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VOLUME CONTROL IN TELEPHONE CIRCUITS

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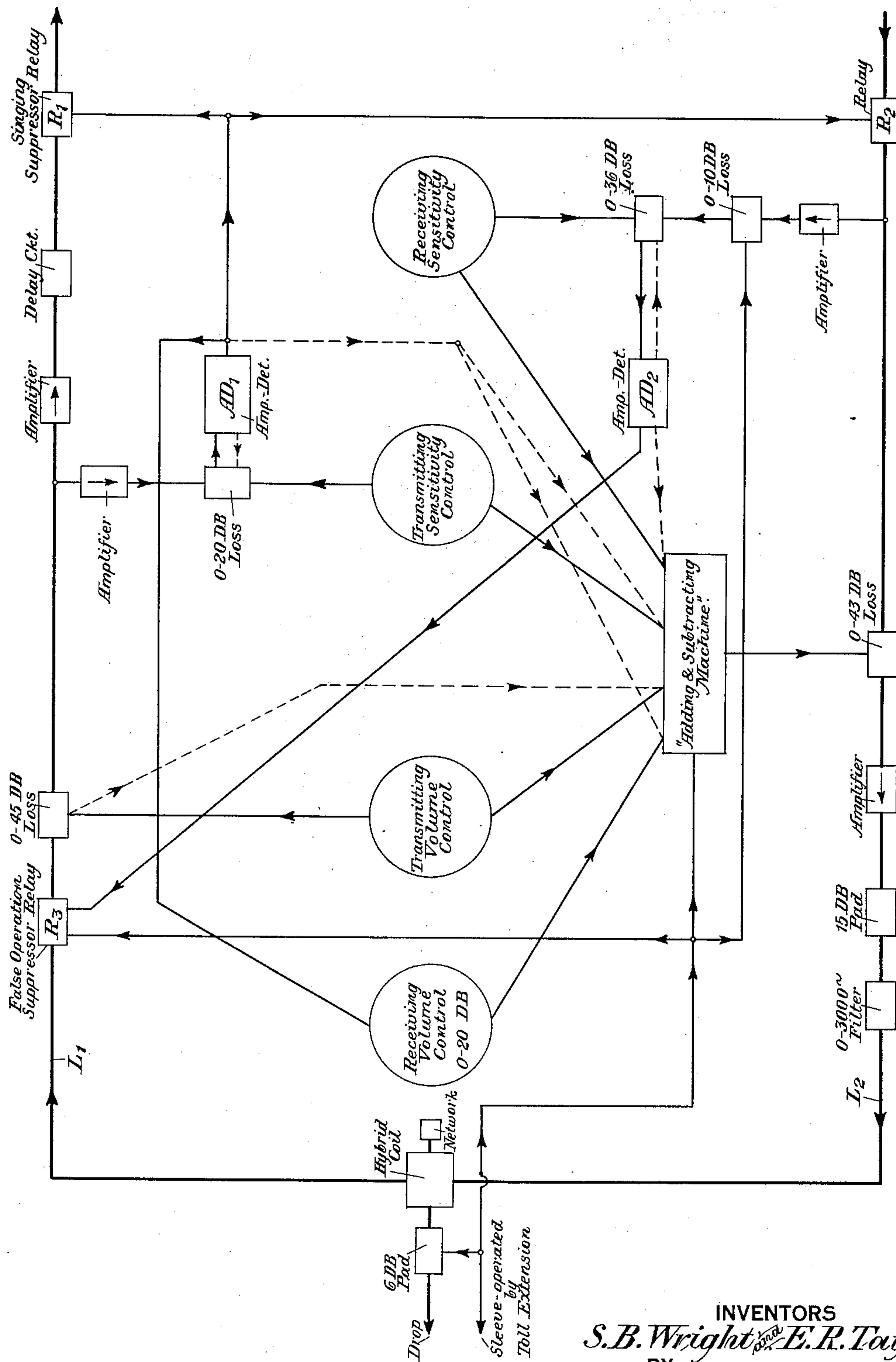


