June 26, 1928.

1,674,679

O. B. BLACKWELL

VOICE OPERATED ECHO SUPPRESSOR

Filed Aug. 3, 1923

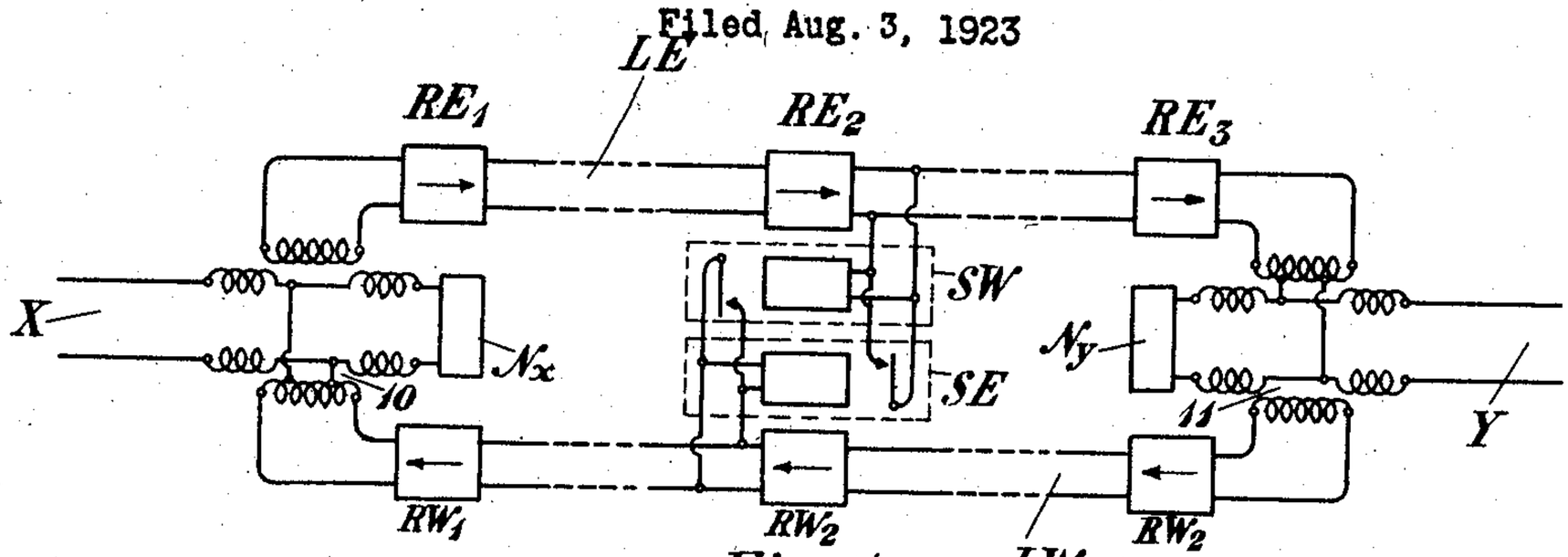

Fig. 1

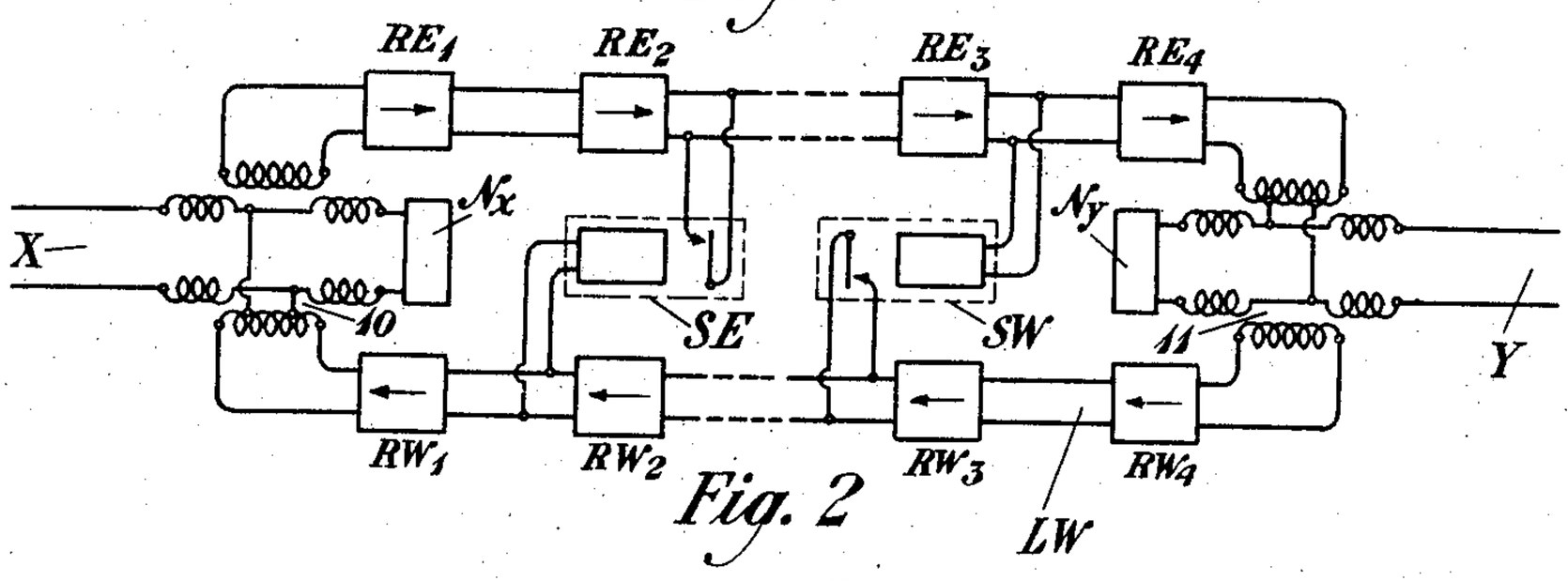

Fig. 2

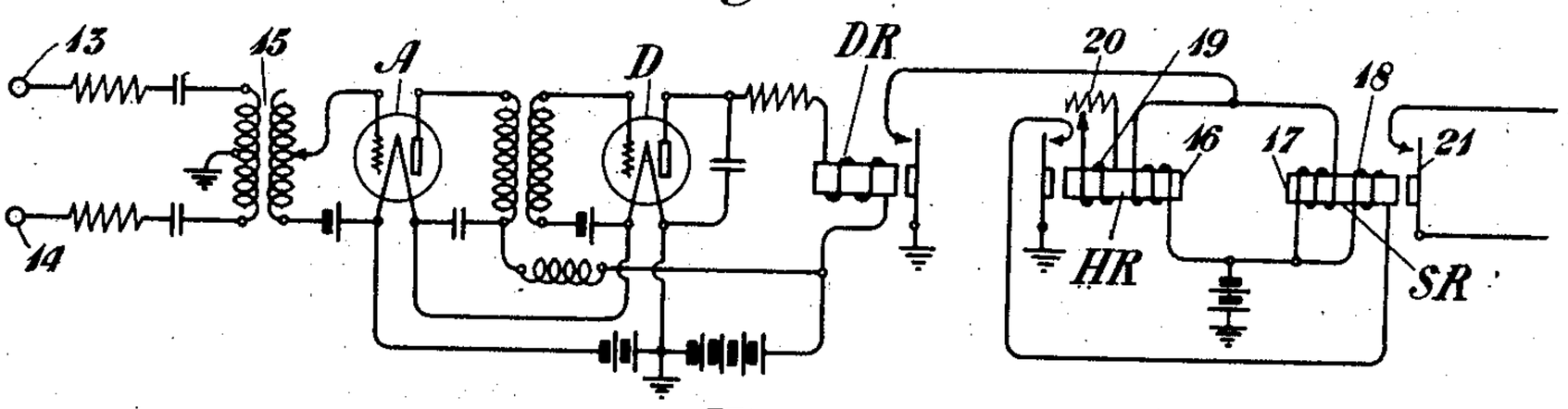

Fig. 3

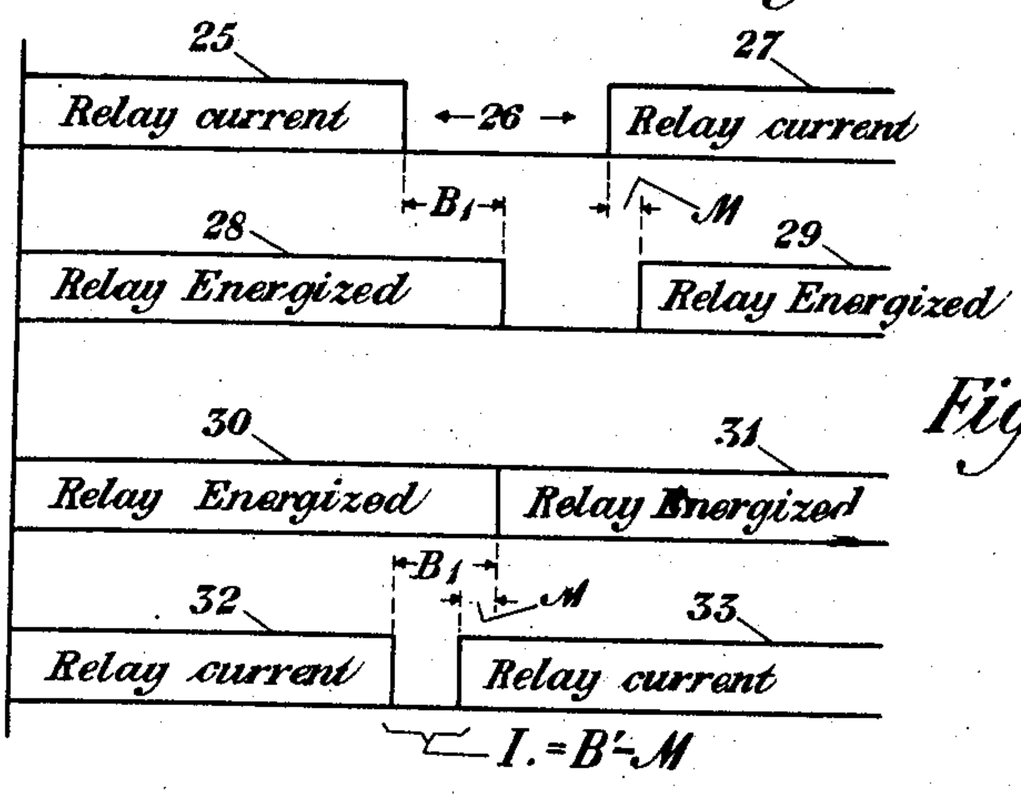

Fig. 4

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Patented June 26, 1928. 1,674,679

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VOICE-OPERATED ECHO SUPPRESSOR.

Application filed August 3, 1923. Serial No. 655,426.

This invention relates to transmission circuits of the four-wire type and more particularly to arrangements for preventing echo effects upon such circuits.

In telephone circuits of the four-wire type, difficulty has been experienced where the lines are of considerable length, due to so-called "echo" effects. These effects arise from the fact that telephone currents flowing over one of the two-wire lines comprising the four-wire circuit are transmitted, due to unbalance at the terminal, back over the two-wire line transmitting in the opposite direction. Since