May 28, 1929. H. C. SILENT 1,714,525

SUPPRESSION OF ECHOES AND SINGING IN FOUR-WIRE CIRCUITS

Filed March 10, 1928

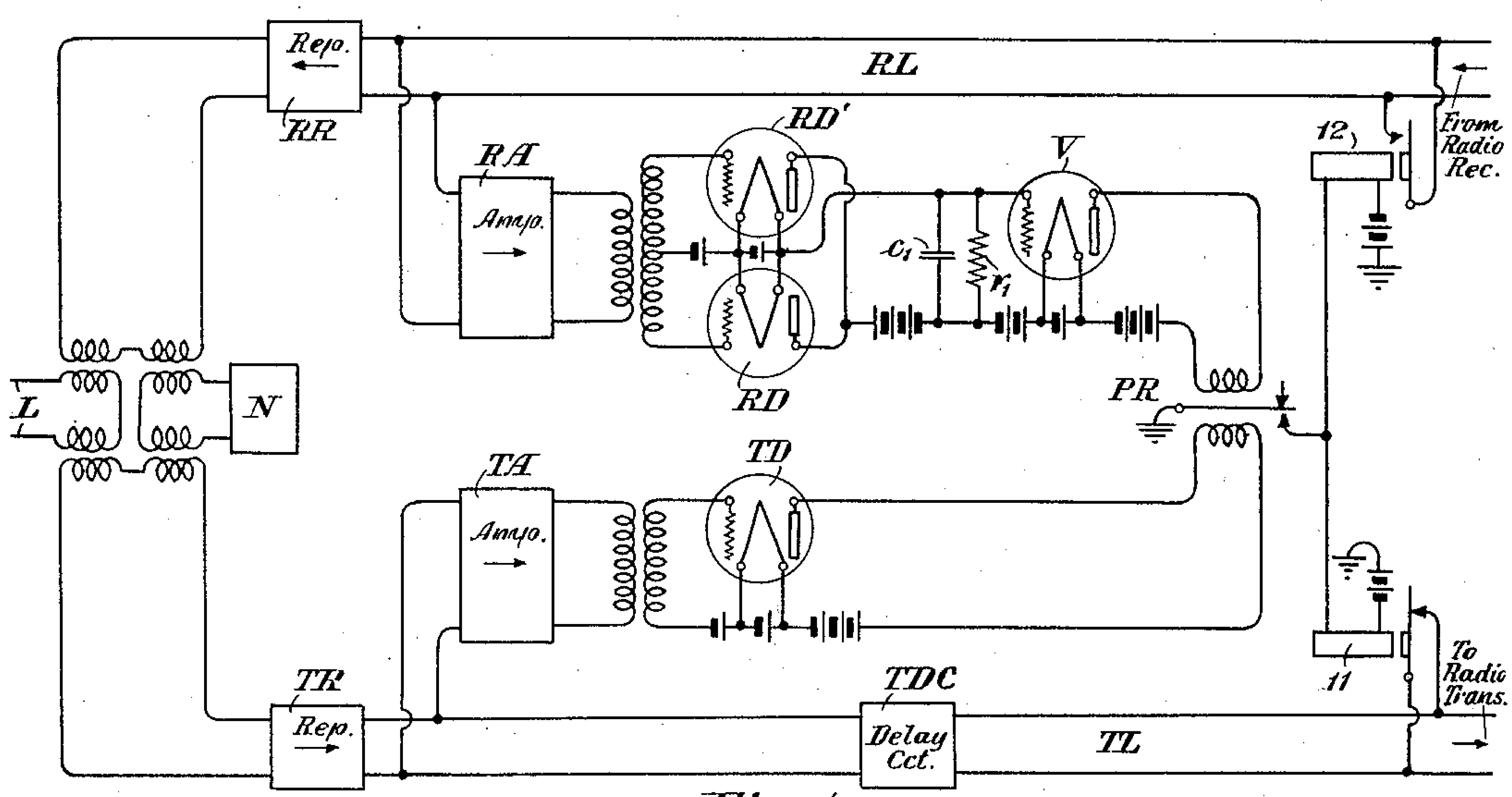

Fig. 1

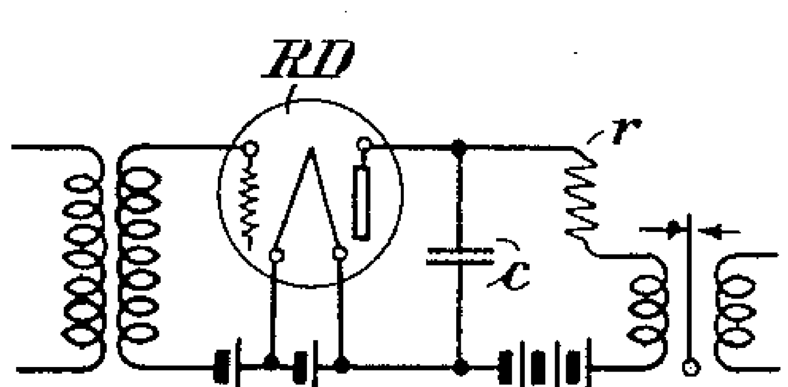

Fig. 2

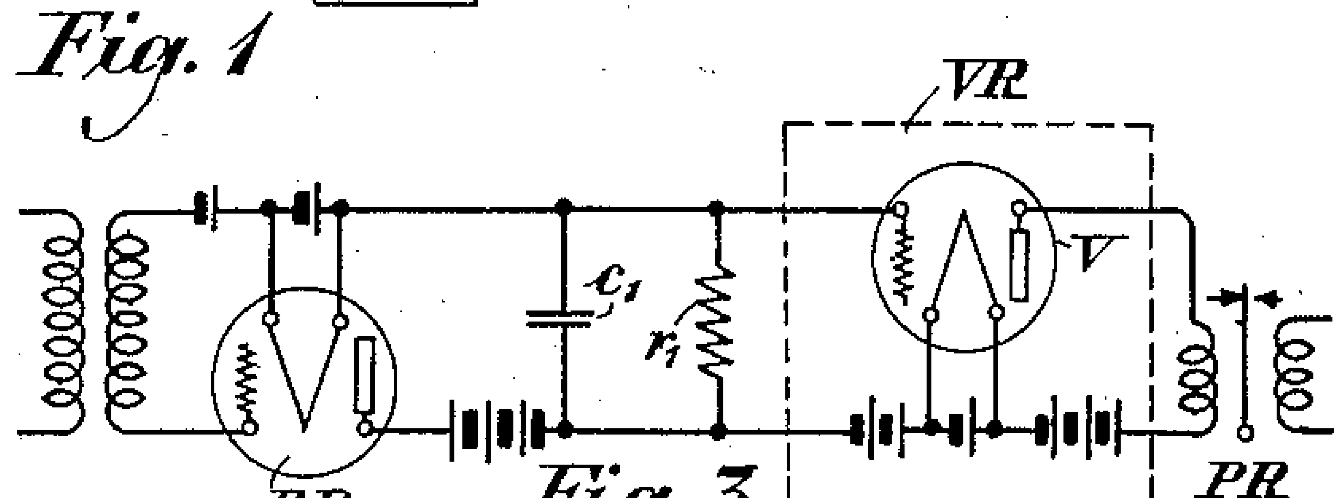

Fig. 3

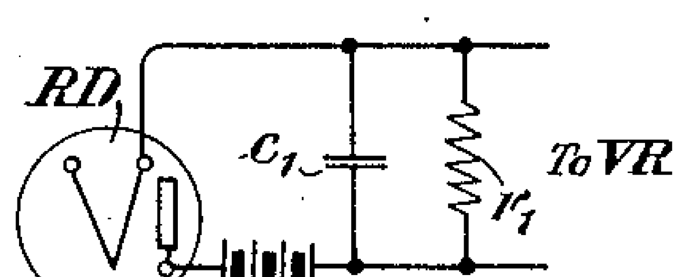

Fig. 4

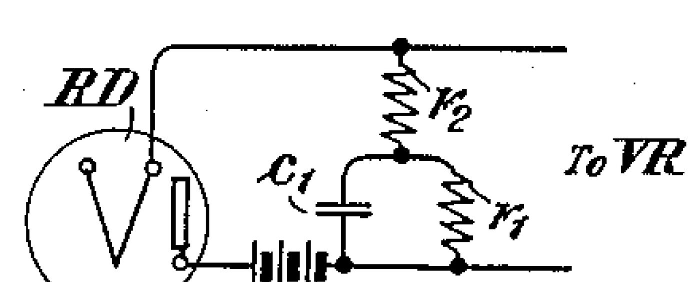

Fig. 5

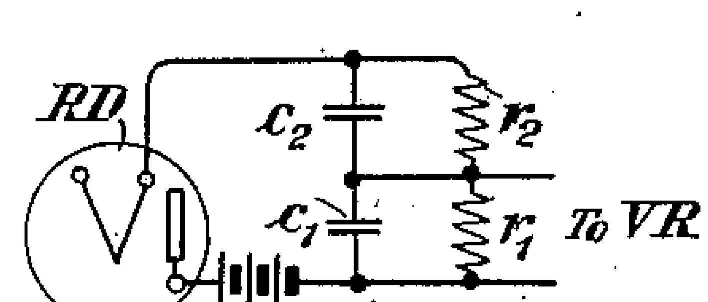

Fig. 6

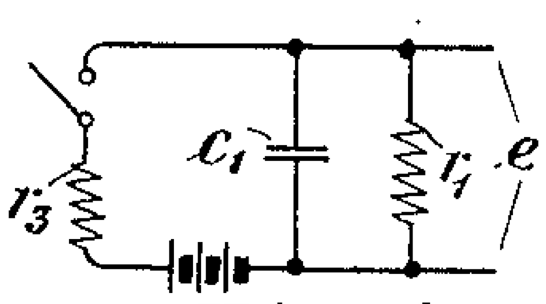

Fig. 4a

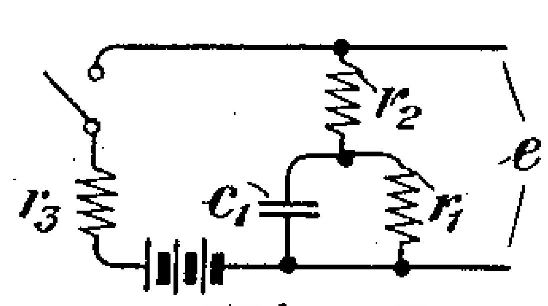

Fig. 5a

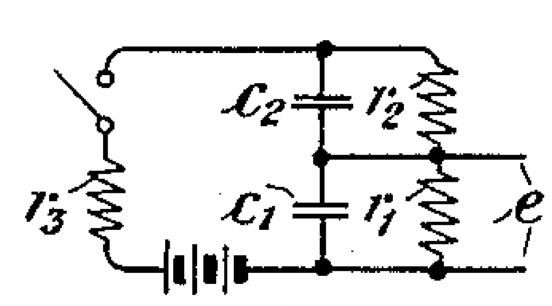

Fig. 6a

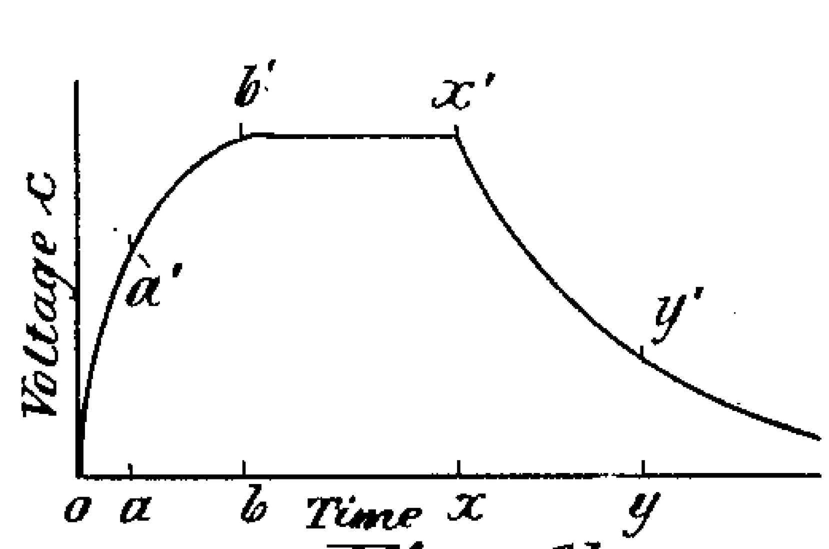

Fig. 4b

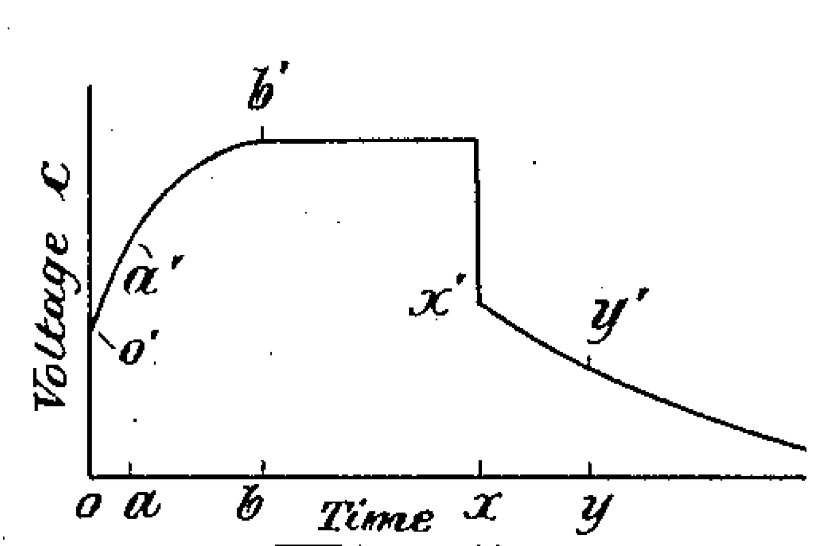

Fig. 5b

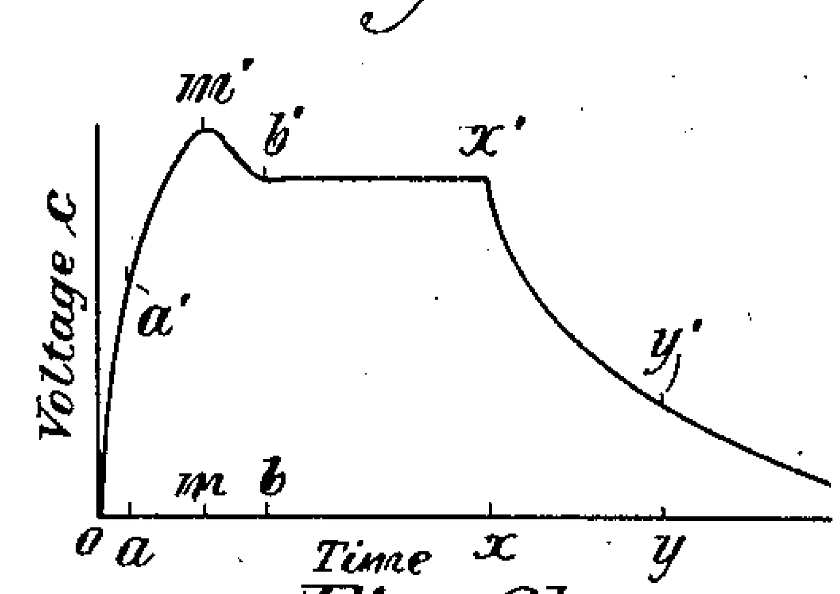

Fig. 6b

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UNITED STATES PATENT OFFICE.

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SUPPRESSION OF ECHOES AND SINGING IN FOUR-WIRE CIRCUITS.

Application filed March 10, 1928. Serial No. 260,652.

This invention relates to two-way communication systems, and, more particularly to two-way telephone systems which include, between two-wire lines, a four-wire circuit containing a radio link.

In such systems, it has been heretofore the practice to associate an amplifier-detector device with each path of the four-wire part of the circuit. Voice waves in the transmission (or outgoing) path enter the associated amplifier-detector, and the output causes the operation of a relay or relays to place a short circuit