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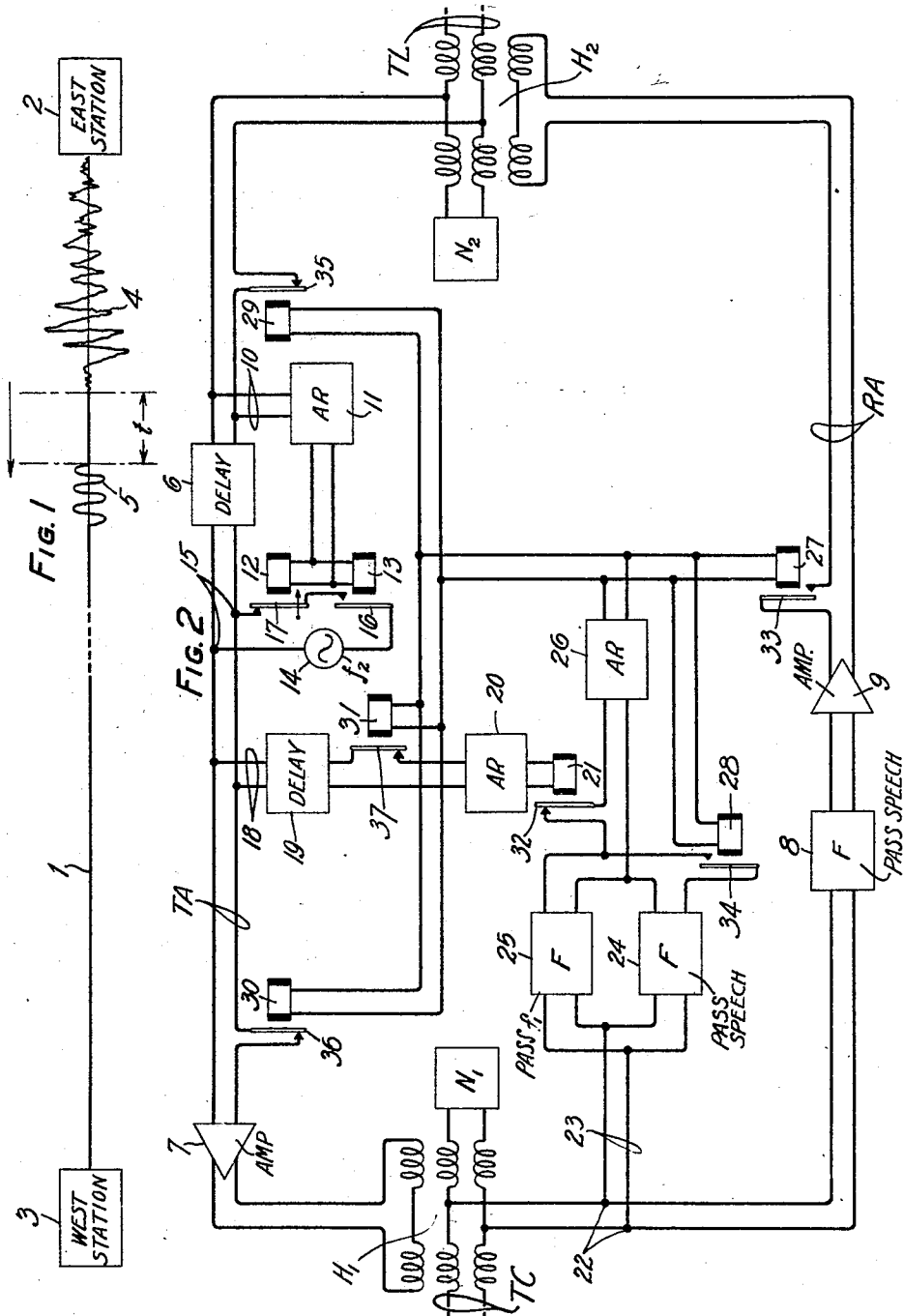
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1,829,805

TRANSMISSION CONTROL

Filed June 11, 1929

2 Sheets-Sheet 1



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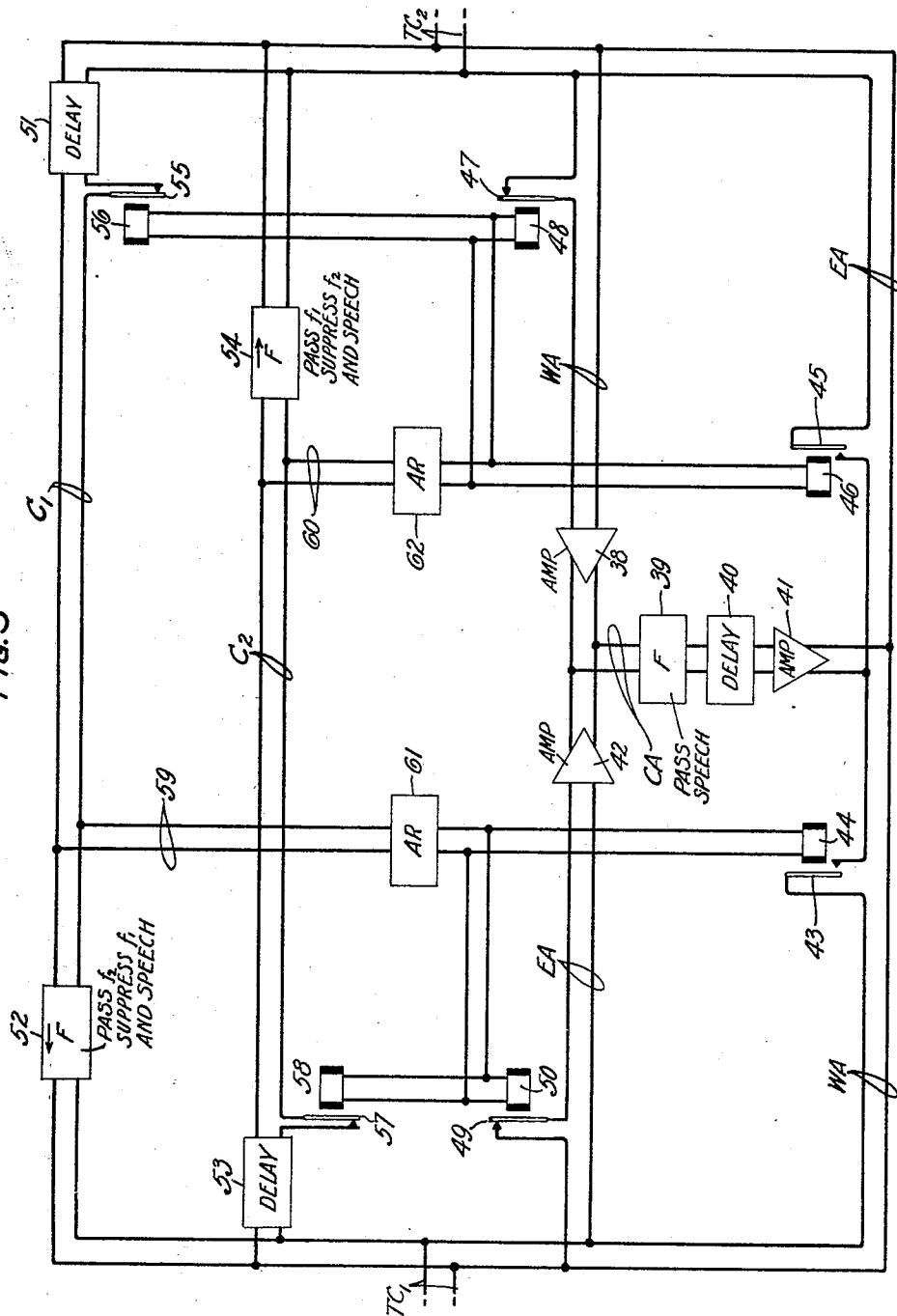
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FIG. 3



