

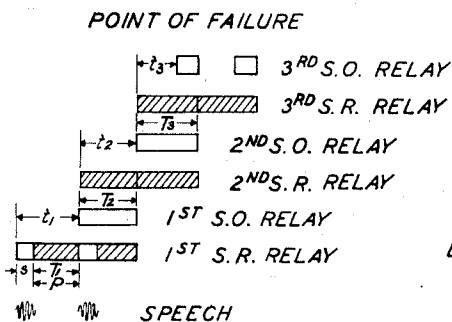
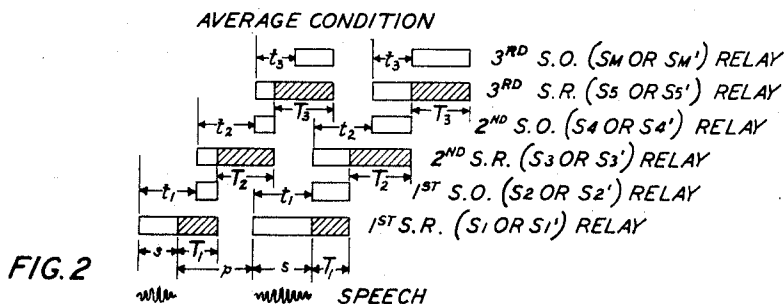
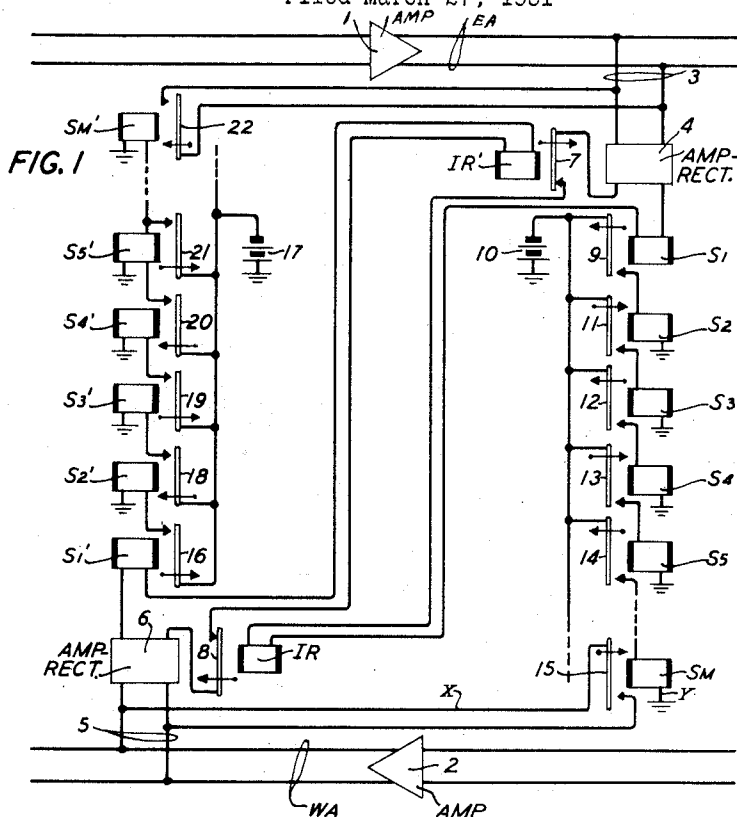
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TRANSMISSION CONTROL IN SIGNALING SYSTEMS

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TRANSMISSION CONTROL IN SIGNALING SYSTEMS

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3 Claims. (Cl. 179—170)

This invention relates to signal wave transmission systems and particularly to the control of transmission in such systems.

The invention more specifically relates to improvements in the operation of two-way signaling systems equipped with so-called echo suppressors. An echo suppressor is that type of signal-controlled device well known in the art, which is utilized for effectively disabling one one-way transmission path of a two-way signaling system, while signal transmission is taking place over the associated, oppositely directed one-way signaling path, thereby preventing echo currents or reflected currents from being transmitted back to the transmitting end of the system and causing a disturbance. The disabling apparatus may comprise, for example, connections which may be closed by a mechanical relay or series of such relays under control of a signal-controlled vacuum tube circuit having its input connected across one one-way path, so as to short-circuit the oppositely directed one-way path and the echo suppressor associated with that path.

