March 8, 1927. **1,619,891**

H. C. SILENT

ECHO SUPPRESSOR RELAY

Filed July 8, 1925 3 Sheets-Sheet 1

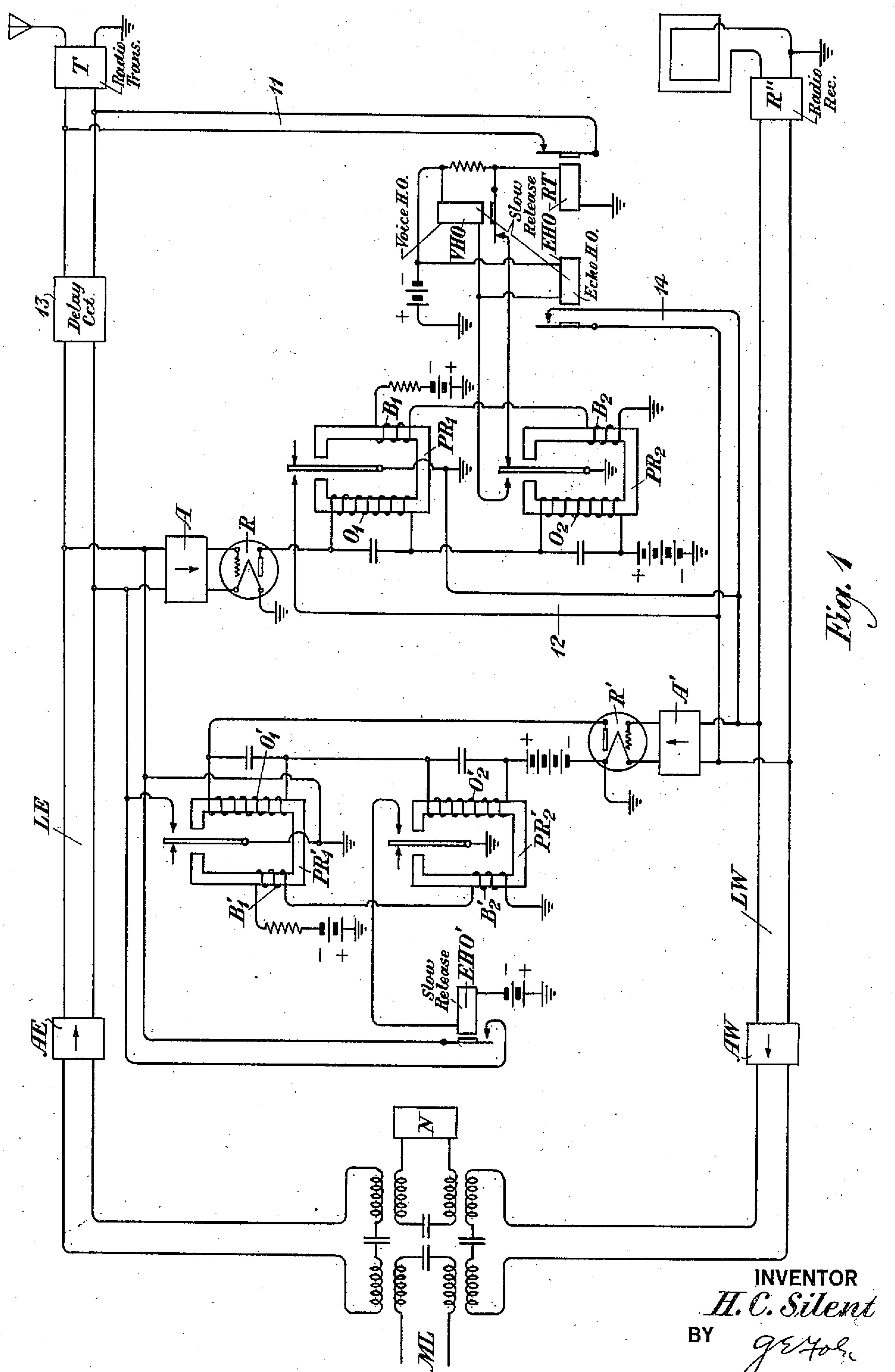

Fig. 1

INVENTOR
H. C. Silent
BY
ATTORNEY

March 8, 1927. 1,619,891

H. C. SILENT

ECHO SUPPRESSOR RELAY

Filed July 8, 1925 3 Sheets-Sheet 2

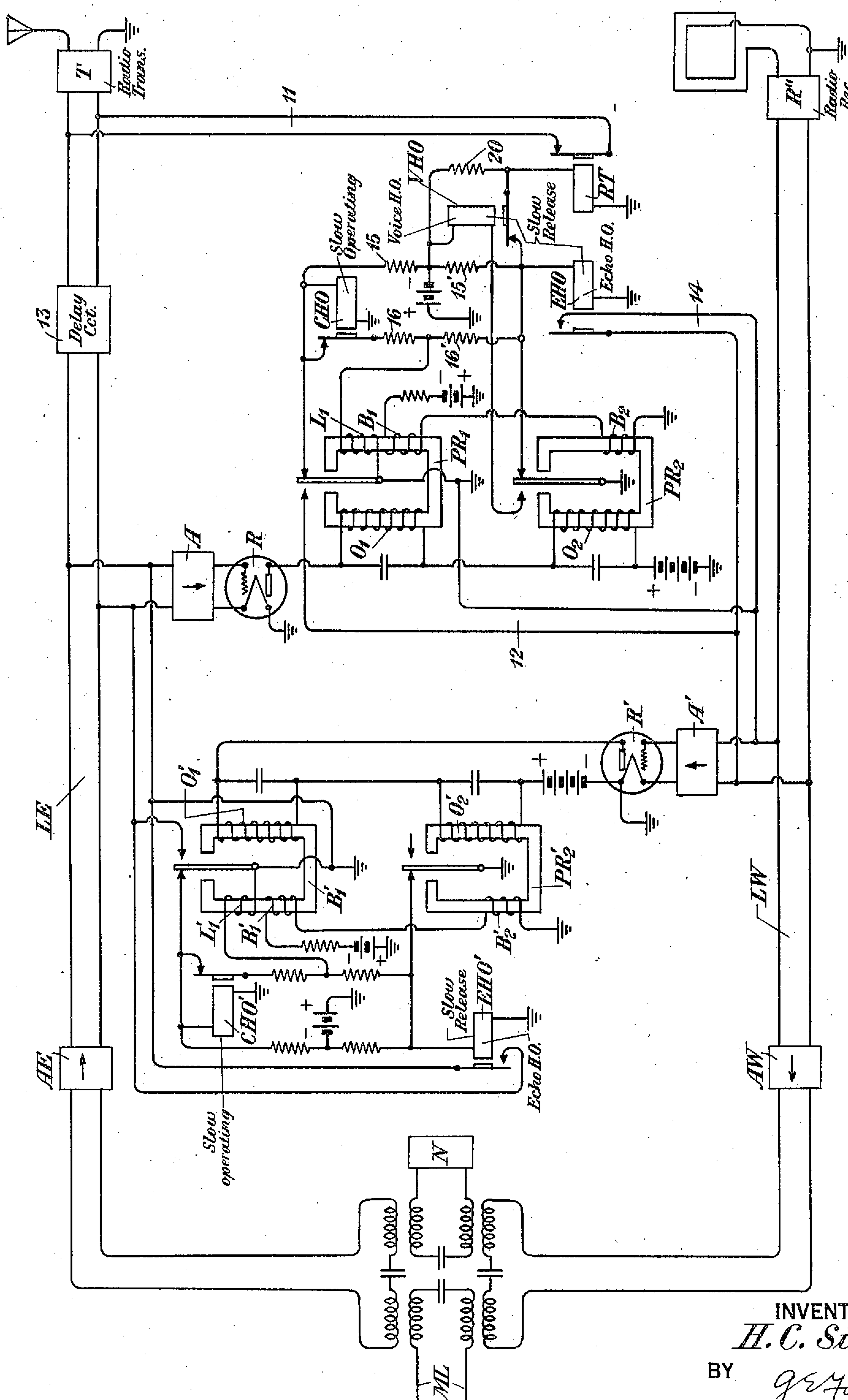

Fig. 2

INVENTOR
H. C. Silent
BY
ATTORNEY

March 8, 1927.

