May 16, 1933. E. R. TAYLOR ET AL 1,909,433

VOICE OPERATED CONTROL ARRANGEMENT FOR RADIO TELEPHONE SYSTEMS

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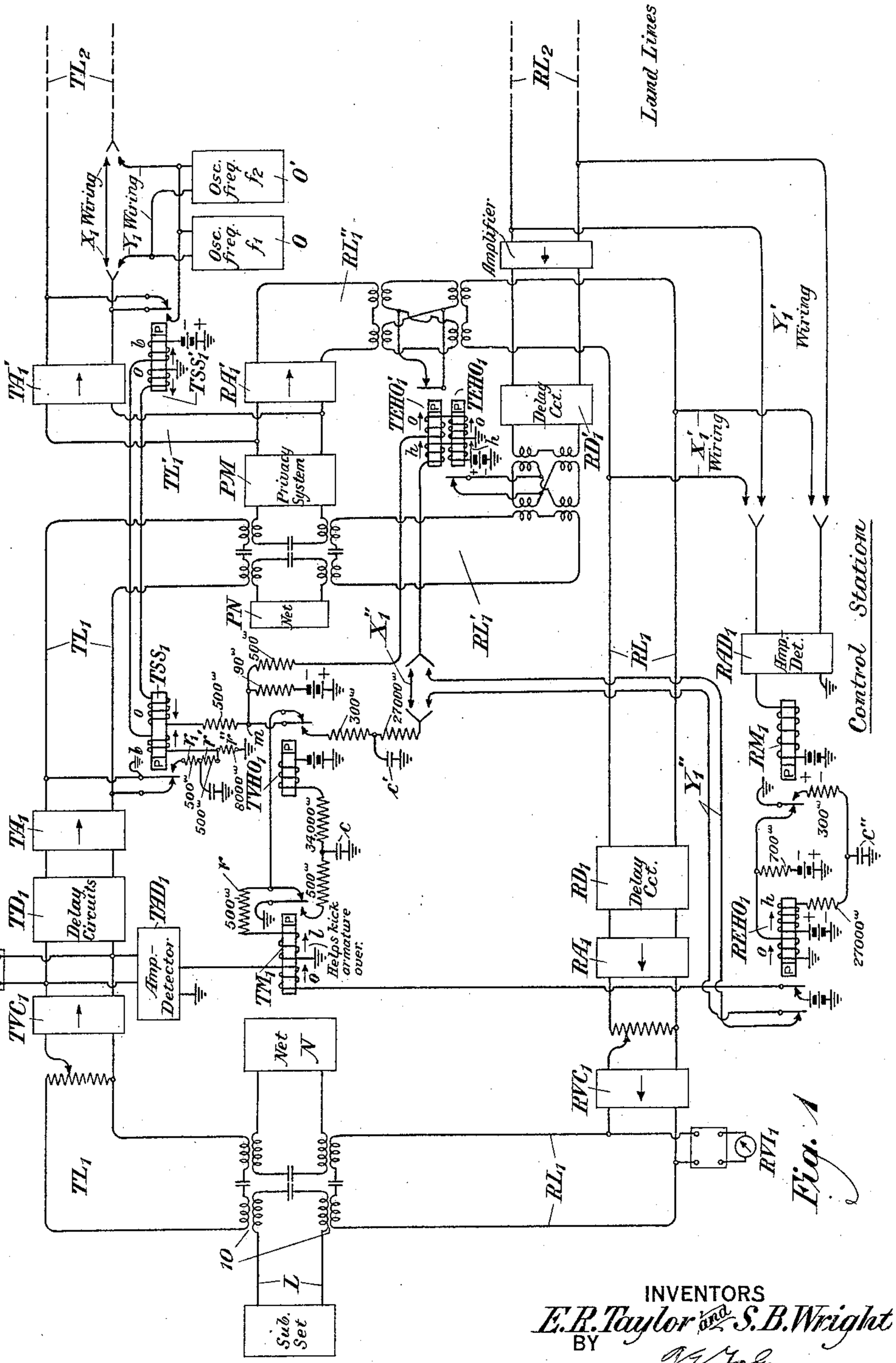

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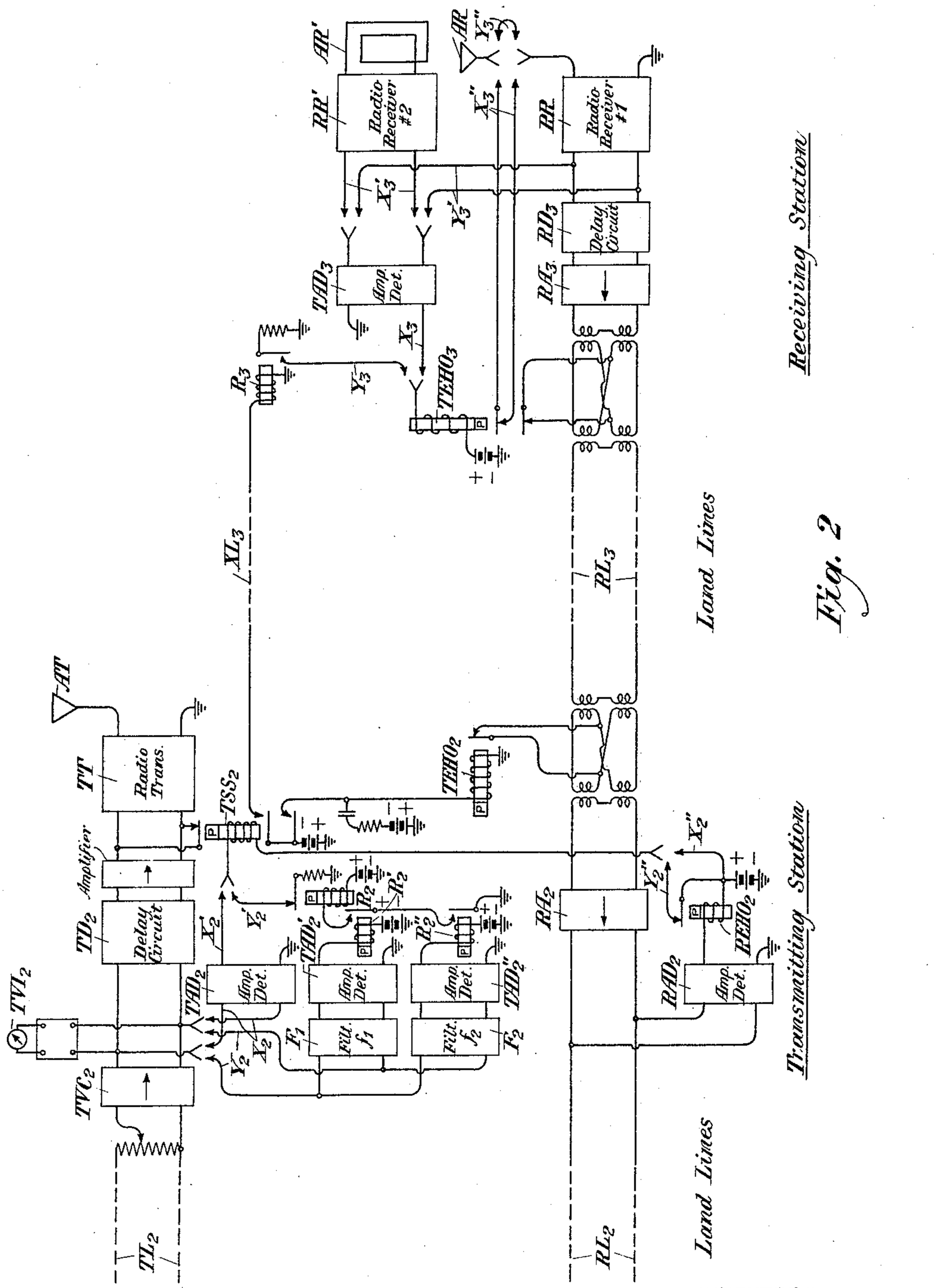