It is often necessary, especially in long four-wire signaling systems when echo suppressors are usually located near the middle of the system, to provide a hangover of considerable duration in the operation of each echo suppressor in order to obtain efficient suppression of echoes and at the same time to prevent false operation of the other suppressor. This long hangover period makes it difficult for a listening subscriber to interrupt the speaker. The listener must wait until the speaker has paused for a sufficient time to enable the echo suppressors to return to their normal condition before he can get control of the talking circuits of the system for the transmission of his own speech currents. When the four-wire system is a very long one, the required hangover time will be of such duration as to affect the naturalness of a conversation between two subscribers.

The time during which the return path is disabled may be greatly reduced and breaking in by a listener made easier if delays are introduced in the operation of the echo suppressor circuits, so as to limit the disabling of the transmission circuit to the time during which echoes are actually arriving at the disabling point in the system. This may be accomplished in part by delaying the effective beginning of the action of an echo suppressor in response to signal transmission in the associated one-way transmission path the same length of time as it takes echoes or reflection components of the controlling sig-

nals to be transmitted to the disabling point in the transmission path to be disabled. This delay, of course, may be obtained by the use of an electrical delay circuit in the echo suppressor, but the use of such a delay circuit for this purpose is objectionable because of its high cost.

An object of the invention is to improve the operation of a long two-way signaling system employing signal-controlled apparatus for suppressing echoes and preventing singing.

A related object is to increase the ease of breaking in a long two-way signaling system equipped with echo suppressors.

Another and more specific object is to introduce a desired amount of delay in the operation of an echo suppressor without using therein expensive electrical delay circuits.

The invention resides in an echo suppressor of the delayed action type utilizing a chain of mechanical relays connected in the output of the amplifier-detector associated with each one-way signaling path and controlled thereby in such manner as to introduce the desired amount of delay in the disabling of the oppositely directed signaling path. The operation of the relay chain is such that the last relay therein will repeat after a predetermined interval of time, the time duration of the signals impressed on the first relay in the chain. The number of relays in the chain and their operation and release times are determined by the rate at which speech signals are normally transmitted in the continuous speech of the average subscriber. This rate is determined by the duration of syllables and the pauses in speech. The delay in the operation of the echo suppressor and its hangover time by proper design of the relay chains may be made such that the signal transmission path for one direction is interrupted when signals are being transmitted over the signaling path for the other direction, only for the time interval in which the echoes or reflected currents would normally be passing the point of interruption. The time for which a talker must pause to enable a listener to break in is thus reduced to a minimum, and the ease of operation of the two-way signaling system is greatly increased.

The exact nature and the advantages of the invention will be better understood from the following detailed description thereof when read in connection with the accompanying drawing,

Fig. 1 of which shows the invention applied to a four-wire repeater equipped with signal-controlled suppressors; and

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Fig. 2 of which shows diagrammatically the time functions of the relays in the echo suppressor circuits of the invention.

To aid in the explanation of the invention, it will be assumed that the overall transmission time of each of the one-way repeating paths between the two-way signal transmission circuits connected by the repeater is t , and that the echo suppressors are connected at the midpoint of the repeater circuits.

The important factors to be taken into consideration in the design of the echo suppressors for a long two-way signaling system in order to obtain increased speed of operation of the system, are the hangover time of the suppressor, the breaking time, the response interval, and the answering time. The hangover time H must be h seconds longer than the time of transmission over the repeating paths from the point of connection of the input of the echo suppressor to one path to the disabling point in the other path or in the system being considered, $t+h$. The additional time h is necessary to provide for the suppression of echoes of transients and weak endings. The breaking time, which may be defined as the time for which a talker must pause in order to allow the listener to answer, without clipping of speech, production of echoes or interruptions, in the present system would be equal to $t+h$. The response interval, which may be defined as the time the listener must wait to reply after a talker has stopped speaking, so that his answer may be transmitted to the talker without clipping and interruptions, in the present system would be equal to h . The answering time, which may be defined as the minimum time a talker must wait after a pause for an answer from the listener before starting to talk again is in the present system equal to $2t+h$.