Fig. 1

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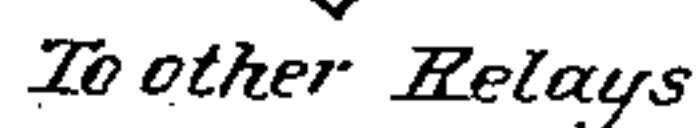


Fig. 2

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VOLUME CONTROL IN TELEPHONE
CIRCUITS

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Serial No. 501,414

7 Claims. (Cl. 179—170)

This invention relates to telephone circuits and particularly to two-way telephone circuits in which four-wire circuits are connected to two-wire lines. More particularly, the invention relates to the control of volume, especially the received volume, at a terminal of the four-wire circuit and to such control in combination with certain other adjustments, as will appear hereinafter. The invention is applicable to wire circuits and to combined wire and radio circuits.

The invention has been made and will be better described with more or less particular reference to a transoceanic radio telephone system. It is to be understood, however, that the invention is applicable to other telephone systems differing from a transoceanic radio system as to transmission media and as to details; for instance, it is applicable to submarine cable circuits. The description will have particular reference to the four-wire circuit which, in the case of the transoceanic radio system, lies intermediate one terminal of the system and the radio link.

It will further the understanding of the invention and obviate the necessity of considerable description and discussion if reference is had to the published disclosures of the prior art represented by the following: Article by Clark and Mathes, Journal of American Institute of Electrical Engineers, June, 1925, pages 618 to 626; United States Patent No. 1,607,687 to H. Nyquist, and United States Patent No. 1,690,182 to H. C. Silent.

Telephone circuits in which are employed voice-operated devices for the suppression of "sing- ing" and in which the signal to noise ratio is of great importance involve certain controls of transmission volume and of the sensitivity of the voice-operated devices. The four major controls found necessary at present are those of the transmitting volume, the sensitivity of the transmitting voice-operated devices, the sensitivity of the receiving voice-operated devices and the volume in the receiving path. When a circuit of this type terminates, as is usually the case, in a two-wire circuit having a return loss less than infinity, there is inevitably present an interdependence between these controls, since a wave coming in over the receiving path of the circuit which is not strong enough to operate the receiving relays will pass into the two-wire circuit and then pass from the two-wire circuit into the transmitting path, where it may cause false operation of the devices associated with this transmission path, which should be operated only by the voice signals coming over the two-wire circuit. The

desired result of improvements in connection with transmission circuits of this type is the prevention of false operation of the voice-operated devices, along with the ability to deliver the greatest possible and desirable volume over the receiving path at the terminal. When anti-singing voice-operated devices are employed on the circuit, the maximum received volume consistent with the suppression of false operation of the anti-singing devices depends upon the following factors: the terminal balance, the ability of the talker to operate the voice-controlled relays, the ratio of the noise to the volume delivered by the talker, the ratio of static to the received volume (in the case of a radio circuit) and the hangover time of relays which are subject to false operation by static.

In connection with the typical four-wire circuit connected at the terminal to a two-wire line with the usual arrangement of hybrid coil and network to balance the two-wire line, let S_r represent the sensitivity of the amplifier-detector connected across the receiving path of the four-wire circuit (expressed in decibels), L_r the loss of the receiving path volume control, RL the return loss of the connection between the four-wire circuit and the two-wire line, L_t the loss of the volume control in the transmitting path of the four-wire circuit, S_t the sensitivity of the amplifier-detector connected across the transmitting path and L_k the algebraic sum of all the fixed losses between the points of connection of the two amplifier-detectors with the transmission paths. False operation of the transmitting voice-operated devices by a signal returning over the two-wire line and entering the transmitting branch of the four-wire circuit will occur if

$$S_r + L_r + RL + L_t - S_t + L_k$$

is less than zero. The condition for false operation so stated has been realized, and the attempt has been made to prevent the false operation by manually decreasing the received volume in the four-wire circuit whenever the step difference of the various manual controls has exceeded a certain predetermined amount. If proper results are to be obtained, such adjustment involving complicated computation must be made very rapidly, and it is evident that the demand upon the average technical operator is excessive. Consequently, this manual adjustment of the received volume is likely to result either in an excessive amount of false operation or in the delivery to the subscriber of unnecessarily low volume. Furthermore, the requirements of the manual ad-

justment have resulted in non-uniform design of control apparatus, with a view to simplifying the computations. The problem is further complicated by the relation between the sensitivity of the receiving voice-operated devices and the hangover time of the receiving relays which may be operated by static in the case of a radio link in the system.