H. C. SILENT

ECHO SUPPRESSOR RELAY

Filed July 8, 1925

1,619,891

3 Sheets-Sheet 3

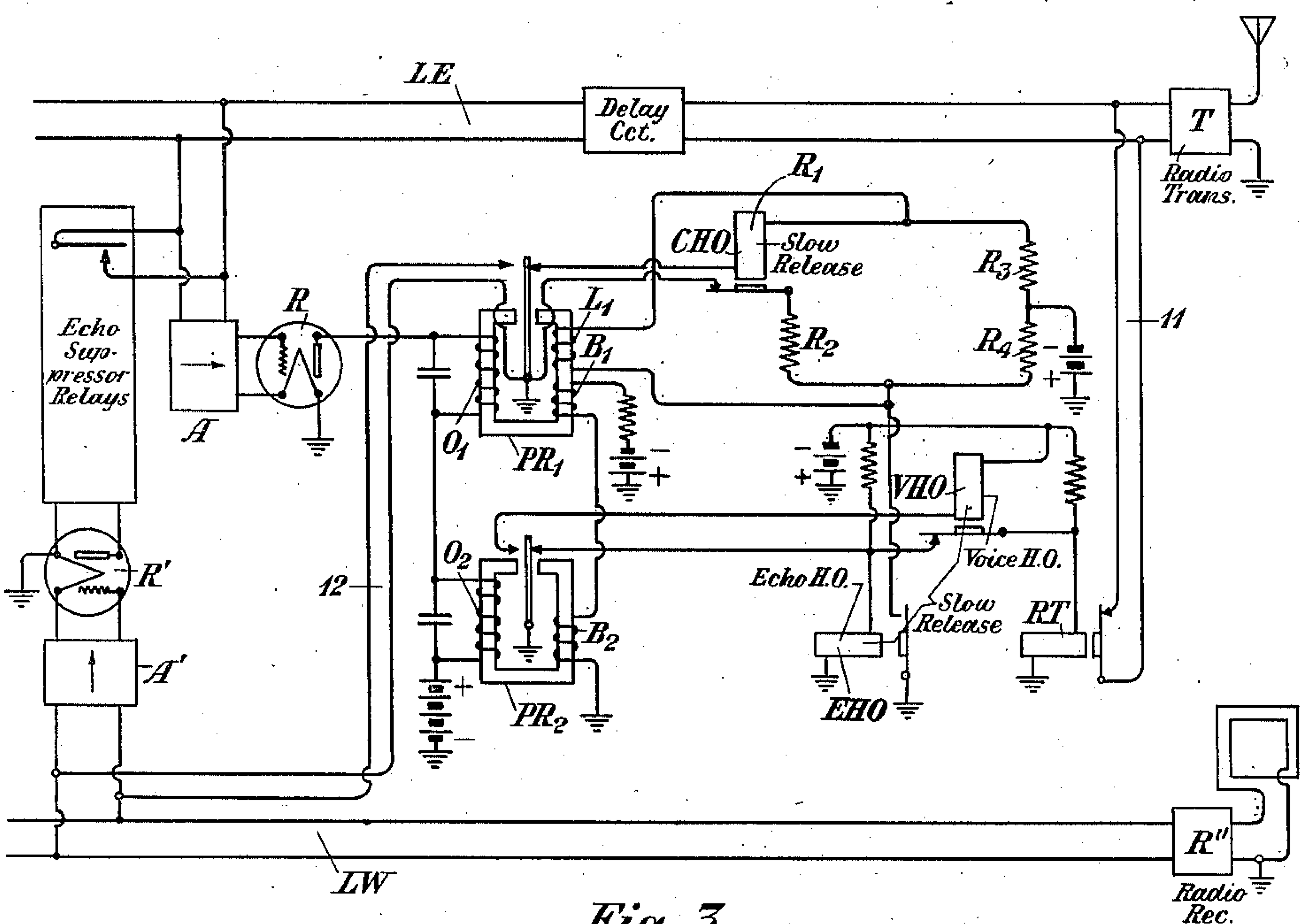

Fig. 3

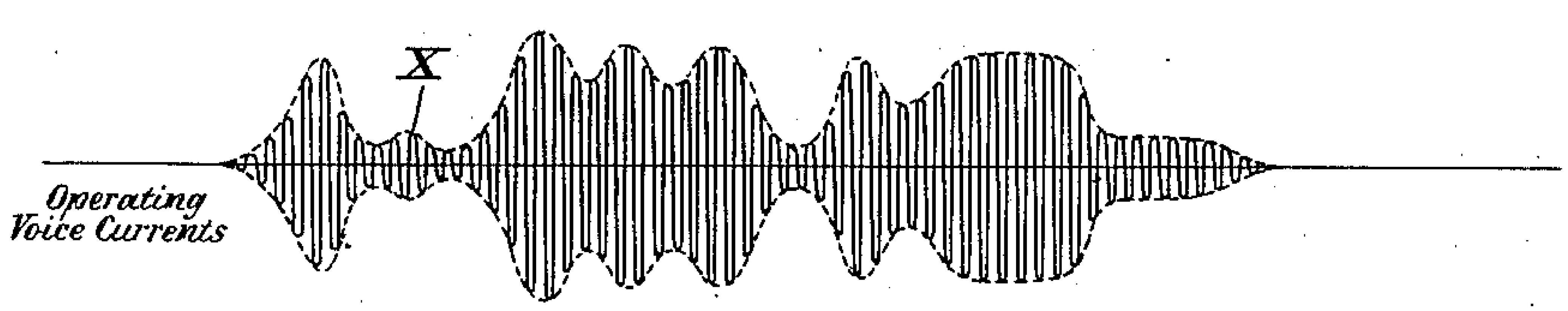

Fig. 4

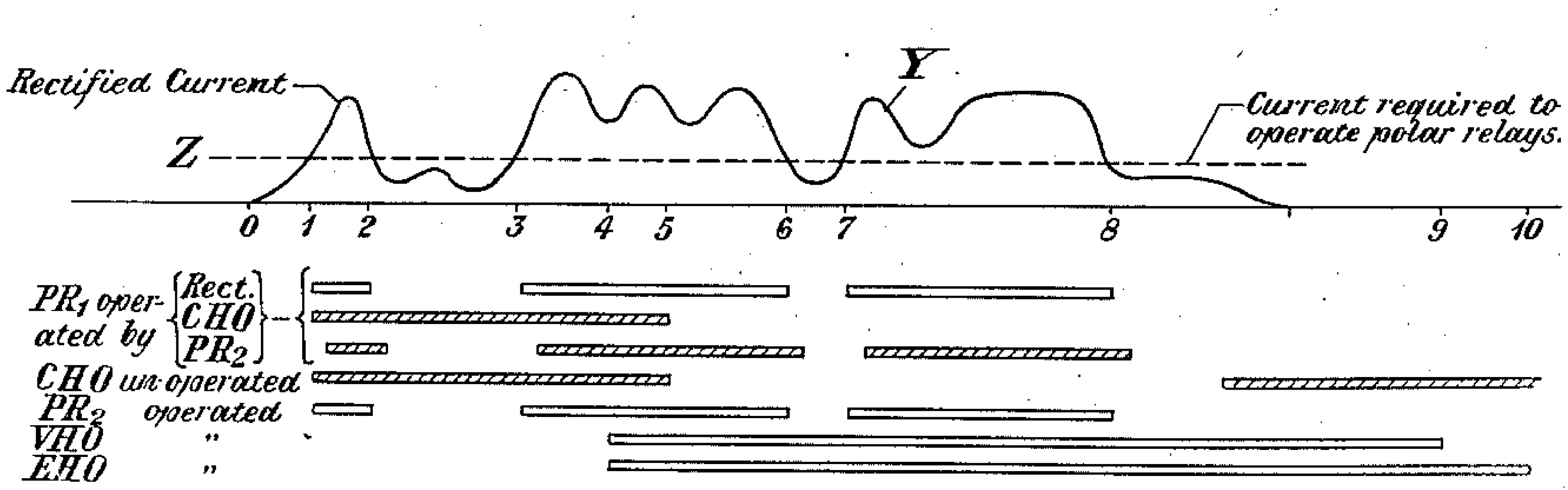

Fig. 5

INVENTOR
H. C. Silent
BY
G. E. Folk
ATTORNEY

Patented Mar. 8, 1927. 1,619,891

UNITED STATES PATENT OFFICE.

HAROLD C. SILENT, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

ECHO-SUPPRESSOR RELAY.

Application filed July 8, 1925. Serial No. 42,288.

This invention relates to voice-operated switching devices for suppressing echoes and singing and more particularly to these devices when applied to circuits in which the time delay of the echo is relatively short as, for example, in radio telephone systems associated with wire telephone lines.

In the discussion which follows, the term "echo suppressor" will be understood to means a voice-operated device associated with a transmission circuit and of such a nature as to suppress either echoes, singing, or both. More particularly in this discussion, a voice-operated device associated with circuits leading to a radio transmitter, for example, will be referred to as the transmitting echo suppressor, and a voice-operated device associated with circuits leading from a radio receiver, for example, will be referred to as the receiving echo suppressor.

In the operation of two-way radio telephone systems it is desirable to provide echo suppressors, which render the circuits operative in only one direction at a time under the control of voice currents, in order to prevent echo currents from being transmitted back over the reverse path during voice transmission in a given direction. While echo suppressors have been successfully applied to long four-wire circuits, the type of suppressor which has been heretofore developed is not suitable for use in suppressing echoes of large magnitude and small delay, such as occur in radio systems. In a radio system the four-wire circuit connecting the radio transmitter and radio receiver to an ordinary two-wire telephone line is usually quite short.

Furthermore, the transmission from the local radio transmitter to the local receiver, particularly when both are operated on the same wave length, may be relatively large so that a transmission gain in the closed path from the two-wire circuit to the radio transmitter, thence to the radio receiver and back to the two-wire circuit may exist. This condition, which would result in singing if no voice-operated devices were applied, tends to make the echo currents resulting from the application of voice current to the circuit considerably greater than the directly applied currents.

To prevent singing in such a circuit a voice-operated device is applied to the transmitter branch of the four-wire circuit in such a manner as to normally block transmission. When speech currents of sufficient magnitude reach this device, they cause operation of relays which do two things; first, they clear the path for direct transmission and second, they disable the path over which echoes would be received. When this transmitting echo suppressor operates in response to the voice-currents and permits even the smallest current to be transmitted, it is necessary for the receiving side of the circuit to be definitely and positively disabled for a time interval greater than that required for the return of the echo.

In order to prevent received transmission from operating the transmitting echo suppressor through the unbalance at the two-wire and four-wire connection, another device is applied to the receiving branch of the four-wire circuit so that whenever transmission is received, relays will be operated to disable the transmitting path and prevent operation of the device in that path.