The breaking and answering times as defined above are determined by the constants of the four-wire transmission circuit. With a given transmission circuit no scheme will shorten these time constants. In order, therefore, to increase the effective speed of operation of the system, it is necessary to provide the listener with some means of letting the talker know that he is trying to break in. This, of course, cannot be accomplished without introducing some clipping, echoes or interruption of conversation. The circuits of the invention effectively accomplish this increased speed of operation as stated above, by providing means for insuring that the return echo path is disabled only during the interval in which the echo or reflected currents normally would be passing the disabling point, requiring that the beginning of the action of the echo suppressor in response to signaling current be delayed for the length of time required for an echo to be transmitted to the disabling point in the path to be disabled, which, according to our assumption as to the overall transmission time of the repeating paths, would be t . In the system of the invention this delay is obtained by a suitable chain of relays in each echo suppressor, as shown in Fig. 1 of the drawing.

The four-wire repeater circuit of Fig. 1 comprises a west to east, one-way amplifying path including the one-way amplifying device 1, and an east to west, one-way amplifying path WA including the one-way amplifying device 2. The one-way amplifying paths EA and WA may be connected at each end in energy transmitting relation with the two-way transmission circuits between which signals are to be repeated (not

shown) and in substantial conjugate relation with each other by hybrid coil transformers and associated balancing networks or by any other suitable means. Connected across the one-way amplifying path EA near the middle thereof is the input of a control circuit 3 comprising the wave-controlled, relay-controlling device 4, and the windings of a mechanical relay IR and the first relay S_1 of a chain of mechanical relays $S_1 \dots S_m$, connected in series across the output of the device 4. Similarly, connected across the amplifying path WA near the midpoint thereof is the input of a control circuit 5 comprising the wave-controlled, relay-controlling device 6, and the windings of a mechanical relay IR' and the first relay S_1' of a chain of mechanical relays $S_1' \dots S_m'$ connected in series across the output of the device 6.

In the output of the control device 4 in control circuit 3 in series with the windings of relays IR and S_1 is a normally closed switch 7 adapted to be opened by operation of the relay IR' in response to the energization of its winding by current from the output of the device 6. In the output of the control device 6 in the control circuit 5 in series with the windings of the relays IR' and S_1' is a normally closed switch 8 adapted to be opened by operation of the relay IR in response to energization of its winding by current from the output of the device 4.

A normally open switch 9 is adapted to be closed by operation of the first relay in the chain $S_1 \dots S_m$ in response to energizing current supplied to its winding from the output of the device 4 to connect the direct current battery 10 to the winding of the second relay S_2 in the chain $S_1 \dots S_m$ so as to supply energizing current thereto. Operation of the relay S_2 in response to the energization of its winding causes the normally open switch 11 to be closed to connect the battery 10 to the winding of the third relay S_3 in the chain so as to supply energizing current thereto. Operation of the relay S_3 in response to the energization of its winding causes the normally open switch 12 to be closed to connect the battery 10 to the winding of the fourth relay S_4 in the chain so as to supply energizing current thereto. Operation of the relay S_4 in response to the energization of its winding causes the normally open switch 13 to be closed to connect the battery 10 to the winding of the fifth relay S_5 in the chain so as to supply energizing current thereto. The operation of relay S_5 in response to energization of its winding causes the normally open switch 14 to be closed to connect the battery 10 to the winding of the last relay S_m in the chain so as to supply energizing current thereto. Operation of the relay S_m in response to energization of its winding causes the normally open switch 15 to be closed to connect a short-circuiting connection across the control circuit 5 in the input of the control device 6, and thus to short-circuit the amplifying path WA in the output of the amplifying device 2 therein.