Fig. 2

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UNITED STATES PATENT OFFICE

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VOICE OPERATED CONTROL ARRANGEMENT FOR RADIO TELEPHONE SYSTEMS

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This invention relates to arrangements for the prevention of echo and singing currents in four-wire telephone transmission circuits and more particularly to such arrangements when used in connection with a radio telephone system.

In radio telephone systems, such, for example, as the radio telephone system between New York and London, a control station is provided at the terminals (New York and London) whereby technical operators and other supervisory attendants may readily control and adjust the various pieces of apparatus located at the terminals and whereby suitable transmission adjustments may be made for telephone transmission in either direction. At each terminal the control station is connected to the associated radio transmitter and radio receiver by a four-wire circuit comprising a transmission line extending from the control station to the radio transmitting station for transmission in one direction and a separate line from the corresponding receiving station to the control station for transmission in the opposite direction.

In existing arrangements of this type the suppression of singing and echo currents either over the local four-wire circuit at each terminal or over the over-all four-wire circuit from terminal to terminal has been accomplished by providing duplicate voice-operated apparatus at each terminal control station, the apparatus at each terminal comprising a voice-operated device associated with the transmitting line to clear the transmitting line which is normally disabled and to disable the local receiving line and a second voice-operated device associated with the local receiving line to disable the local transmitting line. The transmission of noise from the local transmitting line through the radio transmitter at the end thereof to the associated radio receiver and thence into the receiving line during times that the receiving line was being used for reception, has heretofore been prevented by wide geographical separation and by use of directive radio methods. Likewise when the transmitting line and radio transmitter were employed for transmission undue interference from the radio transmitter into the local receiving line was kept at a minimum by having the radio transmitter and radio receiver associated with a given terminal widely separated geographically and by the use of directive radio methods.

There are certain disadvantages in providing a wide geographical separation between the radio transmitter and the radio receiver associated with the same terminal, and moreover, as the number of radio communication channels between the same terminals increases, it becomes increasingly difficult to locate an associated radio transmitter and radio receiver sufficiently far apart from each other to accomplish the desired end and at the same time prevent interference with similar radio stations. It is therefore desirable to locate the radio transmitter and the radio receiver associated with a given terminal in the same general neighborhood. For example, instead of having the radio transmitter for the New York terminal at some point on Long Island the corresponding radio receiver in Maine, as is the case with the existing long wave transatlantic radio telephone system, there are many factors making it desirable to arrange both the radio transmitter and the radio receiver in Maine, with the receiving line of the connecting four-wire circuit running from the receiving station to New York through or in the neighborhood of the radio transmitter. A similar geographical arrangement could of course be made for the London terminal.

Such an arrangement of the radio apparatus makes it necessary to provide special arrangements for preventing the transmission of noise from the radio transmitter to the radio receiver and thence over the receiving line during idle periods of the transmitting line. Due to the proximity of the radio transmitter to the radio receiver the transmission received from the local radio transmitter during transmission over the transmitting line will be so much greater in volume than that received from the distant terminal that such interfering transmission may overload the receiving line and result in crosstalk in

adjacent circuits or in distortion in normally received signals due to potentials set up by the overloading currents. This makes it necessary to provide special arrangements for disabling the receiving circuit when the radio transmitter is transmitting.

Noise from the transmitter is prevented by maintaining the radio transmitter normally disabled and by providing an auxiliary voice-operated arrangement for removing the disabling means whenever the transmitting line is used for transmission. The overloading of that portion of the receiving line extending from the radio transmitter staiton to the control station may be prevented by utilizing the same voice-operated apparatus at the radio transmitter for disabling the receiving line at the radio transmitter station. Where overloading occurs in that portion of the receiving line intervening between the radio transmitter and the radio receiver, such overloading may be prevented by providing auxiliary voice-operated equipment at the radio receiving station for disabling the radio receiving circuit at the radio receiver station when the associated radio transmitter is transmitting. Such voice-operated equipment may be made marginal, so that it will respond only to transmission from the local radio transmitter and not to transmission from the transmitter associated with the distant terminal, thus taking advantage of the fact that the transmission from the local transmitter is much greater in volume than that from the distant transmitter. If desired the voice-operated apparatus at the radio receiving station may be controlled by a separate radio receiver provided with directive equipment so as to render it still further responsive to signals from the direction of the local radio transmitter and less responsive to signals from the direction of the distant transmitter.

It is desirable that the attendants at the control station should have supervision and control so far as possible over all the voice-operated equipment associated with the circuit. Since, for the reasons above given, it is desirable to have auxiliary voice-operated equipment at the radio transmitter and radio receiver, and since such auxiliary equipment is not under the direct supervision and control of attendants at the control station, it is desirable that such auxiliary equipment be made as sensitive as possible so that it will respond to the initial parts of the telephone wave before it reaches its peak value. If the equipment is highly sensitive it will be possible to make the associated delay circuit smaller or even omit it without causing clipping.

On the other hand the auxiliary voice operated equipment must not be operated by noise currents, and if it is made sensitive its operating circuit must be fairly free from noise. If the four-wire circuit from the terminal to the radio equipment is so constructed as to be a high grade circuit and relatively free from noise as, for example, by laying it in cable, noise which might cause false operation of the voice-operated equipment at the radio station will be confined to that arising in connecting circuits which lead from the subscriber to the terminal control station. If such noise is prevented from getting to the radio transmitting station (and from thence to the local receiving station) the voice-operated equipment at the radio transmitting station and radio receiving station may be made very sensitive so that it will always respond to voice transmission. To prevent the terminal noise from being transmitted to the radio transmitter, it is necessary to provide equipment at the control station similar to that heretofore used in radio telephone circuit for suppressing echo and singing currents. Such apparatus will be so arranged as to maintain the transmitting line normally disabled except when transmission is taking place. The voice-operated equipment associated with the transmitting line at the control station will be arranged to remove the disabling means therefrom and will also disable the receiving line when the transmitting line is used for transmission. This equipment may be adjusted as to its sensitivity by the control station attendant who may also by suitable adjustments control the volume of voice transmission to be applied to the circuit. The voice-operated equipment associated with the receiving line of the control station will be arranged to disable the transmitting line when signals are being received from the distant terminal. The voice-controlled apparatus at the terminal station may also be arranged for the switching operations incidental to the use of privacy mechanism where such mechanism is employed.