The principal object of the present invention as applied to the type of circuit under particular discussion is the automatic control of the received volume to prevent false operation of the transmitting voice-operated devices without unnecessary reduction of that volume under any circumstances. Other objects of the invention will be understood from the following statements of various advantages which are found in the use of the invention:

Apparatus may be used for the various controls which is of uniform design, the control sets thus being interchangeable.

Should it be desirable for any reason to shift from the automatic control of the received volume, with which no computation by the operator is required in order to adjust that volume, to the manual control of the received volume, the circuits can be adapted to such shift by a single, simple switching operation.

In the case of automatic control of the received volume and in the case of the manual control, a readily observed signal is given when the circuit is properly adjusted.

If the return loss of the two-wire line connection involves a long delay and consequently the hangover time of the receiving relays must be increased and the sensitivity of the receiving voice-operated device decreased, the decrease of the received volume is only by the amount absolutely necessary.

If the circuit connected to the four-wire circuit is changed from a short local circuit to a long toll line, suitable adjustment is automatically made, the average return loss in the case of either type of circuit being taken into consideration.

If a two-wire circuit of which the return loss is known to differ from the average is connected to the four-wire circuit, suitable adjustment is readily made.

Any one or all of the manual controls can be changed to automatic control without affecting the main circuit which controls the received volume.

In general, the applicants attain the objects of their invention and provide the various advantages thereof by causing the adjustment of the transmitting volume, the adjustment of the transmitting sensitivity and the adjustment of the receiving sensitivity to control jointly and automatically the adjustment of the received volume. In addition, they provide for suitable adjustment in connection with a change in the type of connected circuit, as will appear hereinafter.

The invention will be clearly understood when the following description is read with reference to the accompanying drawings, in which—

Figure 1 shows schematically the application of the applicants' control methods to the terminal of a two-way system such as the transatlantic radio telephone system, and

Fig. 2 shows diagrammatically and in considerable detail one circuit arrangement suitable to the practice of the invention.

In several instances, like reference characters in the two figures of the drawings designate corresponding circuit elements.

With reference, first, to Fig. 1 of the drawings, it is assumed that the transmission path L_1 is a two-wire path forming the branch of a four-wire circuit adapted for transmission from west to east, for instance, that the transmission path L_2 is the two-wire path forming the branch of the four-wire circuit adapted for transmission from east to west and that the two paths L_1 and L_2 are connected at their west terminal to a switchboard drop and an extension circuit through the usual arrangement of a hybrid coil and a network designed to give a compromise balance against a number of different circuits. It is understood that the circuit may have connected to it a toll line of considerable length, as is indicated but not fully shown in the drawings. A circuit-controlling relay R_1 is schematically shown in the transmitting line L_1 , and a second circuit-controlling relay R_2 is likewise shown in the receiving path L_2 . These two relays are controlled by an amplifier-detector AD_1 connected across the transmitting line L_1 , and, as is well understood in the art, the relay R_1 is usually termed the singing suppressor relay. A second amplifier-detector AD_2 is connected across the receiving path L_2 and, as is well understood in the art, has as one of its functions the control of a relay R_3 in the transmitting path L_1 which may be termed the false operation suppressor relay. It is sufficient to state herein that relay R_3 functions to prevent the operation of the amplifier-detector AD_1 and the relays R_1 and R_2 when such operation is undesirable but would occur due to conditions in the circuit were it not for the presence of relay R_3 . The apparatus such as amplifiers and delay circuits schematically shown are well understood in the art.