on, or otherwise block, the reception path and also to clear the transmission path. Voice waves in the receiving path, provided this path is not blocked at the time, enter the associated amplifier-detector, and the output causes the operation of the relay or relays to block the transmission path.

In accordance with the present invention, it is proposed to control the blocking or circuit-controlling means for both paths by the differential operation of the polar relay, which may be effectively actuated by means of the detector-amplifier device associated with one path, while the amplifier-detector device associated with the other path, through a differential control, prevents false operation of the polar relay by means of echoes or noise currents.

In its more specific aspect, the present invention involves the use of a potential operated relay in circuit between the amplifier-detector device and the differential winding of the polar relay, together with such an arrangement of condensers and resistances in the output of the amplifier-detector device as will permit a quick building-up of the differential or protecting potential, and a comparatively long hang-over period during which the differential action may be maintained after the impulse which determined it has ceased.

The invention will be more clearly understood from the following description when read in connection with the accompanying drawing, of which Figure 1 shows an embodiment of the invention applied to the four-wire link interconnecting one terminal of a two-way radio link to a terminal of a two-wire line; Fig. 2 of which shows a typical hang-over arrangement; Fig. 3 of which shows, in simplified form, a type of hang-over arrangement employed in connection with the present invention; Figs. 4, 5 and 6 show three different forms of hang-over arrangements in accordance with the invention; Figs. 4^a, 5^a and 6^a show the same hang-over arrangements in simplified form, while Figs. 4^b, 5^b and 6^b are curves illustrating the principles of the hang-over circuits.

Referring to Fig. 1, L designates an ordinary two-wire telephone line which is balanced by a network N, and, by means of the usual type of hybrid coil, is connected to a transmitting path TL and receiving path RL of a four-wire circuit. The transmitting path TL may be arranged to lead to a radio transmitter (not shown), and the receiving path RL to lead from a radio receiver (not shown). The transmitting path includes a one-way repeater TR, of known type, and, likewise, the receiving path RL includes a similar one-way repeater RR.

A polar relay PR, having its windings differentially arranged, controls the circuits of relays 11 and 12, the former of which, when energized, removes a short circuit from the transmitting path TL, and the latter of which, when energized, applies a short circuit to disable the path RL. An amplifier TA and a detector or rectifier TD are associated with the transmitting path in such a manner that the output current of the detector controls the energization of the lower winding of the polar relay PR. In a similar manner, an amplifier RA and a detector arrangement, comprising tubes RD and RD′, are associated with the path RL to control the energization of the upper winding of the polar relay PR. A potential operated vacuum tube relay V is interposed between such upper winding and the detector arrangement, and the output circuit of the detector has associated therewith a condenser c_1 and a resistance r_1, as shown, for the purpose of giving a desired hang-over action, as will be described later.

A voice wave incoming from the line L is transmitted through the hybrid coil and through the repeater TR to the transmitting path TL. Some of the energy of this wave passes through the amplifier TA to the detector tube TD, thereby causing a unidirectional current to flow through the lower winding of the polar relay PR. The armature of the polar relay, which normally rests upon its upper or back contact, is thereby moved to its front contact to energize the relays 11 and 12. Relay 12 disables the receiving path RL by applying a short circuit thereto, and relay 11 removes the short circuit normally applied to the transmitting path TL. A delay circuit TDC is provided in the path TL, so that the disabling short circuit controlled by the relay 11 may be removed by the time the beginning of the voice wave arrives at the point at which the short circuit was applied.