it takes a finite period of time for the current transmitted back to reach the originating station, especially where the circuits are loaded, the current transmitted back produces a very disconcerting effect, similar to that of an echo.

In order to overcome this difficulty it has been proposed to arrange some device responsive to voice currents transmitted over the one line to disable the line used for transmission in the opposite direction, thereby preventing the transmission of echo currents over the reverse line. It has heretofore been the practice to arrange these echo suppressing devices, one of which is associated with each line, at some intermediate station between the terminal stations, preferably as near as possible midway between the stations.

Such an arrangement of the echo suppressing apparatus, while facilitating maintenance, has been found to have a serious disadvantage in that it prevents the subscriber who desires to talk in the reverse direction from getting immediate control of the circuit after it has been used for transmitting in the opposite direction. This is due to the fact that, owing to the time interval which it takes for an echo to be transmitted from the echo suppressor on one side of the line to the terminal and back to the point at which the opposite line is disabled, it has been found necessary to provide the echo suppressor with a delay device whereby it maintains the line disabled for a period longer than the time just referred to. In accordance with the present invention it is proposed to overcome this difficulty by arranging the echo suppressing arrangement in two units, one located at or near each end of the four-wire circuit. By this arrangement, since the echo time is quite short from the point at which the voice currents operate the echo suppressor around the terminal connections and back to the point at which the echo suppressor disables the return line, the echo suppressor may be made to restore the circuit to normal almost immediately upon the cessation of voice currents in one direction. Consequently, the subscriber who desires to talk in the other direction can do so almost immediately.