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TRANSMISSION CONTROL

Application filed June 11, 1929. Serial No. 370,034.

This invention relates to electric wave transmission systems, particularly to two-way electric communication systems.

The invention in its broad aspects relates to the controlling of transmission in a signal transmission system by control energy transmitted over the system under control of signals, and in advance of the signals, to operate circuit-control means at one or more points in the system.

An object of the invention is to improve the operation of a signal transmission system including therein circuit-control means operated under control of the signals transmitted over the system.

The invention is especially applicable to a system over which two-way transmission of signaling energy is required within the same frequency range, and including as a link therein a long section of two-way cable of high attenuation, such as a deep sea submarine cable. Signal-operated circuit-control apparatus, for example, so-called singing and echo suppressors, are usually associated with the oppositely directed amplifying paths at each terminal of the cable in such a system to insure that the system is operative to transmit in only one direction at a time, so as to effectively suppress echoes, singing or both. This is usually accomplished by making the circuit-control apparatus at each terminal responsive to transmission in one direction to make the circuits operative for transmission in that one direction and to effectively disable the circuits for transmission in the opposite direction.

There are two main characteristics of such a system, the combination of which may introduce difficulties in the application of such signal-controlled, circuit-control apparatus thereto. One of these is the increased time of transmission over the cable due to its length and loading, and the other is the high attenuation of the cable.

The increased time of transmission over the cable greatly increases the chance that two subscribers at opposite ends of the system may both start talking within the time interval equal to the transmission time of the cable, resulting in each subscriber by means

of his circuit-control apparatus securing control of his own terminal for transmitting and locking out the transmission received from the other subscriber. In general, this condition may be avoided by circuits designed to give complete control of the system to that subscriber at one end of the system whose speech energy first reaches the cable. In the prior art, the U. S. patent to Barton No. 1,574,781, issued March 2, 1926 and applicant's U. S. Patent No. 1,678,188, issued July 24, 1928 disclose certain methods for operating a plurality of repeater circuits connected in tandem involving the sending out of a sustained alternating current wave, called the "courier," under the control of the speech waves, from either terminal over the cable or an auxiliary circuit ahead of the speech waves to condition the circuits for repeating in the proper direction. A method of this general nature is adapted for use in a cable system such as described above, but must be considerably modified, because of characteristics peculiar to the system such as the very high attenuation, and the limited, useful frequency range and load capacity of the cable, to make it practicable for commercial use from the standpoint of quality and economy.

To operate such a system it is necessary to have information at both ends of the cable as to when talk is going in at either end, and this information must be positively received through talk going out from the other end. The direction of energy flow is unreliable in giving such information as the weak speech energy incoming from the cable at one terminal may be completely lost among the reflected components of the outgoing speech. The information may, however, in accordance with the invention be carried by auxiliary waves under control of the speech waves. The difficulty associated with applying such auxiliary waves to the cable simultaneously with the speech whose presence they are to indicate is that they will use up part of the load carrying capacity of the transmitting amplifier and, more important still, of the load capacity of the cable, if interference through intermodulation is to be avoided or dangerously high potentials produced.

The above mentioned difficulties in a system of the type described have been substantially minimized in accordance with the invention by a modification of the "courier" method of control. In the method of the invention, the signal energy generated at each terminal of the cable or incoming from a land line connected thereto is made to control the sending out over the transmission circuit ahead of the signals, of control waves, preferably a spurt of a short train of control waves, which will be referred to hereafter as the courier, of a frequency different from each terminal and outside the speech frequency range to operate circuit-control means to establish initial control in proper time relation of the transmitting and receiving circuits at each terminal of the system and of any intermediate repeater circuits, this control being maintained by the speech energy when it arrives at the controlling points. The first courier sent out will determine which terminal or talker gets exclusive control of the system.

One type of terminal circuit utilizing the general method of control of the invention may be used in connection with a system having characteristics such that it is feasible therein to select the incoming courier in the presence of simultaneous outgoing speech energy, such as a system employing a short cable, or one of low overall attenuation, or one having slight modulation effects. Another type of circuit utilizing this general method of control may be used with a system having characteristics such that it is not feasible therein to select the incoming courier in the presence of simultaneous outgoing speech energy, such as a system employing a very long cable, or one of very high overall attenuation, or one having large modulation effects.