As will be observed, while the transmitting path is normally disabled, the short circuit controlled by the relay 12 is not normally applied to the receiving path RL, and consequently the system is in condition to receive at any time. It is therefore unnecessary for a received wave incoming from the radio receiver to actuate any circuit controlling device to condition the receiving path RL for operation, and the received voice wave will therefore be transmitted through the hybrid coil to the line L. If the hybrid coil and balancing network could be designed so that a perfect balance would be obtained, no part of the energy of this voice wave from the path RL would be transmitted to the path TL. In actual practice, however, an imperfect condition of balance exists, so that it is necessary to guard against the possibility of noise currents, static or voice currents incoming from the path RL being transmitted through the hybrid coil to the transmitting path TL with sufficient volume to actuate the polar relay PR through the detector TD and thereby disable the receiving path. Accordingly, some of the energy of the received voice wave (or other wave) incoming over the path RL is transmitted through the amplifier RA and rectified by the tubes RD and RD′.

Normally, a sufficiently negative voltage is applied to the grid of the tube V from the grid biasing battery associated with said tube to prevent any current flowing in the plate circuit thereof, and hence no current will flow in the upper winding of the polar relay PR. When rectified current flows in the output circuit of the detector tubes RD and RD′, however, such current flows through the resistance r_1 as soon as the capacity c_1 is charged, and thus superposes on the normal potential of the grid of the tube V a positive potential which permits a current to flow in the plate circuit of the tube V. The effect of this current is to hold the armature of the polar relay PR against its back contact and prevent a false operation of the polar relay by reason of energy transmitted through the hybrid coil to produce a rectified current in the output circuit of the detector tube TD.

The condition above described prevents operation of the polar relay during the continuance of a received wave. It is necessary, however, to maintain this condition a sufficient time after the end of the wave has passed the point at which the amplifier RA is associated with the receiving path, to insure that the wave passing on from this point, through the hybrid coil and back into the path TL will not actuate the polar relay PR. This hang-over period to allow the echo to die out is provided by the discharge of the condenser c_1 through the resistance r_1. Such discharge takes place as soon as rectified current ceases to pass through RD and RD′. The current discharged by the condenser is of such a direction as to continue to superpose on the normal negative potential of the grid a positive potential, which permits a gradually decreasing current to flow in the output circuit and hold up the armature of the polar relay PR.

By using the discharge of the condenser c_1 to maintain a guarding potential on a voltage operated relay such as V, it is unnecessary to provide a large discharge current through the resistance r_1, and hence the condenser c_1 may be much smaller and r_1 much larger than would be the case if the charge or discharge in this condenser were to be used directly to produce a hang-over current through the winding of the polar relay PR. By making the condenser c_1 small, the desired hang-over time can be obtained by making the resistance r_1 large (since the time of discharge is determined by the product of c_1 and r_1). With the condenser c_1 small, the time required to charge the condenser and thereby initiate the protective action for the relay PR at the beginning of a wave may be made very short.

In order to more clearly understand the advantages of the arrangement employed, in which a voltage controlled relay V is operated by means of the charge and discharge of a condenser through a resistance in the output circuit of the rectifier, a typical circuit in which the charge and discharge of the condenser is used directly to provide the holdover current for the polar relay is illustrated in Fig. 2, the corresponding elements of the improved circuit using the voltage controlled relay being illustrated in similar relation in Fig. 3. In Fig. 3, it will be noted that only one detector tube RD is illustrated, it being obvious that the two tubes RD and RD′, as shown in Fig. 1 may be replaced by a single tube where rectification of only one-half of each alternating wave is desired. In Fig. 3, VR designates that portion of the circuit which comprises the voltage operated relay and which is interposed between the polar relay and the detector RD with its associated condenser and resistance.

Considering the arrangement of Fig. 2, it is apparent that when no voice waves are applied to the detector RD, the output of the tube RD is in effect an open circuit, and the condenser c will therefore be maintained fully charged to the potential of the B battery. During this condition, no current will flow through the protecting winding of the relay PR because the voltage across the condenser c is equal and opposite to that of the B battery. When voice waves are applied to the grid of the detector tube RD, however, the space between the plate and filament becomes conductive, and the condenser c begins to discharge through the impedance of the tube. As the condenser discharges, there is a decrease of the potential across the condenser which opposes the electromotive force of the battery, and consequently current from the B battery begins to build up and flow through the holding winding of the polar relay PR and the resistance r and thence through the plate impedance of the tube.

As only a limited amount of current can flow through the tube, it is obvious that the current through the holding winding can not build up to its full value until the discharging current from the condenser c ceases. The time required for the current through the winding of the polar relay to build up to its operating value depends upon the time required to discharge the condenser c. For reasons which will appear later, it is necessary to make the condenser c very large in this circuit arrangement, and consequently the building-up of the operating current in the winding of the polar relay PR may actually require more time than that required for the echo to occur in which case false operation of the polar relay might occur because of the echo current having had time to enter the transmitting path and energize the other winding of the polar relay before the protecting current could be built up in the output of the detector RD.