In the arrangement so far outlined, bearing in mind that similar apparatus is associated with both terminals, it will be evident that full echo suppressor equipment for two-way control is provided at both terminals; and if no further arrangements are provided than those above described, the time during which "lock-out" may take place by reason of the two subscribers talking at substantially the same time (thereby each seizing control of his own transmitting line while blocking the associated receiving line as to transmission from the other subscriber) will be determined by the time of transmission from one controlling station to the other. Since the four-wire circuit extending from each control room to its corresponding radio transmitter and receiver may be of considerable length, the increased possibility of "lock-out" may become very serious especially if the four-wire circuits are loaded circuits,

It is therefore desirable to limit the lock-out time if possible to the time of transmission from one radio transmitter through the ether to the distant radio receiver and thence over the wire line to a point adjacent the distant radio transmitter.

To accomplish this result an auxiliary voice-operated equipment is associated with the receiving line at the transmitting station and is arranged to disable the auxiliary voice-operated equipment associated with the transmitting line at the transmitting station when the receiving line is used for reception. Full echo-suppressor equipment is thus provided at the transmitting station. At the same time the voice-operated equipment at the control station is modified by connecting the receiving voice-operated device to the receiving line at a point nearer the radio receiver than the point at which the disabling means is applied to the receiving line by the voice-operated device associated with the transmitting line at the control station. By this rearrangement of apparatus it will be evident that if the voice transmission from the distant terminal arrives at a point in the receiving line adjacent the local radio transmitter the voice-operated equipment associated with the transmitting line at the radio transmitter will be disabled and the distant talker will then have control of the circuit. This will be true even though the local talker has already operated the voice-operated equipment associated with his transmitting line at the control station because the transmission arriving over the receiving line from the distant talker can always operate the voice equipment associated with the receiving line at the control station to disable the transmitting line and the voice apparatus associated therewith at the control station.

A further feature of the invention involves the transmission of alternating currents over the transmitting side of the four-wire circuit during the time that the circuit is normally idle in order to enable an attendant at the radio transmitter station to make observations of the transmission equivalent of the circuit and to make such minor adjustments of the transmission equivalent as may be necessary from time to time. Where such alternating currents are provided they may be used to control voice-operated equipment at the radio transmitter in such a manner that intead of performing its functions when voice currents are received, it will perform its function when the alternating currents aforesaid cease, these alternating currents being automatically interrupted whenever voice transmission takes place.

The invention will now be more fully understood from the following description when read in connection with the accompanying drawings, Figs. 1 and 2 of which when placed end to end disclose a preferred circuit arrangement embodying the invention.

Referring to the drawings, a terminal control station is illustrated which is connected by means of a four-wire circuit to a radio transmitter and a radio receiver, it being understood that a similar arrangement is provided for the distant terminal. At the control station the four-wire circuit is associated by means of the usual hybrid coil 10 with a terminal line L which may be a toll circuit over which a subscriber may be connected to the system. Terminal line L is balanced by a suitable network N and is connected to the radio transmitter TT over a transmitting path comprising conductors TL_1 and TL'_1 at the control station and the line TL_2 leading from the control station to the transmitting station. A radio receiver RR is located at a receiving station and is connected to the terminal line L at the control station over a receiving path which includes a line RL_3 extending preferably (although not necessarily) to the transmitting station from whence a line RL_2 extends to the control station, the connection being completed over circuits RL'_1, RL''_1 and RL_1 at the control station.

A voice-operated apparatus is associated with the transmitting path at the control station and comprises an amplifier-detector TAD bridged across the circuit TL_1 and controlling a master relay TM_1, which in turn controls switching relays TSS_1 and TSS'_1 whose contacts normally disable the transmitting path, and echo hangover relays $TEHO_1$ and $TEHO'_1$ whose contacts when open disable the receiving path. A voice hangover relay $TVHO_1$ is also provided and is controlled by the master relay TM_1 which also controls the switching relays and echo hangover relays just described to give them a desired hangover. The TSS relays are quick to operate and quick to release their armatures. The TEHO relays while quick to operate are slow to release their armatures. All four relays are initially operated from the contact of the master relay TM_1, but as their release is determined by the voice hangover relay $TVHO_1$ the armatures of the TSS relays will be held up after the master relay TM_1 has released during the hangover time of the relay $TVHO_1$. The TEHO relays are also given an additional hangover time due to the fact that they are slow to release.

If desired a privacy mechanism PM of known type may be employed for rendering the voice currents unintelligible as they are transmitted over the line TL_2, the same mechanism functioning to restore to normal similarly distorted currents received from the distant station. As this privacy mechanism PM is common to both the transmitting and receiving path, the TSS relays and the TEHO relays perform the additional func-

tion of controlling the association of the privacy mechanism with the transmitting path or the receiving path exclusively. For example, when the TSS relays are in their normal released condition the transmitting paths TL_1 and TL'_1 on either side of the privacy mechanism are short-circuited so that transmission cannot take place over the transmitting path and through the privacy mechanism PM. The TEHO relays, which are also normally released, under the same conditions maintain their contacts closed. These contacts control balanced transformer arrangements, one in the receiving path RL'_1 on one side of the privacy mechanism and the other in the path RL''_1 on the other side thereof. These balanced transformer arrangements are so arranged that when the contacts of the TEHO relays are closed transmission through them will take place. When, however, the contacts are open, as is the case when transmission takes place over the transmitting line, the balanced windings of each transformer arrangement are connected in opposing relation so that transmission is prevented. Under these conditions transmission cannot take place from the line RL_2 through the circuit RL'_1 to the privacy mechanism, and transmission is also prevented from the privacy mechanism and over circuit RL''_1 to the circuit RL_1. During the transmitting condition the short circuits across the path TL_1 and across the line TL_2 will be opened by the TSS relays, so that transmission can take place from the circuit TL_1 through the privacy mechanism to the transmitting line TL_2.