The transmitting echo suppressor operating in response to the voice currents includes a sensitive polar relay which disables the path transmitting in the reverse direction and also operates a so-called hang-over relay which maintains the path in the opposite direction disabled for a definite length of time after the polar relay has been released. The polar relay operates in response to rectified voice currents, and many vocal sounds, when rectified, assume the form of relatively weak pulses at the beginning of the sound, which cause the polar relay to chatter for a brief period before sufficient energy becomes effective to bring the hang-over relay definitely into play to maintain the circuit disabled. The result is that at the beginning of a vocal sound the path in the reverse direction is intermittently disabled for a short period only, and since in a radio system an enormous amount of energy passes from the transmitter to the receiver and back in the reverse direction, almost immediately, some of this energy is able to get through at the point at which the circuit in the reverse direction is supposed to be disabled. The energy thus permitted to pass will then operate the echo suppressor which controls the circuit leading to the transmitter and, due to its large volume, will positively operate said echo suppressor to disable the transmitter path.

This results in tying up the circuit for at least a brief period with the result that the full vocal sound is not transmitted.

In accordance with the present invention it is proposed to improve the relay action by providing a locking action for the polar relay such that, as soon as the relay vibrates in response to the initial energy of a vocal sound, it will be abruptly and positively operated and will be held operated for a sufficient period to suppress the echo of the energy which caused its operation. As a consequence, the path in the reverse direction will be at once positively disabled even though the beginning of the vocal sound is of such a nature as to cause the polar relay without the locking feature to chatter. This locking operation of the polar relay may be attained by providing an auxiliary winding for the relay, which is energized as soon as its armature is lifted from its back contact, and which is maintained energized for a definite period by an auxiliary circuit. After the hang-over relays have come into play, the auxiliary winding no longer locks up the polar relay and it is enabled to respond in a normal manner to the rectified vocal energy and the circuits restore to normal at the termination of the vocal sound.

The invention will now be more fully understood from the detailed description thereof when read in connection with the accompanying drawings, Figure 1 of which shows an echo suppressor circuit of the ordinary type whose operation is effected in the manner above pointed out, Fig. 2 of which shows a preferred embodiment of the improved echo suppressor circuit, Fig. 3 of which shows a modified form of the improved circuit, Fig. 4 of which is a curve showing a characteristic form of the vocal energy which is supposed to operate the echo suppressor, and Fig. 5 of which is a series of curves showing the rectified voice current and the periods of operation of the various relays associated with the echo suppressor circuit in response to the rectified current.

In order to readily understand the nature of the improvement forming the subject matter of the present invention it is desirable to refer briefly to the type of echo suppressor circuit which it has heretofore been proposed to use in connection with a radio telephone system and which, as already pointed out, has been found to operate in an unsatisfactory manner. Referring to Fig. 1, T represents a radio transmitter of any well known type and R″ represents a radio receiver of any conventional form. The radio transmitter T and radio receiver R″ are connected to a terminal telephone line ML through a four-wire circuit comprising paths LE and LW respectively, these paths being connected to the terminal line through a hybrid coil and balancing network N in a manner well known in the art. It is, of course, understood that a similar transmitter and receiver and terminal telephone line will be provided at a distant point so that by means of the circuit illustrated, two-way communication takes place with the similar circuit at the distant point.

Amplifiers AE and AW may be included in the lines of the four-wire circuit if desired. Normally, the transmitter is disabled by means of a short-circuit connection 11 in order to prevent singing due to the unstable condition resulting from the carrier frequency from the transmitter being transmitted to the receiver during the idle condition of the circuit, there detected and thence transmitted by the lines through the hybrid coil and back to the transmitter. An echo suppressor comprising a suitable amplifier A and a detector or rectifier R is associated with the line LE and the plate current from the rectifier passes through the operating windings O_1 and O_2 of relays PR_1 and PR_2 respectively. These relays are of the polar type in the invention described herein for the reason that this type of relay at the present state of the art has higher operating speed than any other commercially available type. It is not to be inferred however that a non-polar relay cannot be used. Any type of relay having the proper operating characteristics might be substituted for either or both of the polar relays PR_1 and PR_2. Normally, the armatures of the polar relays PR_1 and PR_2 are biased by means of biasing windings B_1 and B_2 so that the armatures are held against their back contacts by the biasing current. During the normal condition of the circuit, no plate current flows in the circuit of the rectifier and it is only in response to voice currents that a rectified current flows through the operating windings.

When the armature of the polar relay PR_1 is operated by rectified voice current it closes a short-circuit connection 12 which short-circuits the corresponding echo suppressor apparatus associated with the line LW and also short-circuits the line LW itself. The polar relay PR_2 is similar to the polar relay PR_1 and, when resting upon its back contact, short-circuits the winding of a relay RT, which controls the short circuit 11, for the transmitter T. As soon as the armature of the relay PR_2 leaves its back contact, however, this short circuit is removed, thereby enabling the relay RT to become energized and open the short circuit 11, thus rendering the transmitter operative. A delay circuit 13 is provided in the line LE between the echo suppressor and the transmitter, thereby permitting the short circuit 11 to be opened before the voice currents arrive at the transmitter. The armature of the polar relay PR_2 when operated closes its front contact and thereby completes the circuits of the echo hang-over relay EHO and the voice hang-over relay VHO. Both of these relays are slow-release relays, and the former closes a short circuit 14 in parallel to the short-circuit connection 12, to maintain the line LW disabled after the voice currents have ceased for a period equal to the time of release of the echo hang-over relay EHO. The relay VHO opens a short-circuit connection of the relay RT independently of the polar relay PR_2, and thereby maintains the short-circuit 11 open for a period after the voice currents cease, which is determined by the time of release of the voice hang-over relay VHO and the relay RT.

Under proper conditions, the operation of the combination of relays above described will be satisfactory, but under other conditions it functions in a somewhat erratic manner. In order to understand how it happens that the relays fail to perform the service for which they were intended under certain conditions, it is necessary to analyze the nature of the voice waves which operate the relays. Referring to Fig. 4, the curve shows a form of wave representing a vocal sound such as might be commonly met with in ordinary conversation. It will be observed that this wave varies greatly in amplitude. It may build up to a fairly large amplitude and then fall off to a very small amplitude, after which it may again build up to a large amplitude which varies to some extent, although in general the amplitude of the major portion of the wave is somewhere in the neighborhood of the maximum, after it has once been built, except at the point X where it will be noted that the wave drops down momentarily to a relatively small value. If such a wave as shown in Fig. 4 be rectified, a substantially continuous one-way current of variable amplitude such as shown by the curve Y of Fig. 5 will result. The rectified current is not steady but is pulsating in form and, as noted, at times the pulsations are separated by intervals during which the current is quite small.