During the continuance of the voice wave applied to the grid of the tube RD, the protecting current through the winding of the polar relay PR and through the resistance r continues to flow and hold the armature of the polar relay against its back contact. The condenser c having given up to the tube an amount of energy proportional to its capacity and the reduction of voltage across its terminals, said condenser remains partially discharged, but no current is discharged by it through the tube, and the entire plate current of the tube passes through the winding of the polar relay.

When the voice wave applied to the grid of the tube ceases, the plate circuit of the tube becomes in effect an open circuit. Current now continues to flow from the B battery through the winding of the polar relay PR and through the resistance r to charge the condenser c. This current continues to flow until the condenser c resumes its normal charge. The time required to charge the condenser c depends on the product of c and r. However, c must be made very large in order to draw, during its charging operation, sufficient current through the winding of the relay PR to hold said winding energized during the required hang-over period. But, as already stated, the fact that the condenser c must be large makes the time of the initial building-up of the protecting current through the winding of the polar relay PR so long as to cause a possible false operation.

The advantage of the arrangement in Fig. 3, which employs a voltage operated relay VR between the polar relay PR and the rectifier RD with its condenser c_1 and resistance r_1, will now be apparent. With no voice wave applied to the grid of the tube RD, the plate circuit of the tube is in effect an open circuit. As the B battery must charge the condenser c_1 through the plate circuit of the tube, the condenser c_1 will have no charge under these conditions, and, likewise, no current will flow through the resistance r_1. When a voice wave is applied to the grid of the tube RD, however, a charge begins to build up in the condenser c_1. At the beginning of the current flow, all of the current through the tube flows into the condenser, but, as the condenser charges up its counter E. M. F. opposes the flow of current and more current begins to flow through r_1. When the condenser c_1, reaches its maximum charge, so that no further current flows into the condenser, the current flow through the resistance r_1 reaches a maximum, and this current flow continues during the continuance of the wave applied to the grid of the tube RD. The current through the resistance r_1 causes a drop across said resistance, thereby superposing a positive potential upon the normal negative potential applied by the grid battery to the grid of the tube V. The plate circuit of the tube therefore becomes conducting, and a protecting current is supplied from the B battery of the tube V to the protecting winding of the polar relay PR.

The time required for this plate current to reach its operating value depends upon the time required for the condenser c_1 to reach its maximum charge. Since, as has already been explained, the condenser c_1 may be very small with this circuit arrangement, and still provide the necessary hang-over, the building-up time of the current through the relay PR may be very short. When the voice wave applied to the detector RD ceases, and the plate circuit of the detector becomes in effect an open circuit, the condenser c_1 discharges through the resistance r_1, thereby continuing a superposed positive potential on the grid until the condenser is completely discharged. The time that this superposed potential continues, and hence the hang-over time of the circuit, depends upon the product of the capacity c_1 and resistance of the element r_1. As this product may be made large enough to give the desired hang-over time, by increasing the resistance r_1 and leaving the capacity of the condenser c_1 small, it is evident that the circuit of Fig. 3 will provide the necessary hang-over, and, at the same time, permit of a very quick building-up of the protecting current through the winding of the relay PR.

Various arrangements of resistances and capacities between the detector RD and the voltage operated relay VR, to give desired characteristics, may be employed. In order to compare the characteristics of certain of these arrangements, the arrangement illustrated in Figs. 1 and 3 is shown in simplified form in Fig. 4, and two modifications are likewise shown in simplified form in Figs. 5 and 6.

In Fig. 5, a resistance r_2 is connected in series with the parallel arrangement of resistance r_1 and condenser c_1. So, also, in Fig. 6 the parallel arrangement of resistance r_2 and capacity c_2 is connected in series to the parallel arrangement comprising resistance r_1 and capacity c_1. In the latter case, the conductors leading to the voltage operated relay VR are connected across the terminals of the resistance r_1, whereas in the arrangement of Fig. 5 these conductors are connected to the opposite terminals of the resistances r_1 and r_2.

In order to compare the circuit arrangements of Figs. 4, 5 and 6, the plate circuit of RD may be replaced by a resistance r_3, equal to its impedance when the voice wave is applied, and a switch, which may be opened to disconnect such resistance, to simulate the condition of infinite impedance through the plate circuit of the tube when no voice wave is applied to the grid. The equivalent circuit arrangements are then as shown in Figs. 4^a, 5^a and 6^a. The various values of the voltage e applied to the grid of the voltage operated relay VR under the various operating conditions are shown by the curves of Figs. 4^b, 5^b and 6^b.