The invention will now be more fully understood from the following description when read in connection with the accompanying drawings, wherein Figure 1 is a simplified circuit diagram showing the arrangement of echo suppressors heretofore used, Fig. 2 is a simplified diagram showing the arrangement of the echo suppressor in accordance with the present invention, Fig. 3 is a diagram showing somewhat in detail the apparatus whereby the echoes are suppressed and Fig. 4 is a curve illustrating the operation of the echo suppressor.

Referring to Fig. 1, a four-wire circuit comprising two-wire lines LE and LW is shown interconnected at the terminals to terminal lines X and Y through hybrid coils 10 and 11 and balancing networks N_x and N_y. One-way amplifier schematically indicated at RE_1 and RE_2, etc., and RW_1 and RW_2 are included in the two sides of the four-wire circuit in a well understood manner. In order to prevent voice currents transmitted over the line LE, for example, from being transmitted back over the line LW, due to unbalance at 11, an echo suppressor arrangement is provided, as indicated schematically at SE and SW, the arrangement being essentially a device which operates in response to voice currents to actuate a contact device which will short-circuit or otherwise disable the opposite line.

The details of the echo suppressor are illustrated in Fig. 3. Terminals 13 and 14 in this figure are connected to the line over which voice currents are transmitted so that the high impedance transformer 15 is bridged across the line without absorbing any appreciable amount of energy from the

line. A vacuum tube amplifier A, of well known type is connected to the secondary of the transformer to amplify the voice currents received from the line. A detector or rectifier vacuum tube D, of a type well known in the art, is associated with the output side of the amplifier A for rectifying the voice currents. Normally, the circuit of the detector D is so arranged that no current or, at any rate, an insufficient current flows through the winding of the detector relay DR to operate said relay. When the voice currents are rectified, however, sufficient current flows through the winding of said relay to cause it to attract its armature. The relay DR then closes a circuit through the energizing windings 16 and 17 of the hang-over relay HR and the suppressor relay SR respectively. The hang-over relay HR, upon being energized, closes a circuit through the locking winding 18 of the suppressor relay so that the suppressor relay will be maintained energized as long as the hang-over relay HR is energized. The hang-over relay HR is provided with an auxiliary winding 19 which is closed through adjustable resistance 20. By suitably adjusting the resistance the hang-over relay HR may be made as slow to release as desired and consequently it may be made to release its armature at any definite time after the voice currents have ceased to energize the detector relay DR. Consequently, the action of the echo suppressor is such that when voice currents are transmitted over the line with which it is connected it will almost immediately operate the contact 21 of the suppressor relay SR to disable the line transmitting in the opposite direction and this condition will continue for a predetermined interval (depending upon the adjustment of the resistance 20) after the voice currents have ceased.

In the arrangement of Fig. 1 a small interval of time M must elapse between the arrival of the voice waves at the input terminals of the suppressor and the closure of the contact of the suppressor relay which short-circuits the opposite line. This "make" interval is due to the self-inductance of the relays and the inertia of the armatures, but may be made very short. An interval E_1 elapses between the arrival of the voice wave at the input terminals of the suppressor and the arrival of the echo at the point where the suppressor relay short-circuits the line. (The subscripts 1 and 2 applied to the symbols used in this specification indicate that the symbols refer to conditions in Figs. 1 and 2 respectively.) The echo interval E_1 is equal to the time of transmission of an electrical impulse from the suppressor to the end of the four-wire circuit and back. A different interval B_1 for the "break" operation of the suppressor elapses between the instant at which the last voice wave passes the input terminals of the suppressor and the instant at which the suppressor relay contacts open. In order that the suppression of the echoes may be complete it is necessary that the make time M be shorter than the echo time E_1. Also the break time B_1 must be longer than the echo time E_1. In other words, the relation $B_1 > E_1 > M$ must exist in order that the contacts of the suppressor relay close before the arrival of the echo and remain closed until the echo has ceased.

In the case of a four-wire circuit involving extra light loaded lines a thousand miles long, for example, the interval E_1 will be about 0.05 seconds where the suppressors are located at or near the midpoint of the circuit. There is no difficulty in making the action of the suppressor relay quick enough to disable the opposite circuit in the required time even though the required time be very much shorter than that above given, but a special delay feature must be used to prevent premature opening of the short-circuiting contacts. This feature is, as already stated, provided by the adjustable resistance 20 for controlling the release of the hang-over relay. By this adjustment the time B_1 may be made as small as possible for any given value of E_1.