A voice-operated apparatus is also associated with the receiving side of the four-wire circuit, said apparatus comprisng an amplifier-detector RAD_1 which controls a master relay RM_1 which, in turn, controls an echo hangover relay $REHO_1$. When the amplifier-detector responds to received transmission, the later relay opens a circuit of the master relay TM_1 associated with the transmitting side of the circuit and thereby prevents the operation of the TSS relays and the TEHO relays so that the transmitting path will be disabled while transmisison can take place freely over the receiving path. The amplifier-detector RAD_1 may be bridged across either the receiving path RL_1 by means of the X'_1 wiring or it may be bridged across the receiving end of the line RL_2 by means of the Y'_1 wiring. When the former wiring is employed the arrangement so far described is that heretofore used in connection with the transatlantic radio telephone system.

A delay circuit DT_1 is connected in the transmisison path TL_1 to delay the voice currents until the TSS relays have had time to respond to the amplifier-detector TAD_1 to remove the short-circuits from the transmitting circuit. Similarly a delay circuit RD_1 is provided for enabling the relay $REHO_1$ to respond to the amplifier-detector RAD_1 to disable the master relay TM_1 before the voice currents incoming from the receiving path can pass through the hybrid coil 10 and cause false operation of the amplifier-detector TAD_1. A volume control device TVC_1 which may comprise an amplifier with an adjustable potentiometer is associated with the transmitting path TL_1 to enable an attendant to maintain the volume level substantially constant, a volume indicator TVI_1 being provided to enable the attendant to observe variations in the volume as the speaker raises or lowers his voice. Amplifiers TA_1 and TA'_1 are connected in the transmitting circuits TL_1 and TL'_1, respectively, and similarly, receiving amplifiers RA'_1 and RA_1 are connected in the receiving paths RL''_1 and RL_1, respectively. The receiving path may also include a volume control apparatus RVC_1 and volume indicator RVI_1 for enabling the control station attendant to regulate the received volume.

Assuming that the X'_1 wiring is used for the amplifier-detector RAD_1, the operation will be as follows: Voice currents incoming from the line L will pass into the transmitting path TL_1 and enter the delay circuit TD_1. In the meantime the amplifier-detector TAD_1 is operated to cause current to flow through the operating winding *o* of the relay TM_1 which attracts its armature. As soon as the armature leaves the back contact, ground is removed from the point *m*, thereby removing the short-circuit from the operating windings *o* of the TSS relays and the TEHO relays which are immediately actuated.

During the time that the armature of the relay TM_1 is passing to its front contact, current flows from battery through the 90-ohm resistance to the point *m* and thence over the back contact of the relay $TVHO_1$ and through the 500-ohm resistance *r* and through the locking winding *l* of the relay TM_1, this current flowing by virtue of the removal of the short-circuit from the resistance *r* and winding *l* when the armature of the relay TM_1 is actuated. When the armature of the relay TM_1 reaches its front contact the previously charged condenser *c* is discharged and the relay $TVHO_1$ is operated. This relay is given a hangover time by virtue of the fact that a charging current into condenser *c* flows through the 34,000-ohm resistance and through its winding, thus maintaining the current flow for a predetermined period after the armature of the relay TM_1 leaves its front contact.

As soon as the armature of the relay $TVHO_1$ leaves its back contact, the circuit into locking winding *l* of the master relay TM_1 is opened, leaving the master relay free to fall off in response to cessation of the signal current. Upon arriving at its front

contact the armature of the relay $TVHO_1$ connects the condenser c' (which had been previously charged positively through the holding windings h of the relays $TEHO_1$ and $TEHO'_1$) to the point m, thereby enabling the condenser to discharge to the negative battery through the 300-ohm and 90-ohm resistances and complete a holding circuit from the negative battery through the 90-ohm resistance to the point m and thence through the 300-ohm and 27,000-ohm resistances to the holding windings h of the TEHO relays, from which point the circuit is completed to positive battery. Consequently, when the armature of the voice hangover relay $TVHO_1$ releases to again short-circuit the operating windings o of the TEHO relays, said relays are given an additional hangover time after the release of the hangover relay $TEHO_1$ due to the fact that a charging current flows through the windings h of the TEHO relays to charge the condenser c', this charging current flowing in such a direction as to cause holding windings h to hold up the armatures of the TEHO relays until the charging current through the 27,000-ohm resistance has decayed to a predetermined value. Consequently, the TEHO relays do not release their armatures for a predetermined time after the TSS relays release their armatures, since the latter relays release their armatures instantly when the armature of the relay $TVHO_1$ falls off its front contact.

In connection with the TSS relays it will be remembered that they were energized through their operating windings as soon as the armature of the master relay TM_1 left its back contact to remove the short-circuit from the point m. The TSS relays upon being energized remove the short-circuits from the paths TL_1 and TL'_1, respectively, thereby completing the transmission circuit through the privacy mechanism PM. The armature of the relay TSS_1 at its front contact connects ground through the small 500-ohm resistances r' to the bucking windings b of the TSS relays, thereby increasing the current through these windings (which previously had been very small due to the 8,000-ohm resistance r'' in series therewith). Hence an opposing pull is produced upon the armatures of the TSS relays as soon as their armatures have been shifted, such pull being in a direction to oppose the holding force exerted by the operating windings. This bucking or opposing force will be less than that exerted by the operating windings but tends to effect a quick snappy release of the armatures of the TSS relays as soon as current ceases to flow through the operating windings upon the release of the voice hangover relay $TVHO_1$.

Returning, again, to the TEHO relays which were energized in the manner previously described, it will be noted that in the normal condition of the circuit the receiving path is normally operative from the receiving line RL_2, through the path RL'_1, through the privacy mechanism PM, and through the path RL''_1 to the path RL_1. When the TEHO relays are energized, however, so that their contacts are open, the balanced transformers controlled thereby have their windings connected in opposing relation, thereby blocking the connection from the line RL_2 to the path RL'_1 and similarly blocking the connection from the path RL''_1 to the path RL_1. Consequently, the voice currents which pass through the delay circuit DT_1 by the time the TSS relays have operated, are free to pass through the privacy mechanism and over the line TL_2 to the radio transmitter TT from which they are radiated to the distant terminal.

When the voice currents cease the TSS relays fall off after an interval sufficient to allow all of the voice currents stored up in the voice circuit TD_1 to be transmitted. The TEHO relays, however, hang over a sufficiently longer interval to insure that no echo currents passing over the transmitting line TL_1 come back over the receiving line RL_2 to cause false operation of the amplifier-detector RAD_1. As soon as the TEHO relays release, however, the receiving circuit is in normal receiving condition.