If, in Fig. 4^a, the switch is closed, (this corresponds to the application of a voice potential to the grid of the detector), current flows through the resistance r_3 to charge the condenser c_1. At the beginning of this operation, there is no voltage drop through the condenser, and the full current supplied through the resistance r_3 flows into the condenser. At this instant no current flows in the parallel circuit through the resistance r_1. As the condenser charges up, however, its voltage increases, and hence the current through the resistance r_1 builds up in accordance with the well-known exponential law until the condenser reaches its maximum charge, at which time the current through the resistance r_1 will have reached its maximum value. This occurs at the time b of Fig. 4^b, and the corresponding drop e through the resistance r_1 will then have the value $b—b'$. If we assume that the voltage e must build up to a value $a—a'$ in order to produce the desired protecting current through the winding of the polar relay, it is evident that the time $o—a$ will be required to build up the voltage e to the necessary value.

So long as the switch in Fig. 4^a remains closed (that is, so long as the voice wave is applied to the detector), the voltage e is maintained at the value $b—b'$. If, now, the switch is opened at the time x in Fig. 4^b, the condenser c_1 must discharge through the resistance r_1. This discharge current through the resistance r_1 gradually decreases, and hence the voltage e drops off from the value $x—x'$ in accordance with the exponential law. If it be assumed that this voltage may drop to the value $y—y'$ before the desired protecting current falls to too low a value (it requiring a smaller current to hold the winding of the polar relay than was necessary to energize it in the first place), it is evident that the hang-over time will be $x—y$.

The arrangement of Fig. 5 is such that the voltage e will instantaneously build up to a value determined by the drop through r_2 and will then gradually build up to a maximum as the condenser c_1 is charged. Referring to Fig. 5^a, when the switch is closed, the condenser c_1 will have zero charge so that there will be no potential drop across its terminals, and the resistance r_1 will be in effect short-circuited. The potential difference e will therefore be equal to the drop through the resistance r_2, and will instantaneously rise to the value $o—o'$ of Fig. 5^b. As the condenser charges up, its counter E. M. F. increases and current begins to flow through the resistance r_1, this current increasing to a maximum value when the condenser c_1 receives its full charge. The potential e therefore increases from zero according to the exponential law until it arrives at its maximum $b—b'$.

When the switch is opened, current instantaneously ceases to flow through the resistance r_2 and therefore the potential e drops to the value $x—x'$ of Fig. 5^b. The discharge of the condenser c_1 maintains a gradually decreasing flow of current through the resistance r_1 so that the potential e drops off in accordance with the exponential law. If $a—a'$ be the potential necessary to effectively energize the winding of the polar relay, and $y—y'$ be the potential necessary to maintain it energized, the building-up time will be $o—a$, and the hang-over time $x—y$. It will be seen that by this arrangement the building-up time may be made somewhat shorter.

In the arrangement of Fig. 6, the condensers and resistances should be so designed that the charge in condenser c_1 approaches its maximum more rapidly than the charge in the condenser c_2. With this arrangement, the potential e will, when current begins to flow through the plate circuit of the vacuum tube, build from zero up to a maximum somewhat above the value that it has when a state of equilibrium is reached. It will then drop off to a slightly lower value which is maintained during the state of equilibrium, and when current ceases to flow in the plate circuit of the tube it will decrease in accordance with the exponential law, as shown by the curve of Fig. 6[b].

The reasons for this will be clear from the equivalent circuit of Fig. 6[a]. Here, when the switch is closed, at the instant the current begins to flow, the condenser c_1 has zero charge and in effect short circuits the resistance r_1 so that the potential e will have the value zero.

Assume first that the condenser c_2 is very large compared with c_1, then during an interval following the closure of the switch practically all of the current flows through the condenser c_2 and the resistance r_2 is, in effect, short circuited. During this interval, the charge in the condenser c_1 builds up and the potential e grows according to a curve like $o—b'$ of Fig. 4[b]. If E be taken as the E. M. F. of the battery then e will, during this interval, approach nearly to the value given by the equation:

$$e' = E\frac{r_1}{r_1+r_3} \quad (1)$$

As time passes, however, the condenser c_2 gradually charges causing more of the current to flow through the resistance r_2 and causing the drop across r_2 to rise. This reduces the total current in the circuit and consequently the potential e so that after a sufficient time has elapsed, e will fall to the final value

$$e'' = E\frac{r_1}{r_1+r_2+r_3} \quad (2)$$

By making the condenser c_2 smaller than was assumed above, it becomes partially charged before c_1 has reached its maximum charge so the potential e increases as shown by the curve $o—a'$ of Fig. 6[b] to a maximum value m' in the interval $o—m$. m' is somewhat smaller than the value e' of Equation (1). e then falls, approaching the final value e'' given by Equation (2) which is substantially attained after the additional interval in b has elapsed.

By giving suitable values to the resistances r_1 and r_2 and to the capacities of the condensers c_1 and c_2 the height of the maximum of the potential e, its final value and the intervals of time required to reach the maximum and the final values may be controlled.