My copending application, Serial No. 370-035 filed June 11, 1929, is specifically directed to circuits of the latter type.

This application is specifically directed to circuits of the former type, these circuits being arranged so that the signals are delayed in transmission behind the courier only long enough to allow for completion of the necessary operations under control of the courier to establish initial control of the circuits before the signals arrive at the control points.

The exact nature of the objects and advantages of the invention will be better understood from the following detailed description thereof when read in connection with the accompanying drawings in which Fig. 1 shows a schematic diagram illustrating the principles of the invention, Fig. 2 shows a circuit diagram of a cable terminal station embodying the invention, and Fig. 3 a circuit diagram of an intermediate repeater station embodying the invention.

For convenience, the invention will be de-

scribed as applied to a system for the two-way transmission of speech waves, but it is to be understood that the principles of the invention apply equally well to systems for the two-way transmission of signal waves in general of frequencies within or outside the speech frequency range, such as waves representing speech, entertainment programs comprising music as well as speech, etc.

In Fig. 1 is shown schematically a two-way cable 1 connecting an east station 2 to a west station 3. A speech wave 4 generated at one or both of the stations, for example, at station 2, controls the sending out of a short impulse of control current 5, which will be referred to hereafter as the courier, over the cable 1 towards the other station. As indicated in the figure the courier 5 precedes the speech wave 4 by a time interval t . In a manner described in detail in connection with the following figures, the transmitted courier may be utilized to establish initial control of circuit-control apparatus at the terminal stations and intermediate repeater stations to condition the station apparatus for transmission in one direction and for blocking transmission in the opposite direction, and the speech wave 4 when it arrives at the control points may be utilized to maintain the station apparatus in the condition initiated by the preceding courier. The time interval t is suitably chosen so that the initial control of the circuit-control apparatus by the courier is completed before the arrival of the speech wave at the control points.

Fig. 2 shows the circuits at one terminal of a two-way cable system employing the general principle outlined in connection with Fig. 1 to prevent transmission lock-outs when two subscribers at the opposite ends of the system both start talking within the time interval equivalent to the transmission time of the cable. Since the terminal stations at both ends of the cable may be substantially identical in construction except for the particular frequencies of the courier currents transmitted therefrom and the range of the filters employed, it has been deemed sufficient to illustrate only one terminal station, the east station. In the following description the manner of operation of the system will be clear from reference to the single station shown.

The east terminal station of Fig. 2 comprises, connected between a source of speech waves, such as the toll telephone line TL, and a two-way cable TC of high attenuation, such as a deep sea submarine cable, a one-way transmitting amplifying path TA and a one-way receiving amplifying path RA. The output of the transmitting path TA and the input of the receiving path RA are connected to the east end of the two-way cable TC by means of a three-winding transformer or hybrid coil H_1 , which cooperates with the cable TC and the balancing network N_1 to

insure substantial conjugacy between the paths TA and RA. For a similar purpose the input of the transmitting path TA and the output of the receiving path RA are connected to the signaling line TL through the hybrid coil H_2 having an associated balancing network N_2 .

Connected between the hybrid coils H_2 and H_1 in the one-way path TA is a delay circuit 6 and a one-way transmitting amplifier 7, and connected between the hybrid coils H_1 and H_2 in the receiving path RA is a band-pass filter 8 and the one-way receiving amplifier 9. Connected across the path TA at points between the hybrid coil H_2 and the delay circuit 6 is a control circuit 10 comprising a current-controlled relay controlling device 11, and a fast-operating relay 13 and a slow-operating relay 12 connected in parallel to the output of the control device 11. A source 14 of alternating current of frequencies f_2 , which are outside the speech frequency range, is adapted to be momentarily connected across the transmitting path TA at the points 15 in the output of delay circuit 6 by means of switches 16 and 17 controlled by the operation of relays 13 and 12. Connected to the transmitting path TA between the points 15 and the input of the transmitting amplifier 7 is another control circuit 18 comprising the delay circuit 19, the current-controlled relay-controlling device 20, and the relay 21 connected to the output of control device 20.

Connected across the receiving path RA at points 22 between the hybrid coil H_1 and the filter 8 is a third control circuit 23 comprising the filters 24 and 25 connected in parallel, the current-controlled relay-controlling device 26 in series therewith, and the relays 27 to 31 connected in parallel to the output of control device 26.

Relay 21 is responsive to operation of the control device 20 to open the normally closed switch 32 in control path 23 between the outputs of filters 24 and 25 and the input of control device 26. Relays 27 to 31 are responsive to the operation of control device 26 respectively to close the normally open switch 33 in the output of the receiving amplifier 9 in receiving path RA, to close the normally open switch 34 in the output of filter 24 in control path 23, to open the normally closed switches 35 and 36 in the transmitting path TA, and to open the normally closed switch 37 in the output of delay circuit 19 in control circuit 18.

Although the receiving circuit is shown normally disabled at a single place (normally open switch 33), because of the high gains which are necessary in a system of the type described it may be desirable to have the receiving circuit disabled in several places.

It is apparent that the terminal circuit

which has just been described is of the form which is known in the art as semi-biased, that is, the circuit is normally operative to transmit in one direction (in this case from east to west) and transmission in the opposite direction (in this case from west to east) is dependent upon a switching operation.

The relay controlling devices 11, 20 and 26 may be vacuum tube amplifier-rectifier devices of the type well known in the art, or any other devices which will respond to alternating current impressed upon their inputs to control the operation of switching devices, such as mechanical relays, in the outputs thereof.

The delay circuits 6 and 19 may be networks of any type suitable for producing a delay of the required amounts, which will be specified below, in the transmission of alternating currents impressed upon their inputs; for example, they may be low-pass electrical filters such as disclosed in U. S. patents to Campbell Nos. 1,227,113 and 1,227,114, issued May 22, 1917, acoustic filters, or networks for a similar purpose such as disclosed in Arnold Patent No. 1,565,302 issued December 15, 1925.

