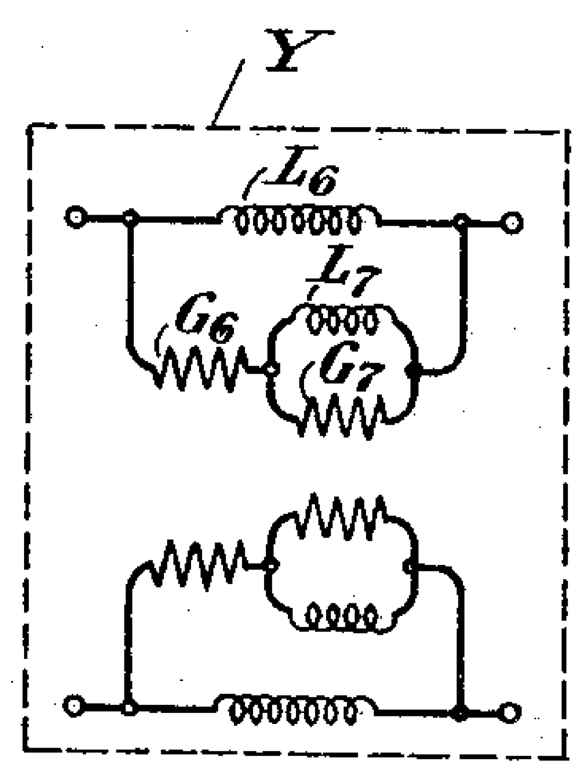

Fig. 9

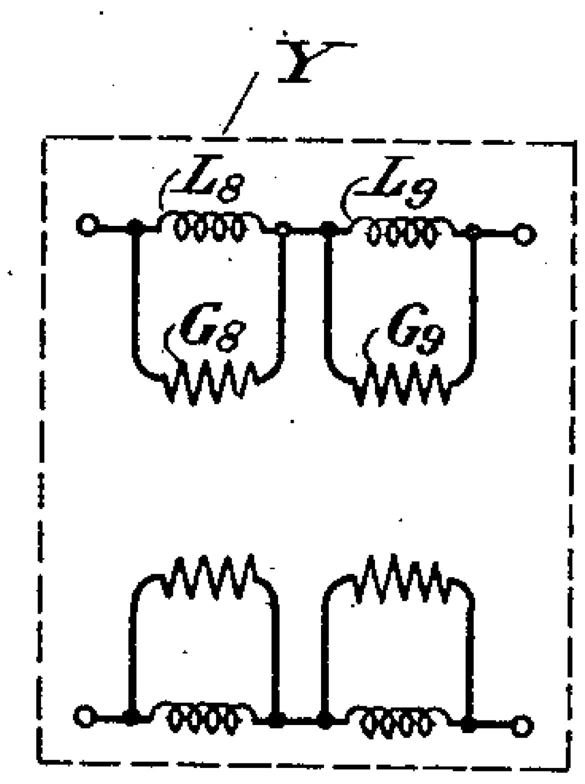

Fig. 10

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UNITED STATES PATENT OFFICE

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TRANSMISSION SYSTEM

Application filed November 20, 1929. Serial No. 408,580.

This invention relates to telephone transmission systems and more particularly to transmission systems involving a long section of submarine cable.

In order that wire telephone transmission may take place between points separated by a large body of water, as, for example, is the case in telephoning between New York and London, it is necessary that at least one long section of submarine cable be incorporated in the transmission circuit. Because of the expense of constructing such a cable, it is impractical to provide two cables for four-wire operation, and therefore the one long section of submarine cable, for example, between Newfoundland and Ireland, must be used for two-way transmission. It is however, quite feasible to operate on a four-wire basis those portions of the circuit which extend between the ends of the cable and the terminal switching stations at say New York and London. Due to various causes substantial echoes may occur in the four-wire part of the circuit.