Similarly, the normally open switch 16 is adapted to be closed by operation of the first relay S_1' in the chain $S_1' \dots S_m'$ in response to energizing current supplied to its winding from the output of the control device 6 to connect the direct current battery 17 to the winding of the second relay S_2' in the chain so as to supply energizing current to said winding. Operation of the relay S_2' in response to energization of its winding causes the normally open switch 18 to be closed to connect the source of direct current 17

to the winding of the third relay S_3' in the chain so as to energize that winding. Operation of the relay S_3' in response to the energization of its winding causes the normally open switch 19 to be closed to connect the source of direct current 17 to the winding of the fourth relay S_4' in the chain so as to energize that winding. Operation of relay S_4' in response to energization of its winding causes the normally open switch 20 to be closed to connect the source of direct current 17 to the winding of the fifth relay S_5' in the chain so as to energize that winding. Operation of the relay S_5' in response to energization of its winding causes the normally open switch 21 to be closed to connect the source of direct current 17 to the winding of the last relay S_m' in the chain so as to energize that winding. Operation of the relay S_m' in response to energization of its winding causes the normally open switch 22 to be closed to connect a short-circuiting connection across the control circuit 3 in the input of the control device 4 therein, and thus across the amplifying path EA in the output of the amplifying device 1 therein.

The wave-controlled, relay-controlling devices 4 and 6 may be vacuum tube, amplifier-rectifier circuits of the type well known in the art or any other devices which will respond to alternating currents impressed upon their inputs to operate mechanical relays in their outputs.

The mechanical relays IR and IR' are designed to be quick operating and slow releasing by any suitable means known in the prior art. The slow release time of the relay IR is made approximately equal to the sum of the release times of the chain of relays $S_1 \dots S_m$ so that the echo suppressor controlled from the path WA is rendered inoperative substantially at the same time the path WA is made operative after being short-circuited in response to speech transmission in the path EA. For a similar reason the slow release time of the relay IR' is made approximately equal to the sum of the release times of the relays in the relay chain $S_1' \dots S_m'$.

The odd numbered relays, in each relay chain, S_1, S_3, S_5 and S_1', S_3', S_5' are designed to be quick operating and slow releasing, and the even number relays, in each chain, S_2, S_4, S_m and S_2', S_4', S_m' are designed to be slow operating and quick releasing by any of the well known means. The first relay in each chain S_1, S_1' is a slow-release relay, whereas the last relay in each chain S_m, S_m' is a slow-operate relay. With a given minimum syllable length, the allowable minimum pause in the continuous transmission of speech currents over the repeating path EA or over the repeating path WA for the relay chain $S_1 \dots S_m$ and $S_1' \dots S_m'$ to function correctly in response to operation of the control device 4 by the speech currents to disable the repeating path WA and control circuit 5, and in response to operation of the control device 6 by the speech currents to disable the repeating path EA and the control circuit 3, respectively, can be reduced to any desired value by going to a larger number of relays in each chain.

The number of relays in the chains $S_1 \dots S_m$ and $S_1' \dots S_m'$ and their operation and release times in order that they may function properly in response to continuous speech signals to give the required delay in the operation of the echo suppressors are determined by the rate at which speech impulses are normally transmitted in the continuous speech transmission of the average subscriber. This rate is determined by

the duration of the syllables and the pauses in speech.

In analyzing the action of such general relay arrangements it is convenient to consider a slow-release and a slow-operate relay as a unit. In the following analysis in each such unit the release time is designated by T_a and the slow operate time by t_a , where a is the number of the unit. In order that the last relay in the chain may faithfully reproduce the time duration of the syllables of the speech waves impressed upon the controlling amplifier-rectifier device, the following relation must be satisfied:

$$s + T_1 + T_2 \dots + T_a \dots + T_m = t_1 + t_2 \dots + t_a \dots + t_m + s \quad (90)$$

or

$$T_1 + T_2 \dots + T_a \dots + T_m = t_1 + t_2 \dots + t_a \dots + t_m \quad (1) \quad (95)$$

where s is the syllable length and m is the number of the last unit.