If, under these circumstances, transmission from the distant terminal is received by the radio receiver RR and transmitted over the lines RL_3 and RL_2 in tandem, such voice currents will pass into the path RL'_1, through the privacy mechanism PM into the circuit RL''_1, and thence over the circuit RL_1 to the receiving delay circuit RD_1. Some of the energy passes over the X'_1 wiring, however, to the amplifier-detector RAD_1, thereby energizing the master relay RM_1, which in turn causes the relay $REHO_1$ to be energized by removing the short circuit from its operating winding o. The relay $REHO_1$ opens the operating circuit of the master relay TM_1 and thereby prevents the amplifier-detector TAD_1 from exercising any control over the TSS and TEHO relays previously described. The armature of the relay RM_1 upon reaching its front contact causes the discharge of the condenser c'' and completes a circuit through the holding winding of the relay $REHO_1$. In the meantime, by the time the relay $REHO_1$ has pulled up its armature to disable the transmitting voice-operated apparatus, the voice currents have passed through the delay circuit RD_1 and pass on to the terminal line L.

When the voice currents cease the relay RM_1 releases its armature, again short-circuiting the operating winding of the relay $REHO_1$. Said relay does not immediately release, however, as a charging current flows through its hold-over winding h and through

the 27,000-ohm resistance to charge the condenser c''. This charging current holds up the armature of the relay $REHO_1$ for a sufficient length of time to enable all of the voice currents stored up in the delay circuit RD_1 to pass to the line L and for the echoes of said currents to return from any unbalances in line L before the relay releases.

The operation above described is that of the apparatus as now used for the existing transatlantic radio telephone system. In this system, however, the radio transmitter and radio receiver are widely separated geographically, and furthermore, additional effective separation is accomplished by radio balance to prevent undue reaction of the radio transmitter upon the radio receiver. It is not always possible, however, to have the radio transmitter and radio receiver widely separated geographically and the radio balance methods are not sufficient where the stations are reasonably close together to prevent interference. In accordance with the present invention, therefore, voice control means are provided for preventing interference.

The interference from the radio transmitter to the radio receiver may be of two kinds. When the transmitting channel is not being used to transmit telephone currents, noise arising in the line or transmitting apparatus may modulate the radio carrier and be transmitted to the ether as interference. Also when the transmitting channel is used for voice transmission the modulated radio currents may be received at the radio receiver in such volume as to overload the receiving line amplifiers, thus resulting in crosstalk into adjacent telephone circuits or distortion in the normally received signals due to potentials set up by the overloading currents. The first of these effects is eliminated by maintaining the transmitter TT normally short-circuited over the contact of the relay TSS_2. The shortcircuit may be removed in response to voice currents by connecting the relay over the wiring X'_2 to the output of an amplifier-detector TAD_2 which, by means of wiring X_2 may be bridged across the transmitting line TL_2. A delay circuit TD_2 is provided to hold up the transmission of the telephone currents until the relay TSS_2 has had time to remove the short-circuit in response to the voice currents.

The auxiliary voice-operated apparatus at the radio transmitter station will not require as careful supervision as that of the control station if the line TL_2 is a line relatively free from noise as will be the case if it is in cable, and if the arriving voice currents are maintained at a substantially constant volume level. The latter is readily accomplished by adjusting the volume at the control station through the volume control arrangement TVC_1. By maintaining the volume level of the transmitted voice currents relatively high and by keeping the line comparatively free from noise, the amplifier-detector TAD_2 at the transmitting station may be made as sensitive as desired. Consequently the relay TSS_2 may always be depended upon to operate in response to received voice currents. An auxiliary volume control apparatus TVC_2 which may comprise an amplifier with a potentiometer adjustable either manually or automatically in response to received signals, is provided at the transmitting station for the purpose of taking care of gradual changes in volume due to slow changes in the attenuation of the circuit TL_2, thereby further insuring that the voice currents to operate the amplifier-detector TAD_2 will have the required volume.

By having the amplifier-detector extremely sensitive the delay circuit TD_2 may be made very small or even omitted entirely, which is an advantage not only from an economic standpoint but from the standpoint of lockout time, as will be explained later. The delay circuit is merely for the purpose of allowing time for the operation of the relay TSS_2 after the voice current is received. The initial voice wave is of course of very small magnitude and builds up to a peak value, thereafter rising and falling in accordance with the nature of the sounds. If the amplifier-detector is very sensitive the relay TSS_2 will open the short-circuit in response to the beginning of the telephone wave and it will be unnecessary to provide a delay circuit of such size as to hold up the beginning of the voice wave until it has been built up in the amplifier-detector TAD_2 to somewhere near its peak value in order to operate the relay TSS_2. Under these circumstances a very small delay circuit serves to prevent initial clipping and, in fact, where a slight amount of clipping can be tolerated, the delay circuit may be omitted entirely.

The arrangement above described takes care of interference due to noise modulation in the radio transmitter during non-transmitting intervals. There remains, however, the necessity of preventing overloading of the receiving circuit during idle periods of the receiving line when the transmitting line is operated. Where the radio transmitter and radio receiver are very close together so that the principal overloading effect will be in the line RL_2 between the control station and the transmitting station, this effect may be overcome by providing a relay $TEHO_2$ under the control of an extra contact of the relay TSS_2, the relay $TEHO_2$ by its contact controlling transmission through a balanced transformer arrangement in the receiving line similar to those previously described. When the relay $TEHO_2$ is deenergized, as is the case during normal condition of the circuit, it establishes such connection over its back contact that the windings of the trans-

former arrangement do not oppose each other and transmission may take place freely from the circuit RL_3 to the circuit RL_2. When the relay $TEHO_2$ is operated in response to voice currents received over the transmitting line TL_2, its contact is opened and the transformer windings oppose each other so that transmission does not take place through the line RL_3 to the line RL_2 and consequently overloading currents will not be transmitted into the line RL_2.

Where that portion of the receiving path RL_3 extending from the receiving station to the transmitting station is relatively long, the overloading effect may be serious in the line RL_3. This may be taken care of by a relay R_3 operated over an auxiliary line XL_3 from an additional contact of the relay TSS_2 at the radio transmitter. By use of the wiring Y_3 the relay R_3 controls the circuit of the relay $TEHO_3$ at the receiving station which, by means of its contact controls a balanced transformer arrangement similar to that controlled by the relay $TEHO_2$ at the radio transmitter whereby transmission from the radio receiver RR to the line RL_3 will be prevented when the radio transmitter TT is operated in response to speech. If the overloading effect occurs in the radio receiver RR itself, the relay $TEHO_3$ may have an additional contact whereby the radio antenna AR may be disconnected by using the wiring X''_3.