Filters 8, 24 and 25 may be of the type disclosed in the U. S. patents to Campbell, mentioned above. The filter 8 and the filter 24 are band-pass filters designed to pass frequencies within the speech frequency range and to substantially suppress other frequencies, while filter 25 is designed to pass the courier frequencies f_1 transmitted from the west terminal station (not shown) and generated thereat by a generator corresponding to the generator 14 at the east terminal station. The frequencies f_1 may be any frequencies outside the speech frequency range and differing from the courier frequencies f_2 generated by generator 14.

The one-way amplifiers 7 and 9 and the relays 12, 13, 21 and 27 to 31 and the corresponding apparatus at the west terminal station may be of any of the types well known in the art.

The operation of the system as a whole will now be described referring to Fig. 1 only. To aid in this it will be assumed that telephonic currents for transmission from east to west are received first at the east terminal station from the toll telephone line TL, and at some time later and within the interval equal to the total transmission time of the cable TC, telephonic currents are received at the west terminal station from a corresponding source for transmission from west to east.

The telephonic currents received from the toll telephone line TL at the east station are impressed on the one-way path TA through the hybrid coil H_2 . A small part of these currents will be diverted from the path TA into the control circuit 10 and operate con-

control device 11 therein, which in turn will energize the windings of relays 12 and 13. Relay 13 will operate quickly to close switch 16 to connect the generator 14 across the transmitting path TA. Slow-operating relay 12 will operate an instant later to open the switch 17 so as to disconnect the generator 14 from the path TA. The effect of this quick connection to and the following disconnection from transmitting path TA of generator 14, will be to cause a short impulse of current of frequencies f_2 to be transmitted out over the path TA. This impulse, or courier, may be made as short as is desired or is necessary by the design of relays 12 and 13. The relays 12 and 13 are so designed that they will remain operated as long as speech waves from the source TL are being continuously supplied to the control device 11. They are designed so that they will release only after a complete pause in the conversation and not for ordinary pauses between words.

A portion of the courier f_2 will be amplified by the transmitting amplifier 7 and impressed on the cable TC through the hybrid coil H_1 and transmitting thereover to establish initial operation of the switching circuits at the west terminal station in the manner which will be explained later. Another portion of the courier f_2 will be diverted into the control circuit 18.

The main portion of the speech currents impressed on the one-way path TA through hybrid coil H_1 will pass through the delay circuit 6 which will delay it in transmission for a short time t . The delay circuit 6 is so designed that the delay time t of the speech behind the courier is only long enough to insure completion of the initial operation of switching apparatus at the west terminal station by the preceding courier f_2 before the speech waves arrive thereat so as to prevent clipping of the speech. The delay time t would be in the order of a few hundredths of a second.

The portion of the courier f_2 which is diverted from transmitting path TA into control circuit 18 is delayed therein by delay circuit 19 for $T-t$ seconds, where T is the total transmission time of the cable TC from the east station to the west station, and then operates control device 20 to energize the winding of relay 21. The delay circuit 19 need not be a high grade one as it is only required for the purpose of delaying an operating impulse. The control device 20 is only initially operated by the diverted portion of courier f_2 , and is maintained operated by the speech waves which follow t seconds later. The device 20 should not be operated by the speech wave unless the control device 11 in control path 10 has been operated. One way of accomplishing this is by relatively designing the sensitivities of the control devices

11 and 20 in proper manner, or by employing another relay, controlled by control device 11 and responsive to operation thereof to close normally open contacts in series with the normally closed switch 37 in the input circuit of the control device 20 in control circuit 18.

The energization of the windings of relay 21 will cause relay 21 to operate to open the normally closed switch 32 in control circuit 23 and will, therefore, prevent the operation of control device 26 to operate relays 27 to 31 by the courier f_1 which is sent out from the west terminal station in response to speech waves thereat later than the courier f_2 sent out from the east terminal station.

In the manner which has just been described complete control of the talking circuits of the east terminal station has been obtained by the westwardly directed telephonic currents at that station.

The manner in which complete control of the talking circuits at the west terminal is obtained for the first talker, which in this case has been assumed to be the talker at the east terminal, will now be described. That the apparatus to be referred to is that of the west terminal station will be indicated by designating the apparatus thereat with the same characters which designate the corresponding apparatus at the east terminal station, but followed by a prime (') mark.

The portion of the courier f_2 which is transmitted over the cable from the east station and in advance of the speech wave by an interval of time t , on its arrival at the west station is impressed on the receiving path RA' through the hybrid coil H_1' . The filter 8' in receiving path RA' will not pass the frequency f_2 so the courier will be diverted at the points 22' into the control circuit 23' and will be selected and passed by the filter 25' to the input of control device 26'. The transmitted courier f_2 will initially operate the control device 26' thus energizing the windings of relays 27' to 31' and causing these relays to operate. The operation of relay 27' will close switch 33' in receiving path RA', making that path operative for transmission of the received speech waves from hybrid coil H_1' to H_2' ; the operation of relay 28' will close switch 34' in control path 23', making that path operative for the transmission of a portion of the received speech currents to the input of control device 26'; the operation of relays 29', 30' and 31' will respectively open the normally closed switches 35' and 36' in the transmitting circuit TA' and switch 37' in the control path 18' connected thereto. The interruptions of the transmitting circuit in so many places is required to prevent false operation of the relay circuits associated therewith by unbalanced received energy or by energy stored in the delay circuit 6 previous to the operation of control device 26'.

The speech wave transmitted from the east terminal station over the cable TC t seconds behind the courier f_2 on its arrival at the west terminal station will be impressed on the receiving path RA' thereat by the hybrid coil H₁', and will divide at the points 22' between the control circuit 23', which passes both the control frequency f_2 and the speech band, and the main receiving path RA' which, because of the filter 8' therein, will pass the speech band only. The portion of the received speech currents diverted into control path 23' will be selected and passed by the band-pass filter 24' and, the switch 34' in the output of filter 24' now being in the closed condition, will then be impressed upon the input circuit of control device 26' maintaining this device in its operated condition initiated by the preceding courier. If the speech waves passed by filter 24' have not been preceded by the courier impulse f_2 , they will not get through to operate control device 26' because the switch 28' in the input of control device 26' will be open. The control of control device 26' by the speech wave will cause relays 27' to 31' to be maintained in the operated condition as long as the westwardly directed speech wave is being received at the west terminal station. Because of the opening of the switch 37' in control path 18' by operation of the switch 31', any energy which might be stored in delay circuits 6' and 19' prior to the operation of control device 26' cannot get through to operate control device 20' and therefore relay 21' to disable the control path 23' by opening the switch 32' therein.