The four circles included in the scheme represent manual controls of the nature indicated, and the solid lines indicate the control by these manual means of losses and the like at certain points in the circuit. It will be noted that a solid line runs from each of the four manual controls to a device schematically shown and labeled "Adding and subtracting machine". It is to be understood that in the case of full manual adjustment of the circuit the technical operator, upon making any one of the manual adjustments, makes certain computations and then adjusts the received volume accordingly. Fig. 1 of the drawings, is intended to convey the idea that, in the case of full manual control, the net adjustment of the received volume is the result of the various computations and resultant manual adjustments of that volume.

The dotted lines of the drawings are intended to indicate that in accordance with the applicants' invention the various adjustments made manually affect jointly and automatically the setting of a device which automatically controls the adjustment of the received volume. This device is represented in the scheme by the box labeled "Adding and subtracting machine". In other words, in place of the operator's computation, it is provided that any adjustment of the transmission volume or of the sensitivity of the voice-operated apparatus sends an impulse to, or in some manner contributes to, the setting of the apparatus which directly controls the received volume.

In addition, it is indicated in Fig. 1 that the connection of the four-wire circuit to a toll line automatically has certain effects which will be more fully considered hereinafter.

While the number of transmission units in-

involved in the volume and sensitivity control is in itself no part of the invention, it will clarify the description if a limited number of figures resulting from the operation of the transatlantic radio telephone circuit are used in this discussion. The receiving volume control takes care of low margins due to such causes as low balance between the two-wire line and the network; it has, of course, the effect of decreasing the received volume when the margin is low and involves a range in transmission units of 20 decibels (db). The transmitting volume control functions to vary the transmitting volume so that a constant volume will be delivered to the associated voice-operated devices, involves a decrease of received volume when the outgoing speech is weak and requires a range of 45 decibels. The transmitting sensitivity control functions to raise the sensitivity of the transmitting voice-operated devices to prevent clipping and to lower the sensitivity to prevent operation by noise, involves a decrease of the received volume when the sensitivity is high and an increase when the sensitivity is low and requires a range of 20 decibels. The receiving sensitivity control lowers the sensitivity of the receiving voice-operated devices to prevent operation by static, involves a decrease of the received volume when the static is high and requires a range of 36 decibels. In addition to these four major controls there is the control of the hangover time of the receiving relays with a change of the circuit connection at the west end of the four-wire circuit, which control increases the hangover time with the connection of circuits having no echo suppressor, for instance, involves a decrease of the received volume and a decrease of the receiving sensitivity with an increase of the hangover time and requires a range of 10 decibels.

From the above discussion, it is seen that if the various adjustments were independent, the proper control of the circuit would involve a volume range of 131 decibels. As a matter of fact, however, it is found that, since the various factors do not apply simultaneously, the actual volume range which must be considered in the circuit under particular consideration is about 43 decibels. The various losses or adjustment ranges indicated in Fig. 1 are based on the experience with the transatlantic circuit as discussed above.

While it is believed that one skilled in the art will have little difficulty in reading Fig. 1 of the drawings without further discussion, the following statements in amplification or clarification of the drawings may prove helpful:

The transmitting volume control operates to adjust the variable loss indicated in the transmission path L_1 . Without the use of applicants' invention, the operator in charge of this control would then make certain computations and make the suitable adjustment of the received volume. In accordance with the applicants' method, the adjustment of the variable loss in the line L_1 automatically affects the "adding and subtracting machine" and thus contributes to the control of the received volume through adjustment of the variable loss indicated in the receiving path L_2 .

The transmitting sensitivity control adjusts the variable loss indicated ahead of the amplifier-detector AD_1 and, with full manual operation, the usual computation would be followed by manual adjustment of the received volume; also a certain auxiliary adjustment of the loss in the path L_2 should be made. The dotted lines indi-

cate how the applicants' automatic arrangement provides for the proper contribution to the "adding and subtracting machine" to take the place of the transmitting-sensitivity-control operator's computations and manual adjustment of the receiving loss.

The receiving sensitivity control adjusts the variable loss indicated at the input of the amplifier-detector AD_2 , which controls the false-operation suppressor relay R_3 . The applicants provide for automatic adjustment of the received volume which is suitable in view of this sensitivity adjustment.