Since the auxiliary line XL_3 involves a certain delay in transmission before the relay R_3 will operate while the radio transmission from the radio transmitter TT to the radio receiver RR is almost instantaneous, it will of course be necessary to provide in the receiving circuit at the receiving station a delay circuit RD_3 to enable the relay $TEHO_3$ to operate before the voice currents received from the radio transmitter TT at the receiver RR will have had time to be transmitted to the line RL_3. Where the line XL_3 is fairly long this will represent a considerable disadvantage and the amount of delay at RD_3 may be considerably reduced by operating the relay $TEHO_3$ by means of the radio currents received from the radio transmitter TT. This may be accomplished by changing the relay $TEHO_3$ from its wiring Y_3 to an alternative wiring X_3 leading to the output of an amplifier-detector TAD_3. This amplifier-detector should be so adjusted that the relay $TEHO_3$ will be non-responsive to current received from the transmitting station at the distant terminal but will respond to the much greater current received from the radio transmitter TT. When the overloading effect is not too large in the receiver RR the input of the amplifier-detector TAD_3 may be connected over the wiring Y'_3 to the output of the radio receiver RR. Consequently, when voice-modulated radio currents are received from the transmitter TT the amplifier-detector TAD_3 causes the relay $TEHO_3$ to disable the connection to the receiving line RL_3. The operation of the amplifier-detector TAD_3 from the radio receiver RR requires that the antenna AR be not disabled by the relay $TEHO_3$ and consequently with this method of operation the antenna should be changed to the alternative wiring Y''_3.

In this case the delay circuit RD_3 must involve sufficient delay to permit the initial received voice wave from the transmitter TT to build up to a value somewhat above that of the maximum voice wave received from the distant terminal. The delay time necessary may be reduced, however, if an auxiliary receiver RR′ is used to operate the amplifier-detector TAD_3 and its antenna AR_3 is made directive so as to increase the response from the antenna AT while discriminating against reception from the transmitting antenna at the distant terminal. In this case the amplifier-detector TAD_3 is changed to the wiring X'_3. The current normally received from the distant radio transmitter in the auxiliary radio receiver RR′ with this arrangement will be very small as compared with that received in the receiver RR and since its response to the radio transmitter TT is very much greater, the initial voice wave from the latter transmitter will have sufficient amplitude to operate the relay $TEHO_3$ and only a minimum amount of delay in the delay circuit RD_3 will be necessary to enable the relay $TEHO_3$ to operate before the voice currents arrive at the switching point. In fact, the delay circuit RD_3 may in such case be omitted entirely without producing bad results. When the amplifier-detector TAD_3 is operated from the auxiliary receiver RR′ the antenna AR of the main receiver RR may be changed to the wiring X''_3 in which case any effect of overloading in the radio receiver RR will be prevented by the operation of the relay $TEHO_3$.

It will be observed that the arrangement so far described involves main voice-controlled apparatus at the control station and auxiliary voice-operated apparatus at the radio transmitter and radio receiving station. The former is necessary in order to effect the switching operations of the privacy mechanism. The apparatus at the radio transmitter is necessary in order to prevent the transmission of noise from the radio transmitter to the receiving line during reception, while the voice-operated apparatus at the receiving station is necessary to prevent overloading the receiving channel during voice transmission over the transmitting line. While the voice-operated apparatus at the radio transmitter and radio receiver might be made effective for the suppression of singing and echoes without providing voice-controlled equipment at the

control station, if no privacy mechanism PM were to be taken care of there is an additional reason for providing voice-operated apparatus at the control station even in the latter case. As has been previously pointed out the delay circuit TD_2 may be made very small or may even be omitted, if the amplifier-detector TAD_2 is made very sensitive and in addition, the voice currents are kept to a standard volume while at the same time the noise received from the line TL_2 is kept to a minimum. Now the noise arising from the line TL_2 itself may be kept very low if the line TL_2 is laid in cable but there is the connecting line L to be taken care of, which may lead across a continent to a subscriber, and in many cases this terminal connecting line may be fairly noisy. It is therefore necessary to provide the voice-operated apparatus at the controlling station in order that the transmitting path may be maintained normally disabled at that point, thereby preventing the transmission of noise from the line L to the amplifier-detector TAD_2 at the transmitting station.

As has been previously mentioned, it is desirable to keep the delay circuits at the radio transmitter and radio receiver small so as to reduce the possible time during which lockout may take place. With the arrangement so far described, where voice-controlled apparatus is provided both at the control station and at the radio transmitting and receiving stations, the lockout time is the time of transmission from the control station at one terminal to the control station at the other. For example, suppose the subscriber at the line L talks and the voice waves coming from his set operate the amplifier-detector TAD_1 at the control station, thereby disabling the receiving path at the control station. If it should happen that the distant talker commenced talking within a period of time equal to that required for transmission from the control station of the distant terminal to the control station at the terminal shown, such current received from the distant terminal will be blocked and cannot get to the subscriber at L, due to the disablement of the receiving path RL_1. In the meantime the subscriber at L, when his transmission arrives at the distant terminal control station, will find his transmission has been previously blocked by the distant subscriber. Both subscribers might thus talk for some time without either subscriber getting through to the other.

The above difficulty arises because each subscriber can block the other at the point of the four-wire circuit nearest the terminal. If the effective blocking action of the two talkers can be transferred to points nearer the middle of the intervening circuit, the possible lockout time will be reduced. For example, if the blocking effected by the two subscribers took place at points separated by zero transmission time, the lockout could only take place when both subscribers commenced talking at the same instant. In accordance with the present invention it is proposed to reduce this lockout time to the time of transmission from one radio transmitting station to the radio transmitting station at the distant terminal. This time will include the time of transmission through the ether, which is practically negligible from the standpoint of lockout, and the time of transmission over the wire line such as the line RL_3 from the radio receiver to the radio transmitter, which time may be made very small if the transmitting and receiving stations are fairly close together at each terminal.

In order that each subscriber's blocking action be made effective against the other subscriber at the radio station instead of at the terminal station, a voice-controlled equipment is associated with the receiving line at the radio transmitting station and the point of connection of the voice-controlled equipment associated with the receiving line at the control station is shifted so as to be bridged across the line ahead of the point at which it is disabled by the voice equipment associated with the transmitting line. Accordingly, as shown in the drawing, an amplifier-detector RAD_2 is bridged across the receiving line RL_2 at the transmitting station and controls a relay $REHO_2$. The circuit of the relay TSS_2 will then be changed from the direct connection to battery over the X''_2 wiring to the Y''_2 wiring which leads to battery over the contact of the relay $REHO_2$. At the control station the input of the amplifier-detector RAD_1 will be changed from the X'_1 wiring to the Y'_1 wiring so that it is in effect associated with the line RL_2 ahead of the disabling means controlled by the contacts of the relays $TEHO_1$ and $TEHO'_1$. A delay circuit RD'_1 is in this case also connected between the bridge point of the Y'_1 wiring and the disabling means controlled by the contact of the relay $TEHO_1$.