With reference to the long section of submarine cable, which is operated on a two-way basis, the attenuation is enormous and although such cable is relatively free from external disturbing influences it will at least have a noise level determined by the resistance noise (or noise due to thermal agitation) of the cable. In order, therefore, that the currents received after transmission over the cable have sufficient volume to be above this noise level, the voice energy must be applied at the sending end of the cable at a very high volume level, so that the difference in level between the sending energy and receiving energy at a given end of the cable is very much greater than is the case with any type of telephone system heretofore employed.

With this great disparity between applied and received energy at the ends of a cable, it is obviously necessary that voice operated switching arrangements be provided for preventing singing in the four-wire circuit, as well as for suppressing echoes. Furthermore, it is necessary to locate the voice operated arrangement adjacent the ends of the cable. This is for the reason that the receiving amplifier must be very sensitive in order to step the weak attenuated currents incoming from the cable up to a normal volume for transmission over the receiving line of the four-wire circuit, and it is therefore necessary to protect such sensitive receiving apparatus from the relatively enormous echo currents coming in from the cable in response to transmission going into the cable from the other side of the four-wire circuit. It is also necessary to protect the receiver from the enormous transmitting currents which might enter the receiving circuit from the transmitting path of the four-wire circuit.

In the operation of echo suppressor equipment in connection with the long submarine cable, a factor which must be considered is the so-called relaxing current. The characteristic impedance of the cable will involve a considerable reactance component. When currents of large energy are applied to one end of the circuit for transmission to the other end, energy is stored up in the reactance of the cable, and, when the voice potential ceases a unidirectional gradually decaying current flows out of the cable because of the energy stored up in its reactance. Since the reactance is large, and the applied energy must necessarily be large (because of the great attentuation of the cable), this relaxing current will, at the instant when the applied energy ceases, be large and may require a considerable time before it decays to a value small enough to cause no disturbance in the sensitive receiving and voice-operated apparatus associated with the cable at its terminal. This relaxing current may therefore be for a considerable period of time very much greater in magnitude than the signaling currents which are to be received over the cable, and, if nothing is done to reduce its effect, the voice-operated relays for disabling the receiving path of the four-wire circuit at the cable terminal might have to be provided with a hang-over much longer than is necessary to take care of the echoes returned from the cable.

It is therefore proposed, in accordance with the present invention, to reduce the effect of the relaxing current. This may be accomplished by associating with the terminal of the cable a network having such impedance characteristic that the impedance of the cable as seen through the network will be a substantially pure resistance over the range of frequencies which the cable is to transmit. With such an arrangement the reactance of the combination comprising the cable and the impedance equalizing network, will approach zero to a degree dependent upon the degree of compensation, so that in the ideal case no relaxing current will flow out of the terminals of the network to the receiving side of the four-wire circuit. In any event in practice the initial value of the relaxing current will be very much decreased so that this factor will be within the limits of the echo effects so far as the hang-over time of the voice-operated relays is concerned.

In the practice of the present invention use may be made of any of several known types of networks which, when associated with a smooth loaded line, will render the characteristic impedance of the combination substantially a pure resistance, it being the purpose of the present invention to utilize the fact that giving to the circuit a characteristic impedance of this nature will prevent, or at least diminish, the relaxing currents of the cable. The invention also includes the use of such terminal connections between the cable and the four-wire circuit, and the employment of such types of voice-operated devices, as will be most effective in the operation of a system provided with impedance equalizers utilized for the purposes above stated.

Other features of the invention will be clear from the following detailed description thereof when read in connection with the accompanying drawings, in which Figure 1 is a schematic diagram of the apparatus associated with the four-wire circuit at one end of a cable, it being assumed that similar apparatus will be provided at the opposite end of the cable, and Figs. 2 to 10 inclusive, are various forms of impedance equalizers which may be used in connection with the cable for reducing relaxing currents.