When the current ceases to flow in the plate circuit of RD in Fig. 6, which corresponds to the opening of the switch in the corresponding circuit of Fig. 6[a], the condenser c_2 discharges through the resistance r_2 without producing any effect upon the potential e. The discharge of the condenser c_1 through the resistance r_1, however, causes the potential e to drop off in accordance with the exponential law, as shown in Fig. 6[b]. An analysis of the curve of Fig. 6[b] indicates that if $a—a'$ is the potential value required to cause the winding of the polar relay to receive its operating current, and the potential $y—y'$ is sufficient to provide a desired holding current, the building-up time will be $o—a$, and the hang-over time $x—y$. While the maximum value $m—m'$ of the potential e is not necessary from the standpoint of producing energization of the winding of the polar relay, it does have the effect of causing the potential to build up more rapidly and therefore to shorten the building-up time $o—a$.

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 two-way communication system, a first path adapted for transmisison in one direction, a second path adapted for transmission in the opposite direction, the first path being normally blocked and the second path being normally cleared, a two-wire line connected to said paths at one end thereof, an amplifier-detector associated with each path, a relay having windings differentially connected and arranged to be energized under the control of said amplifier-detectors, means responsive to the operation of said relay for clearing said first path and simultaneously blocking said second path, a voltage operated relay interposed between the output of the amplifier-detector associated with said second path and the corresponding winding of said differential relay, and means associated with said amplifier-detector and responsive to transmisison over said second path to build up a protecting voltage to enable said voltage operated relay to prevent operation of said differential relay.

2. In a two-way communication system, a first path adapted for transmission in one direction, a second path adapted for transmission in the opposite direction, the first path being normally blocked and the second path being normally cleared, a two-wire line connected to said paths at one end thereof, an amplifier-detector associated with each path, a relay having windings differentially connected and arranged to be energized under the control of said amplifier-detectors, means responsive to the operation of said relay for clearing said first path and simultaneously blocking said second path, a voltage operated relay interposed between the output of the amplifier-detector associated with said second path and the corresponding winding of said differential relay, means associated with said amplifier-detector and responsive

to transmission over said second path to build up a protecting voltage to enable said voltage operated relay to prevent operation of said differential relay, and means to maintain said protecting voltage a predetermined time after transmission over said second path has ceased.

3. In a two-way communication system, a first path adapted for transmission in one direction, a second path adapted for transmission in the opposite direction, the first path being normally blocked and the second path being normally cleared, a two-wire line connected to said paths at one end thereof, an amplifier-detector associated with each path, a relay having windings differentially connected and arranged to be energized under the control of said amplifier-detectors, means responsive to the operation of said relay for clearing said first path and simultaneously blocking said second path, a voltage operated relay interposed between the output of the amplifier-detector associated with said second path and the corresponding winding of said differential relay, and means comprising a combination of resistance and capacity associated with said amplifier-detector to build up a protecting voltage in response to transmission over said second path, said protecting voltage enabling said voltage operated relay to prevent operation of said differential relay.

4. In a two-way communication system, a first path adapted for transmission in one direction, a second path adapted for transmission in the opposite direction, the first path being normally blocked and the second path being normally cleared, a two-wire line connected to said paths at one end thereof, an amplifier-detector associated with each path, a relay having windings differentially connected and arranged to be energized under the control of said amplifier-detectors, means responsive to the operation of said relay for clearing said first path and simultaneously blocking said second path, a voltage operated relay interposed between the output of the amplifier-detector associated with said second path and the corresponding winding of said differential relay, and means comprising a combination of resistance and capacity associated with said amplifier-detector to build up a protecting voltage in response to transmission over said second path, said protecting voltage enabling said voltage operated relay to prevent operation of said differential relay, said capacity being sufficiently small to enable said voltage to be built up quickly, and said resistance being so proportioned to said capacity as to permit said voltage to decay sufficiently slowly to maintain said differential relay unoperated a predetermined time after transmission over said second path has ceased.

5. In a two-way communication system, a first path adapted for transmission in one direction, a second path adapted for transmission in the opposite direction, the first path being normally blocked and the second path being normally cleared, a two-wire line connected to said paths at one end thereof, an amplifier-detector associated with each path, a relay having windings differentially connected and arranged to be energized under the control of said amplifier-detectors, means responsive to the operation of said relay for clearing said first path and simultaneously blocking said second path, a voltage operated relay interposed between the output of the amplifier-detector associated with said second path and the corresponding winding of said differential relay, and means comprising a combination of resistance and capacity associated with said amplifier-detector to build up a protecting voltage in response to transmission over said second path, said protecting voltage enabling said voltage operated relay to prevent operation of said differential relay, said capacity being sufficiently small to enable said voltage to be built up quickly, and said resistance being so proportioned to said capacity as to permit said voltage to decay sufficiently slowly to maintain said differential relay unoperated a longer time after the cessation of transmission over said second path than was required to build up said voltage.

In testimony whereof, I have signed my name to this specification this 9th day of March 1928.

HAROLD C. SILENT.