Suppose now the subscriber talks over the line L and operates the amplifier-detector TAD_1, thereby under the control of the TSS relays opening the transmitting path through to the line TL_2 and at the same time causing the TEHO relays to disable the connection from the receiving line RL_2 through the privacy mechanism PM to the receiving path RL_1. It will be observed that now the receiving path is disabled but the amplifier-detector arrangement RAD_1 is not disabled as it is associated with the line RL_2 ahead of the disabling means controlled by the TEHO relays. When the voice currents arrive at the transmitting station the amplifier-detector TAD_2 will be operated and through the relay $TEHO_2$ will disable the connection from the line RL_3 to the line RL_2 at the transmit-

ting station. The distant talker is now effectively blocked at this point. If, however, voice current from the distant talker had arrived over the line RL_3 so as to enter the amplifier-detector RAD_2 before the relay $TEHO_2$ operated, the relay $REHO_2$, in responding would disable the relay TSS_2 and thereby prevent the relay $TEHO_2$ from operating. Thus the receiving path would still be open to the control station. The current arriving at the control station from over the line RL_2 would enter through the wiring Y'_1 into the amplifier-detector RAD_1 (the path through the Y'_1 wiring not being blocked by the action of the TEHO relays), thereby causing the relay $REHO_1$ to open the circuit of the master relay TM_1 of the voice-operated equipment associated with the transmitting path at the control station. The delay circuit RD'_1 now functions to hold up the transmission of the voice current from the line RL_2 to the privacy mechanism PM until the disabling of the master relay TM_1 has had time to effect the restoring of the TEHO relays. As soon as this latter event occurs, the voice current from the delay circuit passes through the privacy mechanism PM and thence over the circuit RL_1 to the subscriber's line. Thus it will be seen that although the subscriber talking over the line L had operated the voice equipment at the control station and had set the circuit into transmitting condition up to the transmitting station, if the distant talker's current should arrive at the transmitting station before the voice currents from the line L arrived thereat the talker associated with the line L would fail to lockout the distant talker and the apparatus at the control station would be restored to receiving condition so that the distant talker would have control of the circuit.

Where it is desired to restore the TEHO relays more quickly the connection of these relays may be changed from the X''_1 wiring to the Y''_1 wiring. Then relay $REHO_1$ will restore relays $TEHO_1$ and $TEHO'_1$ through its extreme left hand contact without producing the result indirectly through the relay TM_1, thus reducing the time required for the operation.

A little consideration will show that if the current from the distant talker arrived at his transmitting station, prior to the arrival of the current from the line L at the transmitting station shown, by any time interval less than that required for a wave to be transmitted from the distant transmitter to the receiver RR and thence over the circuit RL_3 to the transmitting station, both talkers will disable their respective receiving paths and lock each other out. If, on the other hand, the talk from one subscriber arrives at his transmitter ahead of the time that the talk from the other subscriber arrives at the other transmitter by a time interval greater than the time of transmission from transmitter to transmitter, the first subscriber to talk will obtain control of the circuit without any possibility of the other being able to lock him out.

It is, of course, desirable to maintain the transmission loss of the transmitting path TL_2 substantially constant from the control office to the radio transmitter since a change in loss may cause a poor signal-to-noise ratio or overloading in the transmitter TT even though the relay operation is not impaired due to the high relay sensitivity. In order to enable an attendant at the transmitting station to make occasional adjustments at times when the circuit is not actually being used for transmission, arrangements may be made to transmit pilot waves over the line TL_2 from the control station, the attendant by suitable means observing any change in the amplitude of the received pilot wave and then making adjustments to bring the amplitude to normal. For this purpose oscillators O and O′ may be provided at the control station and the connection of the line TL_2 changed to the Y_1 wiring instead of the X_1 wiring to bring the oscillators into circuit. The waves of frequencies f_1 and f_2 from the two oscillators will then be transmitted over the line TL_2 at all times when the relay TSS'_1 is not operated. When voice currents are applied to the transmitting circuit so that said relay is operated it short circuits the oscillators O and O′ and prevents the transmission of the pilot waves at the transmitting station. The amplitude of the pilot waves may be observed by means of a volume indicator TVI_2, and if the volume is below or above normal the volume control apparatus TVC_2 may be adjusted by the attendant at the transmitting station.

With this arrangement a slightly different circuit for operating the relay TSS_2 is provided. Instead of having the amplifier detector TAD_2 bridged across the line by means of the X_2 wiring, the line bridge is changed to the Y_2 wiring so that the wave of frequency f_1 from the oscillator O will be selected by means of a filter F_1 into an amplifier-detector TAD'_2 and the wave of frequency f_2 from the other oscillator will be selected by means of the filter F_2 into the amplifier-detector TAD''_2. During non-talking intervals the two pilot waves will, while operating these two amplifier-detectors, keep the relays R'_2 and R''_2 energized, thereby maintaining the relay R_2 energized. The connection of the relay TSS_2 is shifted from the X'_2 wiring to the Y'_2 wiring so that the circuit of the latter relay is now controlled by the relay R_2. Consequently, as long as the waves of frequencies f_1 and f_2 are present the circuit of the relay TSS_2 is opened and the transmitter TT maintained short circuited. When voice currents are applied to the circuit and both

waves f_1 and f_2 suppressed in the manner previously described, the relay R_2 is deenergized by the falling off of the relays R'_2 and R''_2 and the relay TSS_2 is energized over the back contact of the relay R_2 to remove the short-circuit from the radio transmitter.

With the foregoing arrangement the function of the delay circuit TD_2 is not primarily to delay the transmission of voice currents but to hold up the transmission of the pilot waves (which enter the delay circuit as soon as the voice current ceases) until the relay TSS_2 has had time to release in response to the pilot waves. More than one pilot wave is provided in order to prevent false operation when the circuit is in condition for voice transmission. When the relay TSS_2 has been operated to put the transmitting circuit into transmitting condition, the short-circuit across the transmitter TT will not be again closed unless both relays R'_2 and R''_2 are energized. While it might happen that the voice current would contain a frequency corresponding to one of the filters F_1 and F_2, it would rarely happen that the voice current would contain both frequencies. One wave alone would not cause false operation of the relay TSS_2 and blocking of the voice current.

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 radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a transmitting line extending from said control station to said radio transmitting station, a receiving line extending from said radio receiving station to said control station, voice-operated means at the control station and responsive to voice currents transmitted over said transmitting line for disabling the receiving line at said control station, voice-operated means at said control station and responsive to voice currents received over said receiving line for preventing transmission over said transmitting line from the control station, means at said radio transmitting station normally preventing the radiation of signaling currents transmitted over said transmitting line, signal-operated means at said radio transmitting station responsive when voice currents are transmitted over said transmitting line to render said radiation-preventing means ineffective, and means at said radio receiving station responsive to radio transmission from said radio transmitting station to prevent transmission over said receiving line from said radio receiving station.

2. In a radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a transmitting line extending from said control station to said radio transmitting station, a receiving line extending from said radio receiving station to said control station, voice-operated means at the control station and responsive to voice currents transmitted over said transmitting line for disabling the receiving line at said control station, voice-operated means at said control station and responsive to voice currents received over said receiving line for preventing transmission over said transmitting line from the control station, means at said radio transmitting station normally preventing the radiation of signaling currents transmitted over said transmitting line, signal-operated means at said radio transmitting station responsive when voice currents are transmitted over said transmitting line to render said radiation-preventing means ineffective, a radio receiver at said radio receiving station for receiving signals from the distant terminal and transmitting them to said radio receiving line, and an auxiliary radio receiver at said radio receiving station responsive to radiation of signals from said radio transmitting station to prevent the transmission of signals from said first-mentioned radio receiver to said receiving line.