If the operating speech impulses follow each other closely, the slow-release relays may fail to release. If the interval between impulses or syllables is called p , then the first relay in each chain will just fail to release when

$$T_1 = p \quad (2)$$

In general, any relay will fail to release when

$$T_1 + T_2 \dots + T_a = p + t_1 + t_2 \dots + t_{a-1} \quad (3)$$

Since all the relays should fail at the same time

$$T_a = t_{a-1} \quad (4) \quad (110)$$

Then from (1) and (4)

$$T_1 = t_m \quad (5)$$

The slow-operating feature involves failure to operate on impulses shorter than a given interval. In order that all of the slow-operating relays may fail at the same time, the following equation must be satisfied:

$$t_1 = s + T_1 = s + T_1 + T_2 - t_2 = s + T_1 + T_2 \dots + T_a - t_2 \dots - t_a \quad (6) \quad (120)$$

from which is obtained

$$T_a = t_2 \quad (7)$$

Therefore, all the slow-release relays with the exception of the first one and all the slow-operate relays with the exception of the last one must stay operated the same length of time.

Then, if H is the normal hangover time,

$$T_1 + T_2 \dots + T_a \dots + T_m = H = T_1 + (m-1)T_a \quad (8) \quad (130)$$

and

$$s = t_1 - T_1 = T_a - T_1 \quad (9) \quad (135)$$

From (7) and (8),

$$T_1 = p = \frac{H - (m-1)s}{m} \quad (10) \quad (140)$$

and,

$$T_a = t_a = \frac{H + s}{m} \quad (11) \quad (145)$$

Equation (9) shows that, since s has a definite value, p could be made zero except that m must be a whole number. But, by going to a number of units, p can be made sufficiently small. From experimental data, it has been found that 0.05 second can be taken as the minimum syllable length in ordinary speech. Then, for a long

cable circuit in which the required hangover time of the relays of each suppressor in order to obtain efficient suppression of echoes and at the same time to prevent false operation of the other suppressor, was found to be 0.25 second.

$$p = \frac{.25 - (m-1) .05}{m} \quad (12)$$

Then two units each comprising one slow-release relay and one slow-operate relay would make $p=0.1$ second, which would be satisfactory. Then, six units would reduce p to zero.

In the upper portion of Fig. 2 is shown diagrammatically how the six relays in each chain, as shown in Fig. 1, should operate under average conditions for succeeding pulses of speech impressed on the first relay in the chain. As in the above mathematical analysis, in the diagram of Fig. 2, s is used to designate the length of the speech syllables, p the interval between speech syllables; T_1 , T_2 and T_3 , the release times of the slow-release relays S_1 , S_3 and S_5 or S_1' , S_3' and S_5' , respectively and t_1 , t_2 and t_3 the slow-operate times of the relays S_2 , S_4 and S_6 or S_2' , S_4' and S_6' , respectively. In the diagram the length of the blocks represents the time for which each relay remains operated in response to the speech pulses, and the length of the cross-hatched portions of the blocks the time for which the slow-release relays remain operated after the controlling impulse has ceased. From this diagram it will be seen that the slow-release and slow-operate times of the several relays may be selected so that these relays will operate in sequence to give the desired delay in the beginning of the operation of the echo suppressors and the required hangover to insure that an echo path is blocked only during the time in which the echo may be passing the blocking point, when the pauses in speech transmission are those which would normally appear in the continuous speech of the subscriber. When the pauses are longer than the normal length, as would occur when the talker paused to allow time for the listener to answer, the sequence of operation of the relays would be broken up at some point, and the final relay in the chain will release to remove the short circuit from the repeating path which is then operative to transmit the listener's speech if he has started to talk.