Now, let us assume that the current must have a value at least equal to that represented by the horizontal dotted line Z in order to operate the relays PR_1 and PR_2 in Fig. 1 through their operating windings. Obviously, then, the voice current will exist in the circuit LE for the period from 0 to 1 in the curve of Fig. 5 before the first pulse of current attains a value sufficient to shift the armatures of the polar relays from the back contacts. Both relays PR_1 and PR_2 will have their armatures shifted to their front contacts, however, during the time from 1 to 2, as is indicated by the first and fifth horizontal lines below the curve Y of Fig. 5. This means that the relay PR_1 has short-circuited the line LW during this interval and the relay PR_2, by shifting its armature from its back contact, has removed the short circuit from the relay RT, enabling the latter to open the short circuit 11 across the radio transmitter T. The polar relay PR_2 also closes a circuit of the hang-over relays EHO and VHO but as these relays are comparatively sluggish in operating they require a greater energy impulse than is provided by the interval 1 to 2 in order to pull up their armatures. As the interval of time 1–2 is too short to enable these relays to pull up their armatures, the result is that the circuit LW is only short-circuited during the period 1–2 and in the period from 2 to 3, during which the rectified current falls below the value Z, the polar relays PR_1 and PR_2 release their armatures so that the short circuit is removed from the line LW and the circuit of the hang-over relays EHO and VHO is opened. During the period 2–3, therefore, it is quite possible for transmission to take place over the circuit LW.

Unfortunately, the relay RT has already operated prior to or during this period to open the short circuit 11 and the voice currents are transmitted through the delay circuit 13 and arrive at the transmitter T to modulate the radio frequency which is transmitted to the receiver R″ and there again demodulated, so that the voice currents, greatly amplified in value, are impressed upon the line LW and may be transmitted over said line during the interval 2–3. If this occurs, the amplified echo current received by the radio receiver R″ passes into the amplifier A′ and rectifier R′ to operate the relays PR_1' and PR_2' of the other echo suppressor. Since the rectified current resulting from the amplified echo is of considerable magnitude, the operation of the relays PR_1' and PR_2' is very positive. The relay PR_1' short-circuits the amplifier A and rectifier R of the echo suppressor associated with the line LE and thereby disables said echo suppressor and the line. The polar relays PR_1 and PR_2 of the first echo suppressor cannot now function as they are disabled by the second echo suppressor so that the whole apparatus remains disabled until all of the relays are restored to normal. The result of this false operation is an interruption during the operated period of the relays PR_1', PR_2', EHO′, to the current wave on line LE over which transmission is being attempted.

By the time the relays are all restored to normal, the portion of the wave represented beyond point 3 of Fig. 5 has been suppressed by the false operation of the relays, and it is evident that at least a large portion of the sound represented beyond 3 is lost.

It is therefore apparent that with a wave of the type shown in Fig. 5 (and this wave is fairly representative of certain kinds of vocal sounds) the first impulse or two may be of too brief duration to permit the hang-over relays to operate and as the polar relays fall back between impulses, the result is that hiatus occurs during which a false operation of the other echo suppressor may result from amplified echo currents. In the case of a radio system where the local receiver receives from the local transmitter a greater amount of energy than it would ordinarily during direct transmission, it is obvious that the echo currents may produce a more certain and positive actuation of the wrong echo suppressor than the original voice waves did of the right echo suppressor. It is therefore necessary to provide something to bridge over this hiatus or gap in the operation which permits of the false operation. An improved circuit arrangement which enables this gap to be bridged is shown in Fig. 2.

In Fig. 2, the echo suppressor associated with the line LE includes the polar relays PR_1 and PR_2, together with the echo hang-over relay EHO and voice hang-over relay VHO as before. The polar relays have the same windings as in Fig. 1 but the polar relay PR_1 is provided with an additional or auxiliary winding L_1 which serves to perform a locking operation to be described hereinafter. The winding L_1 is so designed that when energized it tends to shift the armature from its back contact and to hold it against the front contact,—in other words, the winding L_1 tends to assist the operating winding O_1. The circuit of the winding L_1 is so arranged that it may be energized over either of two paths, one controlled by the contact of a slow-operating relay CHO through resistances 15 and 16, and the other extending in parallel thereto through resistances 15′ and 16′. The winding L_1 is short-circuited as regards the first of these paths over the back contact of the polar relay PR_1. The second path is likewise short-circuited over the back contact of the polar relay PR_2. If a sufficient impulse enters the operating windings of either of the relays PR_1 or PR_2 so that the armature of either relay is lifted from its back contact, a current will instantaneously flow through the winding L_1 of the relay PR_1, tending to shift the armature to its front contact. The lifting of the armature of the relay PR_1 from its back contact also removes the short circuit from about the winding of the slow-operating relay CHO, thereby permitting said relay to operate after an interval. The echo hang-over relay EHO in the circuit of Fig. 2 is arranged to be operated by the lifting of the armature of the relay PR_2 from its back contact rather than by the contact of the armature with its front contact as in Fig. 1.

The apparatus associated with the receiving echo suppressor, that is, the echo suppressor controlled from the line LW is similar to that just described except that no normal short circuit corresponding to 11 need necessarily be provided in connection with the circuit LW and hence the relay RT and the associated voice hang-over relay VHO may be omitted.

Further details of the apparatus will now be clear from a description of the operation, which is as follows:

Voice currents transmitted from the line ML to the line LE enter the echo suppressor and are rectified by the rectifier R, thereby producing pulses of current in the plate circuit. The first pulse, even though it may be relatively weak and of brief duration, will be sufficient to shift the armature of the polar relays PR_1 and PR_2 from their back contacts. This momentarily removes a short circuiting ground from about the winding L_1 so that current now flows through this winding from battery, through resistance 15, over the back contact of relay CHO, through the resistance 16 and the winding L_1 to ground. A parallel path through said winding extends from battery through resistance 15′ and resistance 16′, and thence through winding L_1 to ground. A current thus flows through the winding L_1, causing said winding to positively shift the armature of the relay PR_1 to its front contact where it will remain as long as current flows through the auxiliary L_1. This closes the short circuit 12 to render the echo suppressor associated with the line LW inoperative, at the same time short-circuiting the line LW itself so that no echo can be transmitted over the line LW beyond the point the short circuit is applied. If at the end of the first impulse the armature of the polar relay PR_2 falls back, a short circuiting ground will again be applied to the energizing path of the winding L_1 which extends through the resistances 15′ and 16′. However, the relay CHO is slow to operate, and hence the parallel path through resistance 15 and over the armature of relay CHO and through resistance 16 still remains, so that current still flows through this path and through the winding L_1. Consequently the armature of the polar relay PR_1 is locked in its front position so long as the relay CHO remains unoperated.