The transmitting and receiving circuits of both the west terminal station and the east terminal station are now under complete control of the east terminal station.

It is readily seen that because of the relation specified of the delay times in the delay circuits 6 and 19 at the east terminal station and 6' and 19' at the west terminal station to the transmission time of the cable TC, that whichever terminal first sends out its courier will gain exclusive control of both sets of terminal apparatus.

If the oppositely directed speech wave from the two talkers at the two ends of the system reach the two terminals almost simultaneously, but the east talker starts ahead of the west talker, the cable TC will be charged with outgoing transmission from the west talker at the time control device 26' at the west station operates. Incoming speech at the west station, therefore, will be masked by the reflections from outgoing speech during the time it takes the cable to dissipate the portion of the outgoing speech energy. This means that a small amount of the speech may be lost or distorted if the system of the invention is used. This loss or distortion will not be sufficiently great to be trouble-

some in practice unless a very high grade of quality is desired, especially as such loss will occur relatively infrequently.

In the system of the invention it may be necessary to receive the incoming couriers f_1 and f_2 at the terminals of the cable in the presence of simultaneous outgoing speech energy. The filters and other apparatus in the system should be so designed that the courier may be separated from the speech energy, and so that the outgoing courier or speech does not falsely operate the receiving control apparatus. This should not be difficult if the cable TC is not too long or of too high attenuation, or if modulation products of the speech frequency fall at the frequencies f_1 and f_2 .

Fig. 3 shows an intermediate repeater station which is designed to operate in a system having terminal stations such as has been described in connection with Fig. 2 and which connects two sections of the cable TC which will be designated as TC₁ and TC₂ respectively. The circuits of the repeater are so designed that the terminal station which first sends out its courier will obtain exclusive control of the circuits of the intermediate repeater as well as the circuits of the two terminal stations. Moreover, the intermediate repeater station is arranged so that any loss of speech during the discharge time of a cable section is avoided.

It will be assumed that the section of the cable TC₁ joining the west terminal station and the intermediate repeater station has an overall transmission time of T₁ seconds for the currents transmitted thereover, and the section of the cable TC₂ joining the east terminal station with the intermediate repeater station has an overall transmission time of T₂ sections for currents transmitted thereover.

The intermediate repeater station comprises, connected between the two cable sections TC₁ and TC₂, a westwardly directed amplifying path WA and an eastwardly directed amplifying path EA having a portion CA in common. The path WA comprises in order reading from east to west the one-way amplifier 38, the band-pass filter 39, the delay circuit 40, and the one-way amplifier 41. The amplifying path EA comprises in order reading from west to east the one-way amplifier 42, the band-pass filter 39, the delay circuit 40 and the one-way amplifier 41.

The one-way amplifiers 38 and 42 in the amplifying paths WA and EA respectively are utilized for the purpose of enabling transmission from either path WA or EA to be supplied to the input of transmitting amplifier 41 in the common path CA without getting over into the other amplifying path. Other means may be used for this purpose, for example, a balanced bridge such as dis-

closed in Fig. 8 of my Patent No. 1,695,813, issued December 18, 1928.

The amplifying path WA is normally disabled for transmission from east to west between cable sections TC₂ and TC₁ in the output of the amplifier 41 by the normally open switch 43 controlled by the relay 44. Similarly, the amplifying path EA is normally disabled for transmission from west to east in the output of the amplifier 41 by normally open switch 45 controlled by the relay 46. A normally closed switch 47 controlled by the relay 48 is located in the amplifying path WA in the input of the amplifier 38 therein. Similarly, a normally closed switch 49 controlled by the relay 50 is located in the amplifying path EA in the input of the amplifier 42 therein.

Connected between the cable section TC₁ and the cable section TC₂ is a westwardly directed one-way auxiliary path C₁ comprising the delay circuit 51 and the one-way filter 52, and an eastwardly directed one-way auxiliary path C₂ comprising the delay circuit 53 and the one-way filter 54. A normally closed switch 55 controlled by a relay 56 is located in the path C₁ between the input of the filter 52 and the output of delay circuit 51 therein. Similarly, a normally closed switch 57 controlled by the relay 58 is located in path C₂ between the input of the filter 54 and the output of delay circuit 53 therein.

A control path 59 is connected to the path C₁ at a point between the input of the filter 51 and switch 55 therein. A similar control path 60 is connected to the path C₂ between the input of the filter 54 and switch 58 therein. In the control path 59 is a current-controlled relay-controlling device 61 which controls the operation of relays 44, 50 and 58. In the control path 60 is a current-controlled relay controlling device 62 which controls the operation of relays 46, 48 and 56.

The relay controlling devices 61 and 62 are similar to the controlling devices 11, 20 and 26 in the circuits of the terminal station shown in Fig. 2.

The filters 39, 52 and 54 are similar to the filters at the terminal station shown in Fig. 2. Filter 39 is designed to pass frequencies within the speech frequency range and to suppress the courier frequencies f_1 and f_2 . Filter 52 is designed to pass courier frequencies f_2 , and to suppress courier frequencies f_1 and waves in the speech frequency range. Filter 54 is designed to pass courier frequency f_1 , and to suppress courier frequency f_2 and waves within the speech frequency range.