The lower portion of Fig. 2 shows diagrammatically the point at which the relays will fail to transmit the controlling speech impulses to the last relay in the chain. In this case the duration of one speech syllable is equal to $(t_1 - T_1)$, and the slow-operate relays will stay operated only an infinitesimal time as indicated by the single vertical lines in the diagram. If the duration of the speech syllable is any shorter than $(t_1 - T_1)$, the slow-operate relays will fail to operate and there will be no echo suppression. In this case also the time interval between syllable p has become equal to T_1 and the slow-release relays are on the point of failing to release. The lines in the middle of the cross-hatched areas of the blocks corresponding to the release times of the slow-release relays indicate that these relays release just for an infinitesimal time, giving the slow-operate relays also time to release. If the interval between syllables is any greater than T_1 the final relay will be held continuously operated by speech.

Assuming that the release and operate times of the relays have been set so as to take care of expected changes in the rate of transmitting for

most subscribers, the operation of the system as a whole will now be described in detail. It will be assumed that speech waves are being transmitted from west to east over the transmission path EA from a west subscriber to a listening east subscriber and at that time no speech is being transmitted by the east subscriber in the direction from east to west over the transmission path WA.

The west subscriber's speech waves transmitted over the path EA will be amplified by the amplifier 1 therein. The main portion of the amplifier waves in the output of the amplifier 1 will be transmitted over the output of the path EA to the distant east subscriber. A portion of the west subscriber's speech waves in the output of the amplifier 1 of the path EA, however, will be diverted into the control device 4 therein to energize the windings of the relays IR and S_1 connected in series across the output of the device 4. Relay IR will operate immediately to open the normally closed switch 8 in the output of the control device 6 in the control circuit 5 connected to the repeating path WA thus preventing subsequent operation of the device 6 by the speech currents which may be present in the path WA from causing false operation of the chain of relays $S_1' \dots S_m'$. Relay S_1 will simultaneously operate to close normally open switch 9, which in the manner described above will begin the operation in sequence of relays S_2 , S_3 , S_4 , S_5 and S_m , which chain of operations will be maintained by subsequent pulses of the speech impressed upon the control device 4 until a pause in the continuous transmission of the speech pulses greater than the normal pause between speech pulses in the continuous transmission of speech for most subscribers. The last relay S_m in the chain will cause the normally open switch 15 to be closed to short-circuit the repeating path WA in the output of the amplifier 2 therein as well as the input of the control device 6 in control circuit 5.

The sum of the individual delays introduced by the individual relays in the chain $S_1 \dots S_m$ is such that the switch 15 will be closed to short-circuit the path WA and the control circuit 5 just before the first echoes or reflected waves due to the controlling speech waves in the repeating path EA reach the short-circuiting point in the path WA. Also, the sum of the release times of the individual relays in the chain $S_1 \dots S_m$ is such that the last relay in the chain S_m will remain operated after a pause in the continuous supply of speech waves from the path EA to the control device 4 greater than the normal allowable pause, for a time just sufficient to enable all echoes or reflected waves of the preceding speech waves in the path EA to reach the short-circuiting point in the path WA. In other words, the path WA is disabled in response to speech wave transmission over the path EA only during the interval in which echoes or reflected components of the speech waves would be passing the disabling point in the path WA.

Also, as stated above, the relay IR (as well as the relay IR') is designed to be slow-releasing to the extent that it will remain operated for a sufficient interval of time after the supply of energizing current through its winding ceases in response to a cessation in the continuous supply of the speech waves to the controlling amplifier-rectifier to prevent false operation of the echo suppressor associated with the short-circuited repeating path by echoes and reflected components of the preceding west to east speech waves.

The release times of each of the relays IR and IR' using the notation explained above will be $t+h$.

As soon as relays S_m and IR have released, the short-circuiting connection across the path WA and the input of the control circuit 5 having been removed, the east subscriber may transmit his speech waves over the output of the path WA to the west subscriber, who is now the listener, and seize control of the switching circuits of the system in the following manner.