In Fig. 1, only the apparatus associated with the four-wire circuit at the cable terminal is shown, and the apparatus at the other end of the four-wire circuit may be of any known type for enabling a subscriber to talk over the transmitting side of the four-wire circuit and to receive telephone messages over the receiving side of the circuit. At the cable terminal the cable X is connected through a transformer TT to a transmitting line TL of a four-wire circuit, the corresponding receiving line RL of the four-wire circuit being associated with the cable through a transformer RT. It is not practical to connect the paths TL and RL in multiple to the cable X, as the voice-operated contacts for disabling the transmitting path would have the effect of short-circuiting the receiving path and vice versa. Accordingly, the secondary windings of the transformer TT, and the primary winding of the transformer RT are connected in series. Owing to the enormous difference in transmission level between the sending energy from the transmitting circuit TL and the receiving energy transferred from the cable to the receiving line RL, shielding is provided to protect the low level parts of the receiving circuit from the high level transmitting apparatus. This is indicated by the dotted line rectangles in the figures which surround certain portions of the receiving and transmitting equipment respectively.

The transmitting line includes a line amplifier W_2 for stepping the transmitted energy up to any desired volume. It also includes an auxiliary volume regulator VR_2 to bring the volume to some preassigned value, for example 5 decibels above reference volume and a transmitting amplifier D_2 for bringing the final volume to be applied to the cable up to the desired level which, as indicated, may be +30 db. Normally, the transmitting line is disabled just ahead of the transformer TT by means of the contacts of the relay E_2 which is controlled by an amplifier-detector arrangement F_2 bridged across the transmitting line ahead of a delay circuit O_2 which may be provided for the purpose of enabling the relay E_2 to operate before the voice currents arrive at the point where the circuit is disabled. It will be noted that the contacts of the relay E_2 are bridged across the output circuit of the amplifier D_2 rather than across the input circuit, so that any noise arising within the amplifier will be prevented from reaching the cable and the receiving side of the system. While this contact has the effect of short circuiting the secondary windings of the transformer TT, the fact that the primary windings of the transformer RT is in series with the secondary windings of the transformer TT, prevents the short circuit from being effective in the receiving path RL.

The amplifier-detector F_2 also controls a relay H_2 by means of which the receiving line RL may be disabled. Normally, the receiving circuit is operatively connected over the back contact 3 of the relay H_2 to the input of a low power amplifier P_2 which in turn is connected to a high power amplifier P'_2 for bringing the weak received currents in the cable up to the desired value for transmission over the receiving line RL. Assuming that the attenuation of the cable is 150 db. and that the currents are applied at the distant end at a volume of +30 db., the current will be received from the cable at a volume level of −120 db. If it is assumed that the current is to be applied to the receiving line RL at a volume level of −5 db., the overall gain of the amplifiers P_2 and P'_2 should be 125 db. These figures are, of course, merely given for purposes of illustration.

An attenuation equalizer K_2 may be connected between the two amplifiers P_2 and P'_2 for equalizing the attenuation of the currents transmitted over the cable, the cable, of course, having the effect of attenuating the high frequencies to a much greater extent than the low frequencies. An amplifier-detector arrangement B_2 is associated with the receiving line and controls a relay A_2 for disabling the transmitting line TL. The contact controlled by the relay A_2 is preferably associated with the line TL ahead of the volume regulator VR_2 in order that where an automatically adjusted volume regulator is used it will not be adjusted by echo currents.

The operation will now be described briefly. Waves originating at a subscriber's telephone come in over the line TL and after passing through the line amplifier W_2 and the volume regulator VR_2, operate the amplifier-detector F_2 to cause the actuation of the relays E_2 and H_2. The delay circuit O_2 enables the relay E_2 to open the short circuit across the input side of the transformer TT before the voice waves arrive at this point, thus avoiding initial clipping. This voice-operated apparatus must operate on all voice waves, since failure of the relay E_2 to operate would prevent the transmission of speech to the cable, while failure of the relay H_2 to operate would permit powerful echoes to pass into the receiving line RL and operate the relay A_2, thus interrupting the outgoing speech.