The delay circuits 40, 51 and 53 are similar to the delay circuits at the terminal station shown in Fig. 2. The delay circuit 40 is designed to introduce a time delay in waves within the speech frequency range equivalent

to that introduced in said waves by the one of the cable sections TC₁ or TC₂ which has the longest time of transmission. If the transmission time T_1 of cable section TC₁ is greater than the transmission time T_2 of cable section TC₂, then the delay time of delay circuit 40 should be T_1 seconds. On the other hand, if T_2 is greater than T_1 then the delay time of delay circuit 40 should be T_2 seconds. If T_1 is greater than T_2 , the delay time of delay circuit 53 should be substantially zero, and the delay time of delay circuit 51 should be substantially equal to $T_1 - T_2$ seconds. On the other hand if T_2 is greater than T_1 , the delay time of delay circuit 51 should be substantially zero and the delay time of delay circuit 53 should be substantially equal to $T_2 - T_1$ seconds. For convenience in describing the operation of the intermediate repeater station, it will be assumed that T_1 is greater than T_2 . For this case the delay times of delay circuits 40, 53 and 51 should be substantially T_1 , 0, and $T_1 - T_2$ seconds, respectively.

Let it be assumed that speech waves for transmission from east to west are generated or received at the east terminal station first, and a short time afterwards within the interval equal to the overall transmission time of the whole cable (TC₁ + TC₂), that is, $T_1 + T_2$ seconds, speech waves are generated or received at the west terminal station for transmission from west to east. In the manner described in connection with Fig. 2 the speech waves at the east terminal station will cause the courier of frequencies f_2 to be sent out over the cable section TC₂ in the direction east to west ahead of the speech waves by the time interval t . At the intermediate repeater station the courier f_2 will be divided between the control path C₁ and the amplifying path WA. The portion of courier f_2 in amplifying path WA will be dissipated therein as the band filter 39 therein is designed to suppress frequency f_2 . The portion of the courier f_2 diverted into control path C₁ will be passed through the delay circuit 51 being delayed therein for $T_1 - T_2$ seconds. The passed courier will divide in the input of filter 52. A portion thereof will be passed by filter 52, transmitted directly to cable section TC₁ and transmitted thereover to establish initial control of the transmitting and receiving circuits at the west terminal in the manner described in connection with Fig. 2. The other portion of the courier f_2 will be diverted into control path 59 and will initially operate control device 60 to energize the windings of relays 44, 50 and 58 causing them to operate.

The relay 44 operates to close the normally open switch 43 in amplifying path WA making that path operative for the transmission of speech waves from cable TC₂ to cable TC₁. The relay 50 simultaneously operates to open

the normally closed switch 49 in amplifying path EA disabling that path for transmission from cable section TC₁ to the input of amplifier 42 therein. The relay 58 simultaneously operates to open the normally closed switch 57 in control path C₂ to disable that path for transmission of the courier f_1 or the succeeding speech waves from the west terminal station to the inputs of filter 54 and control device 62.

The speech wave transmitted from the east terminal station over cable section TC₂ t seconds behind the courier f_2 on arrival at the intermediate repeater station will be divided between the amplifying path WA and the path C₁. A small portion of these speech waves will be passed by delay circuit 51 in the path C₁, diverted into control path 59 and impressed on the input of control device 61 causing that device to be maintained in the operated condition initiated by the preceding courier f_2 as long as speech is being transmitted from east to west. Relays 44, 50 and 58 therefore will remain in the energized condition for that length of time.

The main portion of the speech waves received over the cable section TC₂ from the east terminal station will be diverted into the main amplifying path WA. This portion of the speech waves will be amplified by amplifier 38, passed by band-pass filter 39 and after a delay of T_1 seconds in delay circuit 40 will be amplified by amplifier 41 and transmitted directly to cable section TC₁ and over that cable section to the west terminal station. At the west terminal station a small portion of the received speech waves are utilized to maintain the switching apparatus thereat in the operated condition initiated by the preceding courier frequency f_2 , and the main portion of the received speech waves will be transmitted to the receiving apparatus, in the manner described in detail in connection with Fig. 2.

The courier f_1 and its succeeding west-to-east speech wave from the west station, because they are sent out therefrom later than the courier f_2 and the speech wave from the east station, will not be effective on arrival at the intermediate repeater station to affect the operation of the control apparatus thereat or to get through to the cable section TC₂ because the switches 49 and 45 in amplifying path EA, and the switch 57 in the path C₂ are open at the time of their arrival thereat.

It is apparent from the operation described that control of the transmitting and receiving circuits of both terminal stations and the circuits of the intermediate repeater station has been obtained for the east terminal station, that is, for the station at which the speech waves for transmission to the other station were first received or generated.

The delay in transmission of the speech currents from east to west over the amplifying path WA provided by the delay circuit

40, which is equal to the time of transmission over that one of the two cable sections which has the longest transmission time (in the case assumed T_1 seconds) insures that the speech waves follow the preceding courier over the cable section TC₁ with sufficient lag to permit any speech energy on that cable section to be discharged after the courier has obtained control of the distant station, and thus prevents loss of speech during the discharge time of the cable section.

When speech currents are generated or received at the west terminal station for transmission from west to east before the oppositely directed speech currents are generated or received at the east terminal station, the courier f_1 and the succeeding speech wave on their arrival at the intermediate repeater station control over path C₂ and control path 60, the operation of control device 62 to operate relays 46, 48 and 56 in a manner similar to that described in connection with the westwardly directed courier f_2 and the westwardly directed speech wave, to make operative the amplifying path EA by closing switch 45 therein, to disable the amplifying path WA by opening the switch 47 therein, and to disable the eastwardly directed path C₁ by opening the switch 55 therein. Complete control of the intermediate repeaters circuits for the west terminal station is thus obtained.

The obtaining of the control of the circuits is made independent of the relative length of the cable sections TC₁ and TC₂ by utilizing the difference in the delays produced by the delay circuits 51 and 53 in paths C₁ and C₂, respectively, to compensate for the unequal times required by the courier frequencies f_1 and f_2 in traversing cable sections TC₁ and TC₂ respectively.

It is to be understood that the invention is generic in character and is not limited to the particular circuits and details of the terminal and intermediate repeater stations illustrated and described since numerous modifications therein may be made by persons skilled in the art without departing from the spirit and scope of the invention. For example, the terminal circuits illustrated and described comprise a normally operative transmitting circuit, a normally disabled receiving circuit and switching means responsive to energy received over the cable for disabling the former and making operative the latter.