In order for the listener to break in to interrupt or reply to the speaker there must be intervals during which the suppressor relay relaxes and clears the path from listener to speaker. Because of the delay mentioned above there must be intervals of approximate silence of finite length in the speaker's speech if the listener is to have an opportunity to break in.

If it could be assumed that the echo suppressor arrangement was provided with a mechanism whereby the opening of the short-circuiting contacts and the closing of said contacts were made mechanically entirely independent of each other, then the minimum interval I_1 in the speaker's speech, which would just permit the suppressor relay contacts to open, would be

$$I_1 = B_1 - M \quad (1)$$

This will be readily apparent from the curves of Fig. 4. In this figure it is assumed that 25 represents the rectified voice current operating the relay. 26 indicates an interval of vocal silence followed by further rectified voice currents indicated at 27. Since the relay remains operated an interval B_1 after the current 25 has ceased it will be noted that the curve 28, indicating the period during which the relay is operated, continues for its full value for a period B_1 after the curve 25 drops to zero. On the other hand, since an interval M must elapse after the current has again commenced to flow, as indicated at 27, the curve 29, indicating that the relay is again energized,

does not begin immediately after the curve 27 begins. In other words, the period during which the relay is unoperated will be shorter than the period of vocal silence 26. Suppose, now, the interval between curves 28 and 29 be eliminated, as indicated at 30 and 31. Then from curves 32 and 33 it will be at once apparent that the shortest period during which no current flows through the relay without permitting the contacts to open will be equal to $B_1 - M$.

The above results are based upon the assumption that the opening and closing of the contacts are independent. In practice this is not true, however, and a greater interval will be necessary, after the arrival of the voice currents, to produce a closure when the contacts are open than will be required to insure that they will not open when they are already closed. For this reason a greater interval of silence than that given by Equation (1) is required and the following relations holds approximately.

$$I_1 = B_1 \quad (2)$$

In the operation of a circuit of this character there are two time elements to be considered, first, the time which must elapse before the listener can talk in the opposite direction after the voice currents transmitted from the speaker have ceased and, second, the time which must elapse before the listener can take exclusive control of the circuit. The latter period is of little or no consequence because the idea of the echo suppressor is not to give one party exclusive control of the circuit but merely to prevent the echoes from being transmitted over the part of the circuit normally used by the other party. On the other hand, it is extremely desirable that the first period be made as short as possible in order that the listener can reply promptly after the speaker has ceased talking.

In order that the listener may take control it is necessary that the contacts of the suppressor relay remain open long enough for the suppressor working in the opposite direction to operate. If the two parts of the suppressor SW and SE are alike there will be required in addition to the interval I_1, already referred to, an additional interval M for the shortest pause in the talker's speech required to permit the listener to break in. If the total length of the necessary pause in the talker's speech is L_1 the folowing relations hold for Fig. 1.

$$L_1 = I_1 + M = B_1 + M \quad (3)$$

In the case of moderately long circuits there is no difficulty in making the closing interval M of the suppressor relay short compared with the time of propagation from the middle of the circuit to the end and back. In accordance with the present invention, therefore, it is proposed to improve the operation of the system by separating the two parts SE and SW of the echo suppressor, as shown in Fig. 2 of the drawing, and arranging the separate elements at or near the ends of the four-wire circuit, as indicated. By using a relay system having a quick make, that is, a small value of M, it becomes possible to put the suppressor near or even at the end of the circuit without allowing an appreciable amount of echo to escape, the only requirement being that the operation of the relay be sufficiently quick to disable the return circuit before the echo arrives at the disabling point. Where the suppressor apparatus is located near the end of the circuit the echo time E_2 of the arrangement of Fig. 2 would be small and the break or releasing time B_2 could be reduced to a corresponding value.