It remains to consider the adjustments which should be made with a change of circuit connected to the four-wire circuit at its west end. It will be assumed that the hangover time of the voice-operated devices controlled by the amplifier-detector AD_2 , represented by relay R_3 in Fig. 1, is suitable for the case of a local circuit connected to the four-wire circuit. If, however, a long toll line is connected, a longer hangover time must be provided for the relay R_3 , for instance, especially if the toll line is not equipped with echo suppressors. The most suitable arrangement for adjusting in accordance with the difference of connected circuit appears to be the following:

A 6 decibel pad is normally connected into the switchboard circuit at the west end of the four-wire circuit, as indicated. If a toll line is connected to the four-wire circuit, battery is automatically connected to the sleeve lead, and the 6 decibel pad is cut out of the circuit. In addition, this sleeve connection adjusts a variable loss ahead of the amplifier-detector AD_2 , has certain direct effects on the relay R_3 and produces a suitable adjustment of the receiving loss. This hangover control, as it may be termed, will be more fully and satisfactorily described herein after in connection with Fig. 2 of the drawings.

It is now proposed to describe in some detail one circuit arrangement suitable to the practice of the applicants' method more generally discussed in connection with Fig. 1. The following description should be read with reference to Fig. 2 of the drawings.

In general, suitable automatic control of the received volume is provided by arranging potentiometers at the input of the amplifier-detectors in the case of sensitivity control or at the input of one-way amplifiers in the case of volume control, the gain of the amplifiers themselves remaining unchanged. Provision is made for step-by-step change of the setting of the potentiometers. Let it be assumed that the sensitivities of the two amplifier-detectors and their associated apparatus are the same and, as stated above, let L_r represent the loss of the receiving-volume control, RL the return loss of the two-wire connection, L_t the loss of the transmitting volume control and L_k the algebraic sum of the fixed loss between the points of application of the two amplifier-detectors; in addition, let L_{rad} represent the loss immediately ahead of the receiving amplifier-detector and L_{tad} the loss immediately ahead of the transmitting amplifier-detector. We now find that the equation representing the condition for false operation of the singing-suppressor relay becomes:

$$L_{rad} + L_r + RL + L_t + L_{tad} + L_k$$

is less than zero. This is a linear equation, and all of the terms are losses. Accordingly, the applicants use as their control device or "adding

and subtracting machine" a control circuit consisting of a marginal relay arrangement in series with a battery and a plurality of variable resistances which correspond each to one of the variable terms of the equation. Each of the variable resistances is controlled to have a value which at all times varies in accordance with the variation of the corresponding loss. The marginal relay arrangement is made to produce an indication when the equation is solved and a second indication if the equation is a predetermined distance from being solved.

With reference to the details of Fig. 2, the transmission paths L_1 and L_2 , the hybrid coil HC and the network for balancing the line connected to the four-wire circuit are as shown in Fig. 1. The usual amplifiers and delay circuits in the four-wire circuit are shown or indicated; the amplifier-detector AD_1 is connected across the transmission path L_1 , and the amplifier-detector AD_2 is connected across the transmission path L_2 . Ahead of the line amplifier in transmitting path L_1 is a potentiometer arranged for manual control of the transmitting volume by the operation of a switch having contacts "0", "1", "2" and "3". The arrow indicates the movement of the switch arm to increase the loss introduced. The closing of any one of these contacts completes a circuit through a certain relay, and the loss through the potentiometer is thus controlled in a well-known manner. It will be noted that to the left of the potentiometer control contacts and armatures there is shown a second set of contacts controlled by the respective relays to connect into the control circuit, to be discussed below, a resistance having equal steps of $3x$ ohms each, it being understood without further labeling that in this case and other similar cases in Fig. 2 the resistance sections have equal values.