It is, of course, apparent that the invention is applicable as well to such circuits modified so as to comprise a normally disabled transmitting circuit, a normally operative receiving circuit and switching means responsive to energy to be transmitted to make operative the former and to disable the latter; or to comprise a receiving circuit and a trans-

mitting circuit which are both normally disabled and switching means responsive to energy received over the cable to make the former operative, and responsive to energy to be transmitted over the cable to make the latter operative.

The invention has been also illustrated and described in connection with an intermediate repeater station of a particular type comprising oppositely directed amplifying paths having a portion in common, both of which are normally disabled and comprising switching means responsive to transmission in either direction to insure that the path in that direction is operative only. The invention, of course, may be applied equally well to intermediate repeater stations of other types. For example, the oppositely directed amplifying paths may be entirely separate; or one path may be normally disabled and the other normally operative and the switching means may be responsive to transmission in either direction to insure that the paths are operative to transmit in that direction only; or a single amplifying means for both directions of transmission may be used with switching means responsive to transmission in either direction for pointing it in that direction.

Although in the particular embodiments of the invention illustrated and described, current-controlled mechanical relays are employed for producing an open circuit in a transmission path to disable it or closing an open circuit therein to make it operative, it is to be understood that the invention is not limited to conditioning means of this type. For example, within the scope of the invention the transmission path may be conditioned by utilizing current-controlled relays to disable the transmission paths by producing short circuits across the paths or by inserting losses in the path and to make the paths operative by removing a short circuit or a loss therein or by any other suitable means. Instead of utilizing mechanical switching relays and movable contacts for performing the switching operations, stationary means may be used, such as vacuum tube relays, such as disclosed, for example, in an article by C. A. Beer and G. T. Evans in the Journal of the Institute of Electrical Engineers (London), vol. 20, pages 65-72, inclusive, published in April, 1927, or in the U. S. patent to Crisson, No. 1,647,212 issued Nov. 1, 1927 or the U. S. patent to Beatty No. 1,470,954 issued October 16, 1923.

What is claimed is:

1. In a system for transmitting signals between stations, circuit control means at the stations, means at one of said stations under control of the signals to be transmitted therefrom for sending out control current in advance of the signals to another station to actuate the circuit control means thereat, means for transmitting the signals to said

other station and means independent of the control current for maintaining said circuit control means actuated for a time determined by the signals.

2. The system of claim 1 and in which the last mentioned means comprises means controlled by the signals on their arrival at said other station.

3. The system of claim 1 and in which said means at said one station under control of the signals comprises means for sending out a short train of control waves in advance of the signals to said other station to actuate the circuit control means thereat.

4. The system of claim 1 and in which the means at said one station under control of the signals comprises means for sending out an impulse of current having a duration small in comparison with the duration of the signals to said other station in advance of the signals to actuate the circuit control means thereat.

5. The method of securing directional control of signal transmission in a system in which signals are transmitted in both directions between terminal stations comprising circuit control apparatus over a transmission path having an appreciable time of transmission, which method consists in causing impulses of control energy under control of the signals to be transmitted over the transmission path ahead of the signals to control the circuit control apparatus at the several stations, and timing the operation of the circuit control apparatus at the several stations so that the terminal station from which the control energy first starts gets complete control of the circuit control apparatus of the whole system.

6. The method of transmission control comprising sending over a transmission path under control of a signal to be transmitted and in advance of the signal an impulse of current, utilizing said impulse to actuate circuit control means in the transmission path and therefore maintaining said control means in its operated condition by the signal when it arrives at the control point.

7. The method of transmission control comprising sending over a transmission path under control of a signal to be transmitted and in advance of the signal an impulse of current, delaying transmission of the signal at least until the cessation of said impulse at the point from which it is sent, utilizing said impulse to actuate circuit control means in the transmission path and thereafter maintaining said control means in its operated condition by the signal when it arrives at the control point.

8. In a two-way telephone system including signal-controlled circuit-control means at various points therein for conditioning said system for efficient operation in the direction of speech wave transmission, the

method of operation which consists in utilizing the speech wave on its arrival at one point in the system to cause control energy to be transmitted over the system ahead of the speech wave to initially operate said circuit-control means in the proper manner, and utilizing the transmitted speech variations as they arrive at the control points to maintain the circuit-control means in the initially operated condition.

9. In a two-way telephone system comprising signal controlled switching apparatus at various points therein for conditioning said system for efficient operation in the direction of speech wave transmission therein, the method of operation which consists in utilizing the speech wave at its arrival at one point in the system to transmit a momentary impulse of control energy over the system ahead of the speech variations to initially operate the switching apparatus in the proper direction, and utilizing the transmitted speech variations as they arrive at the switching points to maintain the switching apparatus in the initially operated condition.

10. A transmission system comprising a signal transmission path supplied from a source of signals, circuit control means in said path for determining the operation thereof, means under the control of the supplied signals for transmitting an impulse of current over said path ahead of said signals to initially operate said control means, and means for utilizing the signals when they arrive at the control point to maintain said control means in its operated condition.

11. A transmission system comprising a signal transmission path supplied from a source of signal waves, current-controlled means in said transmission path for determining the operation thereof, means under the control of the signal wave for sending over said path and in advance of the signal waves an impulse of current to initially operate said current-controlled means, means to delay the arrival of said signal wave at the control point at least until said current-controlled means has been initially operated, and means for utilizing the delayed signals when they arrive at said control point to maintain said current controlled means in its operated condition.

12. A system for the two-way transmission of telephonic currents including current-controlled switching means at various points therein for conditioning the system for efficient operation in the direction of transmission, means at a point in the system and controlled by the telephonic currents when they arrive at said point, for causing a control current to be transmitted over the system ahead of the telephonic currents to initially operate the switching means in its path, and means for utilizing the telephonic currents when they arrive at the switching

points to maintain the switching means in the initially operated condition.