The relay H_2 is provided with three contacts, 1, 2 and 3, so associated that contact 1 makes before contact 2 makes, while contact 2 makes before contact 3 breaks. The result of making contact 1 is to short circuit the secondary windings of the transformer RT so as to prevent the effect of an open circuit impedance across the terminals of the cable X due to the opening of contact 3. The opening of contact 3 is necessary on the other hand, because the short circuit across the secondary transformer RT would not be sufficient to cut down the transmission from the transmitting line TL which is applied to the cable at the volume level of +30 db. and hence would arrive in the receiving channel at a volume level of 150 db. above the normal received currents. The contact 2 is necessary because the receiving amplifier combination P_2—P_2' is very sensitive, and its input should be short circuited by the contact 2 to prevent it from picking up noise through the capacity of the open contact 3. Relay H_2 must operate before the contact of relay E_2 opens, otherwise the high power noise from the transmitting side would cut into the receiver momentarily, thus operating the voice-operated relay A_2 associated with the receiving line RL to disable the transmitting line TL. While it may happen that both the transmitting line and receiving line are short-circuited momentarily due to the contact 1 of the relay H_2 being closed before the contact of relay E_2 opens, this does no harm. While it has the effect of momentarily terminating the cable X in short circuit instead of in its own impedance, thereby causing echo currents to be reflected back into the cable, such echo currents will be so greatly attenuated before arrival at the distant end as to be negligible.

When waves come in over the cable X they pass without hindrance over the contact 3 of the relay H_2 (assuming that relay H_2 is unoperated) through the receiving amplifier P_2, equalizer K_2 and high power amplifier P_2' and thence over the line RL. In passing, these waves cause the amplifier-detector B_2 to actuate the relay A_2, which latter short circuits the transmitting side of the circuit and so prevents operation of the anti-singing relay E_2 and the echo suppressor H_2 either by voice or echoes during the passage of incoming waves.

The relay A_2 is completely protected from land line and terminal noise when speech is not being received over the cable. The line amplifier M_2 prevents noise coming back from the receiving line RL to operate the relay A_2, while at the distant end of the cable the anti-singing relay corresponding to E_2 prevents any noise from entering the cable at that terminal when speech is not passing, and consequently the only noise coming from that direction to which the relay A_2 is subjected is that arising in the submarine cable itself and in the apparatus such as the amplifier P_2, equalizer K_2, etc. This noise will be due principally to thermal agitation, and, after passing through the equalizer K_2 will be much stronger at high frequencies than at low frequencies. The amplifier-detector B_2 should therefore be most sensitive to the important voice frequencies and should be quite insensitive to the higher voice frequencies, thus reducing the liability of the relay A_2 being operated by thermal agitation.

Owing to the large transmission loss of the submarine cable, which may be assumed to be in the neighborhood of 150 db. at the upper end of the voice range (about 3000 cycles) certain precautions must be taken that ordinarily are not necessary. Assuming that current from the transmitting side is applied to the cable at +30 db. and that current applied at the distant end is received from the cable at a level of −120 db., the total difference in level is 150 db. Consequently, if the circuit from the output of the amplifier D_2 to the transformer TT is not perfectly balanced longitudinally, an unbalanced or longitudinal voltage will act through the system and transfer noise to the cable which is greater in volume than received transmission even when the transmitting circuit is short circuited by the relay E_2. This effect will take place regardless of the loss to normal transmission caused by the contact of the relay E_2, the longitudinal current flowing in effect through the capacity between the windings of the transformer TT. This longitudinal effect can be greatly reduced by placing a shield grounded to the cable sheath between the line and drop windings of the transformer TT. A similar shield, connected to the office ground, should also be provided between the windings of the output transformer (not shown) of the amplifier D_2. The effect of these shields is to shunt to ground the displacement current which tends to pass through the capacity of the windings. Also, it is desirable that the secondary winding of the output transformer of the amplifier D_2 and the primary winding of the transformer TT be made in two closely balanced and closely coupled parts with grounds at the midpoints. The series resistances of the conductors connecting the amplifier D_2 to the transformer TT should also be accurately balanced.