As already stated, the first pulse or two may be of relatively short duration, with the result that the armature of the relay PR_2 will chatter or vibrate without operating the hang-over relays EHO and VHO. As soon, however, as a sufficiently long pulse arrives to shift the armature of the relay PR_2 from its back contact a sufficient length of time, the relays EHO and RT will be energized due to the fact that the short circuiting ground is removed from about their windings. The current for the relay EHO flows from battery through the resistance 15′ to the winding of relay EHO, and the current for the relay RT flows from battery through the resistance 20. Relay EHO, when actuated, closes the short circuit 14 to maintain the line LW short-circuited and to prevent the operation of the associated echo suppressor as long as the hang-over relay EHO remains energized. Relay RT in turn opens the short circuit 11 to permit the voice current to be transmitted to the radio transmitter T. The armature of the relay PR_2, upon being held against its front contact a sufficient length of time, causes the slow release hang-over relay VHO to be actuated. This relay opens the possible ground connection which might be established over the back contact of the relay PR_2 when the armature falls back, and therefore maintains the relay RT energized until such time as the relay VHO releases.

During the interval required for the operation of the relays EHO, VHO and RT, current flows through the winding L_1 of the relay PR_1, thereby holding its armature against its front contact, and this condition remains until the relay CHO is energized. The circuit for this relay is established as soon as the short circuiting ground is removed at the back contact of the relay PR_1. The relay CHO is sufficiently slow in its operation, however, that it does not open the circuit of the winding L_1 until the echo has had time to pass from R″ along LW and to the short circuit at 12 or until the hang-over relays EHO and VHO have had time to operate. Consequently the polar relay PR_1 is positively operated by the first impulse of rectified current and remains operated until the relay CHO is energized. Longer impulses of rectified current hold relay PR_2 operated long enough to operate relays VHO and EHO. When this has occurred weak current intervals are without effect in releasing the short circuit 14, because the echo hang-over relay EHO maintains this short circuit until the end of the train of impulses and until the armature of the relay PR_2 has remained upon its back contact a sufficient length of time to permit the hang-over relays to be released.

The operation of the hang-over relays bridges the gap in the operation of the relays PR_1 and PR_2, which is caused by the fall in the value of the rectified wave between points 6 and 7, so that during the period between 3 and 8 the line LW is disabled either by the relay PR_1 or by the echo hang-over relay EHO, and similarly the short-circuit 11 of the transmitter is removed during said period by the relay R_2 either under the control of the polar relay PR_2 or the voice hang-over relay VHO. During this period there is no possibility of the echo suppressor controlled by the rectifier R′ being actuated because no current can get past the short circuit 12 or 14, as the case may be. The hang-over relays VHO and EHO are slow-acting, and maintain the condition of the circuits 14 and 11 during the times represented by 8—9 and 8—10 respectively, thus enabling the circuit conditions previously established to continue long enough for the last part of the wave transmitted over the circuit LE to pass from the transmitter T to the receiver R and back over the line LW to the short circuit at 12 before the short circuit is removed.

Each time the relay PR_2 vibrates its armature in response to a pulse after the relay CHO has operated, the armature of the relay PR_1 will also vibrate, but with each pulse current flows through the winding L_1 through the resistance 15′ and 16′ due to the removal of the short circuit by the armature of relay PR_2. Therefore, even though the pulses be weak the armature of the relay PR_1 will be moved positively against its front contact. At the end of the last pulse of the train of rectified pulses, the armatures of both relays PR_1 and PR_2 fall against their back contacts and there remain. The relay CHO is released, and after an interval determined by the time of release of the relays EHO and VHO, these two relays also release their armatures, the relay VHO in turn causing the deenergization of relay RT. The short circuit 14 is accordingly opened and the short circuit 11 is closed, and the apparatus is in its original condition.

In order to more clearly understand the effect of the relay CHO and the auxiliary winding L_1 of the relay PR_1, reference is again made to the curves of Figure 5. It will be seen that during the time from 1 to 2 the polar relay PR_2 is operated and the polar relay PR_1 is also operated through its operating winding O_1. The operation of the relay PR_2 results in sending a pulse through the winding L_1, this pulse being slightly delayed in respect to the original impulse as indicated in the third section line below the current curve Y. In addition, the winding L_1 receives current as soon as its armature leaves its back contact by means of the circuit over the back contact of the relay CHO. This current continues from the time 1 to the time 5 as indicated by the sectioned line in second position below the curve 1. The result of this latter operation is to maintain the armature of the relay PR_1 locked against its front contact during the entire time from 1 to 5.

During the period from 2 to 3 the rectified current is insufficient to effectively energize the operating windings O_1 and O_2 of the polar relays PR_1 and PR_2. Furthermore, the pulse from time 1 to time 2 was not sufficiently long in duration to permit the hang-over relays EHO and VHO to become energized. Beginning with the time 3, however, the rectified current is strong enough to again energize the operating windings of relays PR_1 and PR_2. No effect is produced upon the former relay as it is already locked in its operated position. The latter relay, however, shifts its armature to its front contact, and after the interval of time from 3 to 4, permits relays EHO and VHO to be energized. These two hang-over relays when energized, remain energized until the end of the train of impulses and for a short period thereafter, and during this time maintain the short circuit 11 open and the short circuit 14 closed so that transmission may take place freely from the transmitter T and no echoes can be returned through the circuit LW.

Prior to the time 4, however, the locking of the armature of relay PR_1 against its front contact, which condition exists up to time 5, positively short-circuits the line LW at 12 and prevents any possibility of energy being radiated from the transmitter T to the receiver R, and thence over the line LW, to operate the echo suppressor relays associated with the rectifier R′. There is therefore no possibility of false operation of the echo suppressor controlled from the line LW interfering with transmission over the line LE until after the train of waves has ceased. During the brief interval between 6 and 7, the armature of relays PR_1 and PR_2 are restored to their back contacts, but this is without effect because the hang-over relays EHO and VHO maintain the short circuit 11 open and the short circuit 12 closed so that the voice currents may still be transmitted from west to east, and the short circuit 14 prevents transmission from east to west.

At the end of the train of waves the armatures of both relays PR_1 and PR_2 fall off. It may be noted at this point that the locking winding L_1 of the relay PR_1 is no longer effective due to the energization of relay CHO, so that the armature of relay PR_1 can be restored at the end of the last impulse of the train. The relays EHO and VHO remain operated, however, for a period of time determined by their slowness in releasing, the former relay releasing its armature at time 10 and the latter relay at the time 9, well after the train of impulses has ceased. The circuit is now restored to normal, ready for transmission of a new vocal sound in the same direction or for transmission of a vocal sound in the opposite direction. The effect of the auxiliary winding L′ and the control of said winding in part by the relay PR_2 together with the effect of the relay CHO in maintaining the locking circuit, is clearly indicated by the section lines in the several positions below the curve Y of Figure 5.