13. A system for the two-way transmission of telephonic currents including current controlled switching means at various points therein for conditioning the system for sufficient operation in the direction of transmission, means at a point in the system and controlled by the telephonic currents when they arrive thereat for causing a momentary impulse of control current to be transmitted over the system ahead of the telephonic currents to initially operate the switching means in its path in the proper manner, and means for utilizing the telephonic currents when they arrive at the switching points to maintain the switching means in its initially operated condition.

14. A system for the two-way transmission of telephonic currents including current controlled switching means at various points therein for conditioning the system for efficient operation in the direction of transmission, means at a point in the system and controlled by the telephonic currents when they arrive thereat for causing a momentary impulse of control current to be transmitted over the system to initially actuate the switching means in its path in the desired direction, means for delaying the arrival of the telephonic currents at the switching point until after the switching means has been initially operated by said impulse, and means for utilizing said telephonic currents when they arrive at said switching points to maintain said switching means in the initially operated condition.

15. A system for the two-way transmission of telephonic currents comprising a two-way line, stations at various points along said line comprising oppositely directed amplifying paths for said currents connected to said two-way line, switching means at said stations responsive to transmission in one of the amplifying paths thereat for disabling the other of said paths, means at one of said stations and controlled by the telephonic currents in the amplifying path for one direction thereat for causing control energy to be transmitted in said one direction over said system ahead of the telephonic currents to initially operate the switching means in its path so as to condition the system for efficient transmission of the telephonic currents in said one direction, and means for utilizing the telephonic currents when they arrive at the switching points to maintain said switching means in their initially operated condition.

16. A system for the two-way transmission of telephonic currents comprising a two-way line, stations at various points therealong and comprising oppositely directed amplifying paths for said currents, current controlled switching means at said stations and responsive to transmission in said system

in one direction for conditioning the amplifying paths thereat for efficient operation in said one direction only, and responsive to transmission in the opposite direction for conditioning said amplifying paths for efficient operation in said opposite direction only, means at one of said stations and controlled by the transmission of telephonic currents in the amplifying path for said one direction thereat for sending out an impulse of control energy ahead of the telephonic currents over said line in said one direction to initially operate the switching means in its path, means for delaying said telephonic currents in transmission to said switching means until after the initial operation thereof by said impulse of control energy, and means for utilizing the telephonic currents when they arrive at the switching points to maintain said switching means in their initially operated condition.

17. A system for the two-way transmission of telephonic currents comprising a two-way section of line connecting two stations each comprising oppositely directed amplifying paths for said currents, switching means at each station responsive to transmission over the system in one direction for conditioning said paths for efficient operation in said one direction only, and responsive to transmission over the system in the other direction for conditioning said paths for efficient operation in said other direction only, and means for insuring complete control of the switching means at both stations to the one of the two stations at which telephonic transmission first starts, the last mentioned means comprising at each station means controlled by the telephonic currents to be transmitted therefrom over said two-way section of line for sending out over said section of line a short spurt of current of a frequency outside the frequency range of the telephonic currents to initially operate the switching means at the other station, means for delaying the arrival of the transmitted telephonic currents at said other station for an interval of time at least sufficient to enable completion of the initial operation of the switching means thereat by the preceding impulse, means for utilizing the delayed telephonic currents on their arrival at said other station to maintain the switching means thereat in their initially operated position, and means for preventing currents from the other station if generated thereat later than the oppositely directed telephonic current generated at the first station by an interval of time which is less than the full transmission time of said two-way line section, from affecting the operation of the switching means at said first station.

18. The system of claim 17 and in which the last mentioned means comprises means for utilizing a portion of the delayed telephonic currents at the first station to prevent cur-

rents received over said two-way line section from reaching the input of the switching means at said first station.

19. The system of claim 17 and in which the portion of said two-way line connected between said two widely separated stations is a two-way section of cable of limited load capacity and high attenuation.

20. The system of claim 17 and in which one of the two amplifying paths at each of said two widely separated stations is normally operative, and the other of said amplifying paths is normally disabled, and in which said switching means is responsive to transmission in said other path to make operative said other path and to disable said one path.

21. The system of claim 17 and in which the portion of said two-way line connected between said widely separated stations is a two-way section of submarine telephone cable.

22. A two-way signal transmission system comprising two sections of two-way line coupled by an intermediate repeater including a one-way amplifying path for repeating the westwardly directed signals between the line sections, a second one-way amplifying path for repeating the eastwardly directed signals between the line sections, said paths being normally disabled, a one-way circuit including delay means, connected to said two sections of line, for by-passing westwardly directed control waves of characteristic frequencies outside the signal frequency range around the repeater between the line sections, a second one-way circuit including delay means, also connected to said two sections of line, for by-passing eastwardly directed control waves of other characteristic frequencies around the repeater between line sections, a control circuit for diverting from the first mentioned by-passing circuit and the westwardly directed amplifying path a portion of the delayed, westwardly directed control waves and signals, a second control circuit for diverting from said second by-passing circuit and said eastwardly directed amplifying path a portion of the delayed eastwardly directed control waves and signals, means responsive to the delayed diverted waves in the first mentioned control circuit for effectively disabling said second control circuit and further disabling the eastwardly directed amplifying path, and for rendering the westwardly directed amplifying path operative, means responsive to the delayed diverted waves in said second control circuit for effectively disabling the first mentioned control circuit and further disabling the westwardly directed amplifying path, and for rendering the eastwardly directed amplifying path operative, and means in each of the two amplifying paths for delaying the transmission of signals therethrough.

23. The system of claim 22 and in which the delay means in the first mentioned control circuit delays the transmission of the waves therein for substantially T_2 seconds and the delay means in said second control circuit delays the waves therein for substantially T_1 seconds, where T_1 and T_2 are respectively the overall transmission times of the west and east two-way line sections.

24. The system of claim 22 and in which the delay times of the delay means in the first mentioned and said second control circuits are T_2 and T_1 seconds respectively, where T_1 and T_2 are respectively the overall transmission times of the west and east line sections, and the delay time of the delay means in each of the two amplifying paths is equal to the overall transmission time of that one of the two line sections which has the longest time of transmission.

In witness whereof, I hereunto subscribe my name this 10th day of June 1929.

ROBERT C. MATHES.