As already described the relay H_2 is arranged to disable the receiving circuit by opening the contact 3. It is undesirable to open both sides of the receiving circuit by contacts of the relay A_2, as a momentary unbalance would occur if the two contacts did not open simultaneously, and this might produce enough disturbance to cause false operation of the relay A_2, thereby clipping speech outgoing from the transmission line TL to the cable X. In order to make possible the use of this unsymmetrical arrangement of the relay H_2, the transformer RT is provided. The transformer also serves to insulate the cable from the input circuit of the amplifier P_2 and to shield said amplifier from the longitudinal voltages on the conductors. For this purpose a shield between the windings of the transformer RT is provided which is connected to the sheath of the cable X.

The operation so far described has not taken into any account the effect of the so-called relaxing current from the cable X. The loaded submarine cable has a characteristic impedance which is not a pure resistance but involves a very considerable reactive component. As has been previously stated, the voice currents are applied to the cable from the line TL at a very high volume level, and the voice potentials thus store up in the reactance of the cable a very large volume of energy, with the result that when the applied voice potential ceases, the energy stored up in the reactance causes a gradually decaying unidirectional current to flow out of the cable. This current, at the moment of cessation of voice waves, is so large in magnitude that it might produce very serious disturbing effects in the receiving circuit. Unless some means were provided to reduce its effect, the relaxing current from the cable might require a longer hang-over time for the relay H_2 than might be required for reflected currents due to irregularities in the cable. To take care of this condition it is proposed to interconnect between the terminals of the cable X and the transformer connections associating the cable with the transmitting line TL and the receiving line RL, a so-called impedance equalizer indicated schematically at Y in Figure 1. This impedance equalizer is a network of known type which is designed to have such an impedance characteristic that the overall impedance of the combination of the cable X and the network Y will appear to be a pure resistance as seen through the equalizer network Y. If the impedance thus seen is an absolutely pure resistance no relaxing current would flow out of the cable into the receiving line RL as the overall combination would have no reactance as seen from its terminals. Even though this ideal effect can only be approximated in the design of the impedance equalizer Y, so that there will be some remanent reactance in the characteristic impedance of the combination, the relaxing current may be reduced to such a small initial value that it will have decayed to an ineffective value within the hang-over time required by the relay H_2 to take care of echo currents reflected from the cable.

Various known types of impedance equalizers may be designed for producing the aforementioned results. For example, in Fig. 2, the equalizer Y may take the form of a shunt across the line comprising a series combination of resistance R and inductance L. Such an equalizer will produce a moderate reduction in the overall reactance component of the combination of equalizer and cable. This type of equalizer structure and its method of design are fully disclosed in the application of Ray S. Hoyt, Serial No. 408,577 filed November 20, 1929.

Where greater precision of equalization is desired, shunt equalizers of any of the types illustrated in Figs. 3 to 6 inclusive, may be employed. These four types of equalizers are all equivalent electrically, and their structures are claimed and their methods of design are disclosed in the application of Ray S. Hoyt, Serial No. 408,578 filed November 20, 1929. The equalizer of Fig. 3 comprises a shunt arrangement including a resistance R_1 in series with an inductance L_2, these elements being in turn conected in series with a parallel combination of an inductance L_3 and a resistance G_3. In the equalizer of Fig. 4, the inductances L_2 and L_3, and the resistance G_3, are replaced by an inductance L_4 in parallel with a series combination of inductance L_5 and resistance G_5. In Fig. 5, the shunt element comprises an inductance L_6 in series with a parallel combination of resistance G_6 shunted by a series combination of inductance L_7 and resistance G_7. In Fig. 6, two shunt elements are provided, one comprising a series combination of inductance L_8 and resistance G_8, and the other comprising a series combination of inductance L_9 and resistance G_9.