Transmission in the opposite direction in Figure 2, that is, from a distant station from the receiver R, passes along the line LW, and the rectifier R_1' rectifies the voice currents and operates the polar relays PR_1' and PR_2' in a manner similar to that described in connection with the echo suppressor relays associated with the line LE. The relay PR_1' is positively operated as soon as its armature is lifted from its back contact, and short-circuits the line LE, remaining in this condition until the relay CHO′ pulls up. In the meantime, as the result of an impulse lasting for a sufficient length of time, the hang-over relay EHO′ is energized to maintain the short circuit until the end of the train of impulses. The relay CHO′ does not unlock the polar relay PR_1' until the hang-over relay has had time to take control of the circuit. In this instance no apparatus is provided to remove a normal short circuit from the line LW as no such short circuit is necessary. It is only necessary to maintain one of the lines normally short-circuited in order to prevent singing.

Should transmission take place from a distant station to receiver R which is too weak to operate the receiving echo suppressor, it will also be too weak to falsely operate the transmitting echo suppressor on account of the balance at the hybrid coil. Since the receiving echo suppressor has no disabling short circuit similar to 11 on the transmitting side, it has no effect on the received transmission and could be omitted if balance of a sufficiently high order could be obtained at the hybrid coil. Since balance of this order cannot ordinarily be obtained in practice, it is necessary to provide the receiving echo suppressor in order to prevent false operation of the transmitting echo suppressor by the received energy through the unbalance of the hybrid coil when the received energy is of normal strong volume.

A modified form of echo suppressor relay circuit is shown in Figure 3. In this form of the invention the polar relay PR_2 controls the hang-over relays EHO and VHO as well as the relay RT in the same manner as in Figure 2. The locking control of the relay PR_1 is effected in a somewhat different manner, however. The auxiliary winding L_1 of the relay PR_1 is connected across neutral points of a Wheatstone bridge comprising resistances R_1, R_2, R_3 and R_4, the resistance R_1 being the resistance of the winding of a slow release relay CHO. The relay CHO is normally energized and at its front contact maintains the arm R_2 of the bridge closed. The arm R_1 of the bridge is controlled over the back contact of the relay PR_1. Battery is connected to the bridge between arms R_3 and R_4 and ground is connected to the bridge between arms R_1 and R_2 at the armature of the relay PR_1. The auxiliary control of the winding L_1 from the polar relay PR_2 is effected indirectly through the upper contact of the echo hang-over relay EHO which, when said relay is energized, connects ground to the lower terminal of winding of L_1.

Further details of the circuit arrangement may be understood from the operation, as follows:

As soon as the first impulse of rectified current flows in the plate circuit of rectifier R, the windings O_1 and O_2 of polar relays PR_1 and PR_2 are energized to shift their armatures from their back contacts. The latter relay removes a short circuiting ground from the relays EHO and RT, the latter promptly opening the short circuit 11 to enable the voice current to flow to radio transmitter T. The armature of the relay PR_1 when shifted from its back contact, opens the arm R_1 of the Wheatstone bridge so that the bridge is now unbalanced, thereby enabling current to flow from the battery connected to the junction point of R_3 and R_4, through the winding L_1, and through the resistance R_2, and over the front contact of relay CHO to ground at the armature of relay PR_1. The armature of the relay PR_1 is accordingly positively shifted to its front contact and is locked in this position so long as current flows through the winding L_1. After an interval the slow release relay CHO releases its armature and opens the arm R_2 of the bridge so that the bridge is now again balanced with respect to the winding L_1.

In the meantime, however, the armature of relay PR_2 has been shifted to its front contact a sufficient length of time to enable the voice hang-over relays VHO and EHO to become energized. Relay VHO at its lower contact opens the short circuiting ground for the relay RT controlled by the polar relay PR_2, so that the relay RT remains energized as long as the relay VHO holds up its armature. The relay EHO at its upper front contact connects ground to the lower terminal of the winding L_1 so that current may flow from battery through the winding R_3 of the Wheatstone bridge, through the winding L_1, and over the front contact of relay EHO to ground. The locking winding L_1 is therefore energized so long as the relay EHO holds up its armature. Consequently the relay PR_1 maintains its armature locked against its front contact to keep the short circuit 12 closed during the continuance of the train of waves. This is evident from the fact that the relay EHO exercises its locking control over the winding L_1 before the relay CHO has released its armature to prevent the bridge current from energizing the winding L_1.

After the relay PR_1 has once been locked up the relay PR_2 alone vibrates its armature in response to variations in impulses, and at the end of the last impulse of the train the armature of this relay falls upon its back contact and there remains.

The armature of the relay PR_2 opens the circuit of the relay VHO which, after a short interval, releases its armature thereby short circuiting relay RT whose armature falls off and closes short circuit 11. The relay EHO is also short circuited. Its upper contact disconnects ground from the lower terminal of the winding L_1. As no impulse is flowing through the operating winding O_1 at this time, the bias winding B_1 shifts the armature to its back contact, thereby closing the arm R_1 of the bridge and opening the short circuit 12. This energizes the relay CHO to close the arm R_2 of the bridge which is again balanced so that no current flows through the auxiliary winding L_1. It may be seen that in this modification of the circuit the relay PR_1 is locked up on the first impulse of sufficient strength to lift its armature from its back contact, and it remains so locked up until the end of the last impulse of the train when it is unlocked under the control of the relay PR_2 thru EHO. This circuit arrangement has a slight advantage over the circuit arrangement of Figure 2, owing to the fact that the hang-over effect produced by the relay CHO at the beginning of the train of waves, and which allows the hang-over relays EHO and VHO time to operate, is under the control of a slow release relay CHO instead of a slow operating relay as in the case of Figure 2. It is easier to attain the necessary delay by means of a slow release relay than a slow operating relay.

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. An echo suppressor comprising a translator, a first relay responsive to impulses of translated current from said translator, a disabling circuit controlled by said relay, a second relay responsive to impulses of translated current from said translator, a hang-over relay controlled by said second relay, said hang-over relay also controlling said disabling circuit, a locking winding for said first relay, and means including said locking winding operating in response to the actuation of said first relay to maintain it actuated for a predetermined period of time.