In this case, since B_2 is short, the interval I_2 (compare Equation 2) required to permit the relay contacts to open and allow a disturbance to pass from the listener back to the talker, is short and the listener not only has an increased number of opportunities to interrupt the speaker but is enabled to reply to the speaker a minimum interval after the speaker has ceased talking. On the other hand, since the two parts of the echo suppressor are separated from each other, the listener cannot so easily and quickly gain exclusive control of the circuit, although as already stated, the latter consideration is of minor consequence in the design of echo suppressors. An interval of time T is required for the transmission of an impulse from one part of the echo suppressor to the other, consequently, the total interval of silence required to permit the listener to completely cut off the talker is made up of B_2, the time for the suppressor relay nearer to the listener to release, T, the interval required for the listener's voice to travel to the suppressor nearer the talker, M the interval required to operate this suppressor nearer the talker and a further interval T to insure that there will be no impulses traveling between the suppressors from the talker which will reach the suppressor nearer the listener and operate it. However, an impulse of speech from the talker lasting less than M seconds would be insufficient to operate the suppressor nearer to the listener and prevent him from taking control. This would shorten the interval of silence required in the speech of the talker necessary to enable the listener to take control by M seconds and we have the relation:

$$L_2 = B_2 + T + M + T - M = B_2 + 2T \quad (4)$$

Assuming, for simplicity, that Figs. 1 and 2 are symmetrical with respect to the middle of the circuit, that is, in Fig. 1 the suppressors are both at the middle of the cir-

cuit and in Fig. 2 they are equally spaced from the ends, and assuming further that B_1 and B_2 are made as short as possible, then

$$B_1 = E_1 \quad (5)$$

and

$$B_2 = E_2 \quad (6)$$

but

$$E_1 = E_2 + T \quad (7)$$

hence

$$B_1 = B_2 + T \quad (8)$$

from which substituting in Equation (3)

$$L_1 = B_1 + M = B_2 + M + T \quad (9)$$

from (4) and (9)

$$L_2 = L_1 + T - M \quad (10)$$

From Equation (8) it is evident that the arrangement shown in Fig. 2 requires an interval in the speaker's speech shorter by T seconds than Fig. 1 to enable the listener to interrupt the speaker, but Equation (10) shows that Fig. 2 requires T−M seconds more than Fig. 1 to enable the listener to take control. As has already been stated, the latter factor is of negligible consequence and the advantage obtained by shortening the break interval as indicated by Equation (8) so that the listener may quickly reply to the speaker will more than offset any disadvantages which the circuit possesses in respect to exclusive control.

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 transmission system, two distantly separated stations, transmission paths interconnecting said stations, one of said paths transmitting in one direction and the other of said paths transmitting in the opposite direction, said paths extending at least in part over different systems of conductors and each of said paths being normally operable for transmission in their respective directions when no signaling currents are being transmitted, means at said terminal stations whereby currents transmitted over one path will cause echo currents to be transmitted in the opposite directions over the other path, means for preventing the transmission of such echo currents comprising two units each responding to voice currents transmitted in one path for disabling the path transmitting in the opposite direction, one of said units being associated with one path at a point near the station opposite that from which operating voice currents are transmitted and where the paths extend over different systems of conductors, and the other unit being associated with the other path at a point near the other station and where the paths extend over different systems of conductors.

2. In a transmission system, two distantly separated stations, transmission paths interconnecting said stations, one of said paths transmitting in one direction and the other of said paths transmitting in the opposite direction, said paths extending at least in part over different systems of conductors and each of said paths being normally operable for transmission in their respective directions when no signaling currents are being transmitted, means at said terminal stations whereby currents transmitted over one path will cause echo currents to be transmitted in the opposite directions over the other path, means for preventing the transmission of such echo currents, said means comprising two units one associated with each path at a point where the paths extend over different systems of conductors, each unit including means responsive to currents transmitted over the path with which it is associated for disabling the path transmitting in the opposite direction over a separate system of conductors, and said units being arranged one at a point near the terminal station opposite that from which operating voice currents are transmitted, and the other at a point near the other terminal station.

3. In a transmission system, two distantly separated stations, a four-wire circuit for interconnecting said stations, said four-wire circuit comprising two independent one-way paths extending over different systems of conductors, one being used for transmission in one direction between the terminals and the other being used for transmission in the opposite direction between the terminals, said paths being normally operable for transmission in their respective directions when no signaling currents are being transmitted, means for interconnecting said paths at the terminal stations with terminal transmission systems whereby currents transmitted over one path will cause echo currents to be transmitted in the opposite direction over the other path, means for preventing the transmission of such echo currents, said means comprising two separate units, one of said units be associated with one path near the terminal station opposite that from which operating voice currents are transmitted, and the other unit being associated with the other path near the other terminal station and each unit including means responsive to voice currents transmitted from the distant station over the path with which it is associated for disabling the path transmitting in the opposite direction.

In testimony whereof, I have signed my name to this specification this 2nd day of August, 1923.

OTTO B. BLACKWELL.