Instead of employing a shunt type of impedance equalizer an equal degree of precision of equalization may be provided by the series type of equalizer. Four forms which the series type of equalizer may assume are illustrated in Figs. 7, 8, 9 and 10. These four forms of equalizer are claimed and their methods of design are disclosed in the application of Ray S. Hoyt, Serial No. 408,579 filed November 20, 1929.

The series type of equalizer has the objection that in order to provide longitudinal balance between the two sides of the cable system the equalizer must be split in half, and one half be included in each line conductor, thus requiring twice as many inductances and resistances as in the case of the shunt type impedance equalizer. In the case of Figure 7, the series equalizer connected in one line wire comprises a resistance S shunted by a combination consisting of an inductance L_2 in series with a parallel combination of inductance L_3 and resistance G_3. It will be understood, of course, that similar elements are serially connected in the other line conductor. In the case of Fig. 8, the resistance S is shunted by a combination of inductance L_4 arranged in parallel with a series combination of resistance G_5 and inductance L_5. In the case of Fig. 9, the equalizer connected in one line wire comprises an inductance L_6 shunted by a combination consisting of a resistance G_6 in series with a parallel combination of resistance G_7 and inductance L_7. In the case of Fig. 10, the equalizer in one line wire comprises two units, each comprising an inductance shunted by a resistance. For example, the inductance L_8 shunted by resistance G_8 forms one unit, and the inductance L_9 shunted by the resistance G_9 forms a second unit, the two units being in series with each other.

The present invention, from the standpoint of reduction of relaxing currents, utilizes the principle that when a known type of impedance equalizer is combined with a loaded submarine cable so that the impedance, looking into the cable through the equalizer approaches a pure resistance, the relaxing current flowing back from the terminals of the equalizer is correspondingly reduced. This is because the energy stored up in the reactance of the cable and tending to cause a relaxing current to flow from the cable, is balanced by opposing energy stored up in the opposing reactance of the network. The specific types of equalizer structures per se and their methods of design are not a part of the present invention, and hence are not disclosed in detail or claimed herein, but, as already stated, form the subject matter of certain applications of Ray S. Hoyt previously identified.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a signaling system, a transmission path of large attenuation and whose characteristic impedance includes reactance of such value that in response to the cessation of applied signaling currents a relaxing current will flow out of the path having an initial value which is large as compared with attenuated signaling currents received over the path, and means to substantially suppress said relaxing current comprising a network associated with the transmission path, said network having such impedance characteristic that the impedance of the combination of network and transmission path will be substantially a pure resistance.

2. In a signaling system, a transmission path of large attenuation and whose characteristic impedance includes reactance of such values that in response to the cessation of applied signaling currents a relaxing current will flow out of the path having an initial value which is large as compared with attenuated signaling currents received over the path, and means to substantially suppress said relaxing current comprising a network associated with the transmission path, said network having such impedance characteristic that the impedance of the combination of network and transmission path will be substantially free of reactance in which energy to produce relaxing currents may be built up.

3. In a signaling system, a transmission path of large attenuation and whose characteristic impedance includes reactance of such value that in response to the cessation of applied signaling currents a relaxing current will flow out of the path having an initial value which is large as compared with attenuated signaling currents received over the path, means to substantially suppress said relaxing current comprising a network associated with the transmission path, said network having such impedance characteristic that the impedance of the combination of network and transmission path will be substantially a pure resistance, a transmitting line including means to apply signaling cur-

rents of large amplitude to said transmission path, a receiving line including sensitive receiving apparatus to receive attenuated signaling currents from said transmission path, signal operated switching means associated with each of said lines for controlling the other line, and means for so associating said lines with said transmission path that said signal operated switching means will not disable said transmission path.