The portion of the east subscriber's speech currents diverted into the control circuit 5 will cause the operation of the control device 6 therein to energize the windings of relays S_1' and IR'. Relay S_1' will operate immediately to close normally open switch 16 initiating operation of the relay chain culminating in the operation of the last relay in the chain, relay S_m' , to close the normally open switch 22 to short-circuit the easterly directed repeating path EA in the output of amplifier 1 therein, and the input of the associated control circuit 3, this occurring because of the delay introduced by the relay chain, just prior to the time at which the echoes or reflected waves due to the controlling speech from the path WA begin to arrive at the short-circuiting point in the path EA. The relay IR' operates simultaneously with the first relay in the chain $S_1' \dots S_m'$ to open the normally closed switch 7 in the output of the control device 4 in the control circuit 3 associated with amplifying path EA, thus preventing subsequent operation of the control device 4 by energy stored in the path EA from causing false operation of the relay chain $S_1 \dots S_m$.

Because of the slow-release features of the relays S_1' , S_3' and S_5' in the chain $S_1' \dots S_m'$, the last relay in the chain S_m' will not release to open the short circuit across the path EA and across the control circuit 3 with a cessation in the supply of the speech waves from the path WA to the control circuit 6 until a sufficient time thereafter to enable all echoes and reflected waves due to the preceding speech currents in the path WA to have reached the short-circuiting point in the path EA. The relay IR' is designed to release at approximately the same time as the relay S_m' (i. e. its hangover is $t+h$), so as to allow the immediate operation of the echo suppressor associated with the repeating path EA by the west talker's speech current immediately after the path EA has been made operative.

From the above description of the system of Fig. 1 it will be seen that the first talker will always control the system and the second talker will get through to the first talker only those portions of his (the second talker's) speech which are transmitted during the pauses in the first talker's speech unless the first talker pauses for more than $t+h$ seconds enabling the second talker to get control of the system. It will be seen that the system provides a means for the second talker to let the first talker know that he is trying to break in.

If the two subscribers at the opposite ends of the system both start to talk within a time interval of t seconds, each will be able to get his speech currents through to the other subscriber, but there is no echo suppression due to the si-

multaneous blocking of the two echo suppressors by the relays IR and IR' under control of the speech currents of the respective subscribers. In this case the system functions in a manner similar to a four-wire circuit equipped with echo suppressors at the receiving terminal.

Although in the circuit of the invention as illustrated and described, six relays comprising alternate slow-release and slow-operate relays were utilized to give the required delay in operation of the echo suppressors, it is to be understood that the use of different numbers and other arrangements of the relays to perform this function is within the scope of the invention. Many other modifications in the circuit of the invention will occur to persons skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In combination, two two-way circuits, two oppositely directed one-way paths for transmitting signals in opposite directions between said circuits, a mechanical relay which when operated disables one of said one-way paths at a certain point therein, control means connected to the other one-way path and operatively responsive to transmission of signals therein, and a chain of mechanical relays operating in sequence in response to operation of said control means to cause operation of the first-mentioned relay, said first-mentioned relay and the relays in said chain having such operating times as to delay the disabling of said one path in response to transmission of signals in said other path until the time at which echoes or reflected waves due to said signals begin to arrive at said certain point in said one path.

2. In combination, two two-way circuits, two oppositely directed, one-way paths for transmitting signals in opposite directions between said circuits, a mechanical relay which when operated disables one of said paths at a certain point therein, control means connected to the other of said one-way paths and operatively responsive to transmission of signals therein, and a chain of mechanical relays operating in sequence in response to operation of said control means to cause operation of the first-mentioned relay, said first-mentioned relay and the relays in said chain having such operating and release times as to limit the disabling of said one path in response to substantially continuously transmitted signals in said other path to the time interval during which echoes or reflected waves due to said signals are arriving at said certain point in said one path.

3. The system of claim 2 and in which said chain of relays comprises alternate slow-release and slow-operate relays and the number of relays in the chain and the release and operate times apportioned to each relay in the chain and to said first-mentioned relay are determined by the transmission time-constants of said one-way paths and the normal rate of transmission of signals thereover so that the disabling of said one path in response to signals in said other path will only be interrupted by a pause in the continuous transmission of said signals greater than a normal pause.

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