3. In a radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a transmitting line extending from said control station to said radio transmitting station, a receiving line extending from said radio receiving station to said control station, voice-operated means at the control station and responsive to voice currents transmitted over said transmitting line for disabling the receiving line at said control station, voice-operated means at said control station and responsive to voice currents received over said receiving line for preventing transmission over said transmitting line from the control station, means at said radio transmitting station normally preventing the radiation of signaling currents transmitted over said transmitting line, signal-operated means at said radio transmitting station responsive when voice currents are transmitted over said transmitting line to render said radiation-preventing means ineffective and to disable said radio receiving line at a point in the neighborhood of said transmitting station, and means at said receiving station responsive to transmission of signals from said radio transmitting station to prevent the transmission of received signals from said radio receiving station to said receiving line.

4. In a radio telephone system, a control station at which connections may be made

to a terminal line, a radio transmitting station, a radio receiving station, a one-way transmitting path extending from said control station to said radio transmitting station, a one-way receiving path extending from said radio receiving station to said control station, said paths being so isolated from each other that no part of either path serves as a common two-way transmission medium for both paths but the path to one of said radio stations passing in the immediate vicinity of the other radio station, voice-operated means at the control station and responsive to voice currents transmitted over said transmitting path for disabling the receiving line at said control station, voice-operated means at said control station and responsive to voice currents received over said receiving path for preventing transmission over said transmitting path from the control station, means at said radio transmitting station normally preventing the radiation of signaling currents transmitted over said transmitting path, signal-operated means at said radio transmitting station responsive when voice currents are transmitted over said transmitting path to render said radiation-preventing means ineffective, means responsive when voice currents are effectively transmitted from said transmitting path to said radio transmitting station to disable said receiving path at one of said radio stations, and means associated with said receiving path in the vicinity of said transmitting station and responsive to signals received over said receiving path from the distant terminal to prevent radiation from said radio transmitting station in response to currents transmitted over said transmitting path, said voice-operated means associated with the receiving path at the control station being so arranged as to defeat the disabling of said receiving path at the control station under the control of the voice-operated means associated with the transmitting path at the control station when said voice-operated means associated with the receiving path in the neighborhood of the radio transmitting station has been effectively operated.

5. In a radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a one-way transmitting path extending from said control station to said radio transmitting station, a one-way receiving path extending from said radio receiving station to said control station, said paths being so isolated from each other that no part of either path serves as a common two-way transmission medium for both paths but the path to one of said radio stations passing in the immediate vicinity of the other radio station, voice-operated means at the control station and responsive to voice currents transmitted over said transmitting path for disabling the receiving path at said control station, voice-operated means at said control station and responsive to voice currents received over said receiving path for preventing transmission over said transmitting path from the control station, said last mentioned voice-operated means being associated with the receiving path ahead of the point where it is disabled by said first mentioned voice-operated means, means controlled by said voice-operated means associated with the receiving path for defeating the disablement of said receiving path by said first mentioned voice-controlled means, means at said radio transmitting station normally preventing the radiation of signaling currents transmitted over said transmitting path, signal-operated means at said radio transmitting station responsive when voice currents are transmitted over said transmitting path to render said radiation-preventing means ineffective, means responsive when voice currents are effectively transmitted from said transmitting path to said radio transmitting station to disable said receiving path at one of said radio stations, and means associated with said receiving path in the vicinity of said transmitting station and responsive to signals received over said receiving path from the distant terminal to prevent radiation from said radio transmitting station in response to currents transmitted over said transmitting path.

6. In a radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a transmitting line extending from said control station to said radio transmitting station, a receiving line extending from said radio receiving station to said control station, means for normally disabling said transmitting line at the control station, voice-operated means associated with said transmitting line at the control station for defeating said disabling means, voice-operated means associated with said receiving line at the control station for disabling said transmitting line, means at said control station for maintaining the volume of the voice currents applied to said transmitting line at a substantially constant volume, highly sensitive voice-operated means associated with said transmitting line at said radio transmitting station, said last mentioned voice-operated means being effectively responsive to the weak initial part of a voice current wave, and means operated by said voice-operated means at the radio transmitting station to normally prevent transmission from said transmission station except when said voice-operated means is effectively operated, and means controlled by said voice-operated means at said radio transmitting station to disable said receiving line at a point remote from said control station.

7. In a radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a transmitting line extending from said control station to said radio transmitting station, a receiving line extending from said radio receiving station to said control station, voice-operated means associated with said transmitting line at said control station for normally controlling the transmission of pilot waves over said transmitting line to the radio transmitting station, an adjustable transmission element at said radio transmitting station for making transmission adjustments in accordance with the pilot waves received thereat, said voice-operated means at the control station operating in response to voice currents to prevent the transmission of said pilot frequencies and to permit the transmission of voice currents over said transmitting circuit, switching means at said radio transmitting station operating when said pilot waves are received to prevent radiation from said radio transmitting station but to permit radiation of energy corresponding to voice currents received over said transmitting line when the pilot waves cease.

8. In a radio telephone system, a control station at which connections may be made to a terminal line, a radio transmitting station, a radio receiving station, a transmitting line extending from said control station to said radio transmitting station, a receiving line extending from said radio receiving station to said control station, voice-operated means associated with said transmitting line at said control station for normally controlling the transmission of pilot means over said transmitting line to the radio transmitting station, an adjustable transmission element at said radio transmitting station for making transmission adjustments in accordance with the pilot waves received thereat, said voice-operated means at the control station operating in response to voice currents to prevent the transmission of said pilot waves and to permit the transmission of voice currents over said transmitting circuit, switching means at said radio transmitting station operating when said pilot waves are received to prevent radiation from said radio transmitting station but to permit radiation of energy corresponding to voice-currents received over said transmitting line when the pilot waves cease, and means controlled by said switching means at the radio transmitting station for disabling said receiving line at a point remote from said control station when said pilot waves cease.

9. A transmission system including an intermediate section with connecting sections, means at each end of said intermediate section to block the transmission of waves in either direction while waves are passing in the opposite direction, means at points of the connecting sections distant from the ends of said intermediate section to block the transmission of waves toward the intermediate section while waves are passing in the opposite direction, and means at said points to permit the passage of waves away from said intermediate section when such waves have passed the blocking means at the ends of said intermediate section.

In testimony whereof, we have signed our name to this specification this 6th day of September, 1929.

EDMUND R. TAYLOR.
SUMNER B. WRIGHT.