4. In a signaling system, a transmission path of large attenuation and whose characteristic impedance includes reactance of such value that in response to the cessation of applied signaling currents a relaxing current will flow out of the path having an initial value which is large as compared with attenuated signaling currents received over the path, means to substantially suppress said relaxing current comprising a network associated with the transmission path, said network having such impedance characteristic that the impedance of the combination of network and transmission path will be substantially free of reactance in which energy to produce relaxing currents may be built up, a transmitting line including means to apply signaling currents of large amplitude to said transmission path, a receiving line including sensitive receiving apparatus to receive attenuated signaling currents from said transmission path, signal operated switching means associated with each of said lines for controlling the other line, and means for so associating said lines with said transmission path that said signal operated switching means will not disable said transmission path.

5. In a signaling system, a submarine cable for two-way signal transmission, said cable having large attenuation and its impedance including reactance of such value that in response to the cessation of applied signaling currents a gradually decaying relaxing current will flow out of the cable with an initial value so great that at the end of a period during which echo currents are reflected from the cable with disturbing effect the decayed relaxing current will be of greater effect than reflected currents, and means to substantially suppress said relaxing current comprising a network associated with the cable, said network having such impedance characteristic that the impedance of the cable as seen through the network will be substantially a pure resistance.

6. In a signaling system, a submarine cable for two-way signal transmission, said cable having large attenuation and its impedance including reactance of such value that in response to the cessation of applied signaling currents a gradually decaying relaxing current will flow out of the cable with an initial value so great that at the end of a period during which echo currents are reflected from the cable with disturbing effect the decayed relaxing current will be of greater effect than reflected currents, and means to substantially suppress said relaxing current comprising a network associated with the cable, said network having such impedance characteristic that the impedance of the cable as seen through the network will be without sufficient reactance in which to build up a substantial relaxing current.

7. In a signaling system, a submarine cable for two-way signal transmission, said cable having large attenuation and its impedance including reactance of such value that in response to the cessation of applied signaling currents a gradually decaying relaxing current will flow out of the cable with an initial value so great that at the end of a period during which echo currents are reflected from the cable with disturbing effect the decayed relaxing current will be of greater effect than reflected currents, means to substantially suppress said relaxing current comprising a network associated with the cable, said network having such impedance characteristic that the impedance of the cable as seen through the network will be substantially a pure resistance, a transmitting line including means to apply signaling currents to the cable with such amplitude that they will arrive at the other end without being attenuated to the level of the resistance noise of the cable, a receiving line including amplifying apparatus sufficiently sensitive to amplify signaling currents so attenuated to a normal transmission level, signal operated switching means associated with each of said lines for controlling the other line, and means for so associating said lines with the same end of said cable that the signal operated switching means when operated to disable either line will not interfere with transmission between the other line and the cable.

8. In a signaling system, a submarine cable for two-way signal transmission, said cable having large attenuation and its impedance including reactance of such value that in response to the cessation of applied signaling currents a gradually decaying relaxing current will flow out of the cable with an initial value so great that at the end of a period during which echo currents are reflected from the cable with disturbing effect the decayed relaxing current will be of greater effect than reflected currents, means to substantially suppress said relaxing current comprising a network associated with the cable, said network having such impedance characteristic that the impedance of the cable as seen through the network will be without sufficient reactance in which to build up a substantial relaxing current, a transmitting line including means to apply signaling currents to the cable with such amplitude that they will arrive at the other end without being attenuated to the level of the resistance noise of the cable,

a receiving line including amplifying apparatus sufficiently sensitive to amplify signaling currents so attenuated to a normal transmission level, a signal operated switching means associated with each of said lines for controlling the other line, and means for so associating said lines with the same end of said cable that the signal operated switching means when operated to disable either line will not interfere with transmission between the other line and the cable.

In testimony whereof, I have signed my name to this specification this 14th day of November, 1929.

GEORGE CRISSON.