2. An echo suppressor comprising a translator, a first relay responsive to impulses of

translated current from said translator, a disabling circuit controlled by said relay, a second relay responsive to impulses of translated current from said translator, a hang-over relay controlled by said second relay, said hang-over relay also controlling said disabling circuit, a locking winding for said first relay, means including said locking winding operating in response to the actuation of said first relay to maintain it actuated for a predetermined period of time, and means for controlling said locking winding by said second relay.

3. An echo suppressor comprising a translator, a first relay responsive to translated impulses from said translator, an armature for said relay having front and back contacts, a disabling circuit controlled from the front contact of said relay, a second relay responsive to impulses of translated current from said translator, a hang-over relay controlled by said second relay, said hang-over relay also controlling said disabling circuit, a locking winding for said first relay, and means to energize said locking winding for a predetermined period in response to the shifting of the armature of said relay from its back contact.

4. An echo suppressor comprising a translator, a first relay responsive to translated impulses from said translator, an armature for said relay having front and back contacts, a disabling circuit controlled from the front contact of said relay, a second relay responsive to impulses of translated current from said translator, a hang-over relay controlled by said second relay, said hang-over relay also controlling said disabling circuit, a locking winding for said first relay, means to energize said locking winding for a predetermined period in response to the shifting of the armature of said relay from its back contact, and means for controlling said locking winding by said second relay.

5. An echo suppressor comprising a translator, a first relay controlled by impulses of translated current from said translator, an armature for said relay having front and back contacts, a disabling circuit controlled from the front contact of said relay, a second relay controlled by translated impulses from said translator, a hang-over relay controlled by said second relay, said hang-over relay also operating said disabling circuit, a locking winding for said first relay, means to energize said locking winding when the armature of said first relay is shifted from its back contact, and a timing relay controlled by said armature to maintain said locking winding operated for a predetermined period of time sufficiently long to enable said hang-over relay to operate said disabling circuit.

6. An echo suppressor comprising a translator, a first relay controlled by impulses of translated current from said translator, an armature for said relay having front and back contacts, a disabling circuit controlled from the front contact of said relay, a second relay controlled by translated impulses from said translator, a hang-over relay controlled by said second relay, said hang-over relay also operating said disabling circuit, a locking winding for said first relay, means to energize said locking winding when the armature of said first relay is shifted from its back contact, a timing relay controlled by said armature to maintain said locking winding operated for a predetermined period of time sufficiently long to enable said hang-over relay to operate said disabling circuit, and means whereby the circuit of said locking winding may be controlled from said second relay.

7. An echo suppressor comprising a translator, a first relay controlled by impulses of translated current from said translator, an armature for said relay having front and back contacts, a disabling circuit operated over the front contact of said armature, a second relay controlled by impulses of translated current from said translator, a hang-over relay operated by said second relay after it has responded to said translated current, means controlled by said hang-over relay for operating said disabling circuit, a locking winding for said first relay, a circuit for said locking winding established upon the shifting of the armature of said relay from its back contact, an auxiliary relay also controlled by the armature of said first relay and operating to open the circuit of said locking winding a predetermined period after said first relay has shifted its armature, said predetermined period being sufficiently long to enable said hang-over relay to operate said disabling circuit.

8. An echo suppressor comprising a translator, a first relay controlled by impulses of translated current from said translator, an armature for said relay having front and back contacts, a disabling circuit operated over the front contact of said armature, a second relay controlled by impulses of translated current from said translator, a hang-over relay operated by said second relay after it has responded to said translated current, means controlled by said hang-over relay for operating said disabling circuit, a locking winding for said first relay, a circuit for said locking winding established upon the shifting of the armature of said relay from its back contact, an auxiliary relay also controlled by the armature of said first relay and operating to open the circuit of said locking winding a predetermined period after said first relay has shifted its armature, said predetermined period being sufficiently long to enable said hang-over relay to operate said disabling circuit, and

means to establish an independent circuit for said locking winding under the control of said second relay.

9. A transmission system having a pair of paths one of which transmits in one direction and the second of which transmits in the opposite direction, means to normally disable the first of said paths, an echo suppressor associated with said first path comprising a translator, a relay responsive to impulses of translated current from said translator, an armature for said relay having front and back contacts, a disabling circuit for said second path operated over the front contact of said armature, a second relay responsive to impulses to translated current from said translator, means controlled by said second relay to defeat the disabling means for said first path and maintain said path in condition for transmission for a predetermined time after the translated impulses cease, a hang-over relay controlled by said second relay, said hang-over relay operating after said second relay responds to translated impulses and being maintained in operation for a predetermined time after the translated impulses cease, means controlled by said hang-over relay for operating said disabling circuit for said second transmission path, a locking winding for said first relay, means to establish an energizing circuit for said locking winding upon the shifting of the armature of said first relay from its back contact, and means to maintain said circuit closed for a predetermined period sufficiently long to enable said hang-over relay to operate the disabling means for said second mentioned path.

10. A transmission system having a pair of paths one of which transmits in one direction and the second of which transmits in the opposite direction, means to normally disable the first of said paths, an echo suppressor associated with said first path comprising a translator, a relay responsive to impulses of translated current from said translator, an armature to said relay having front and back contacts, a disabling circuit for said second path operated over the front contact of said armature, a second relay responsive to impulses of translated current from said translator, means controlled by said second relay to defeat the disabling means for said first path and maintain said path in condition for transmission for a predetermined time after the translated impulses cease, a hang-over relay controlled by said second relay, said hang-over relay operating after said second relay responds to translated impulses and being maintained in operation for a predetermined time after the translated impulses cease, means controlled by said hang-over relay for operating said disabling circuit for said second transmission path, a locking winding for said first relay, means to establish an energizing circuit for said locking winding upon the shifting of the armature of said first relay from its back contact, means to maintain said circuit closed for a predetermined period sufficiently long to enable said hang-over relay to operate the disabling means for said second mentioned path, and an independent circuit for said locking winding established under the control of said second relay.

11. A relay system, comprising a relay, means to impress impulses of current upon said relay, an armature for said relay having front and back contacts, means responding to the lifting of the armature of said relay from its back contact to positively shift said armature to its front contact independently of the impulse which initiated the movement of the armature, and means controlled by said relay for maintaining its armature against its front contact for a predetermined interval.

12. A relay system, comprising a relay, means to impress impulses of current upon said relay, an armature for said relay having front and back contacts, means responding to the lifting of the armature of said relay from its back contact to positively shift said armature to its front contact independently of the impulse which initiated the movement of the armature, and means controlled by said relay for maintaining its armature against its front contact for a predetermined interval and permitting the return of the armature to its back contact at the end of said interval.

In testimony whereof, I have signed my name to this specification this 7th day of July, 1925.

HAROLD C. SILENT.