Potentiometers and the manually-operated controls therefor, similar to those just described, are found in the circuit as follows: one ahead of the transmitting amplifier-detector AD_1 for controlling the sensitivity thereof, one ahead of the receiving amplifier-detector AD_2 to control its sensitivity and one ahead of the line amplifier in the receiving branch L_2 for the control of the received volume. It is this last control, that of the received volume, which applicants propose to operate automatically under the joint control of the other three major adjustments and of the hangover adjustment to be discussed more fully hereinafter. In the showing of the transmitting sensitivity control, the arrow indicates the movement of the switch arm for a decrease of sensitivity; in the receiving sensitivity control a like direction of adjustment is indicated, and in the case of the receiving volume control the arrow indicates the movement of the switch arm for an increase of loss. It will be understood, of course, that any suitable number of steps may be introduced to meet the conditions and requirements of a particular circuit.

The main control circuit includes the relays R and R' . Relay R is adjusted to operate when the external resistance of the control circuit has a certain value, which may be called y ohms, and the relay R' is adjusted to operate when the external resistance of the circuit is $y-6x$ ohms. This marginal effect is produced in each case by the lower winding in circuit with a battery and a resistance of suitable value. These margins are so adjusted that the operation of relay R indicates the condition in which the equation

stated above is solved—that is, the operation of this relay indicates that without adjustment false operation is to be expected; similarly, the operation of relay R' indicates that the equation is more than a predetermined amount from being solved and that the receiving volume may be increased without immediate danger of false operation. Associated with the relays R and R' are relays R_4 , R_5 , R_6 , certain other relays directly controlling the receiving loss, and relays R_8 and R_9 , which have to do with the hangover adjustment and are operated along with a relay R_7 in connection with the inclusion in the circuit of a toll line.

The main control circuit which corresponds to the "adding and subtracting machine" of Fig. 1 may be traced as follows: from ground at G through battery, the right-hand armature of relay R_5 , the upper winding of relay R' , the upper winding of relay R , through the resistance associated with the receiving-sensitivity control, through resistance r and r' (to be discussed hereinafter), through the resistance associated with the receiving volume control, through a switch and resistance arrangement called the "return loss compensator", to be discussed hereinafter, through the resistance associated with the transmitting volume control and through the resistance associated with the transmitting sensitivity control to ground at G' . It will be understood that the various loss controls, including the received volume control, not only make the volume or sensitivity adjustment desired but also adjust the series resistances in the control circuit. As indicated above, the proper margins for relays R and R' are obtained from the lower or biasing windings, which are in series with a resistance and with battery. It should be noted here that if the battery connected to these biasing windings is the same as the battery of the control circuit shown normally connected to the right-hand armature of relay R_5 , battery fluctuations are rendered negligible. It will be understood, of course, that the external resistance of the control circuit determines whether the relay R and the relay R' are in operated or unoperated condition. It will be noted that signal lamps S_1 and S_2 are connected in circuits controlled by relays R and R' . If both relays are unoperated, the lamp S_1 lights to indicate that the received volume may be increased without immediate danger of false operation of the voice-operated device. If both relays are operated, lamp S_2 lights to indicate that there is danger of false operation and that the received volume should be reduced. The advantages of these signal lamps will be discussed further hereinafter.

The direct control of the received volume will now be described. It is seen that the switch for the received volume control with manual operation makes contact at the point "0" or at point "1" or at point "2" or at point "3". If the contact is at point "0", the uppermost of the four relays operates (assuming that ground is connected to the switch arm) and the right-hand armature of this relay completes the transmission circuit at the top of the potentiometer—that is, with the minimum loss. If the contact is made at point "1", the first step of the potentiometer (shown between the delay circuit and the line amplifier in line L_2) becomes effective. If contact is made at point "2", the next degree of loss is introduced in line L_2 , and so on. With the circuit connections shown in the drawings, however, the control of these four relays which func-

tion to adjust the received volume is taken from the manually operated switch and is given to a group of automatically operated relays—11, 12 and 13 corresponding to contact "1"; 21, 22 and 23 corresponding to contact "2", and 31, 32 and 33 corresponding to contact "3". This automatic control functions to increase the received volume when the characteristics of the control circuit are such as to cause lamp S_1 to light and to decrease the received volume when lamp S_2 is caused to light.

Let it be assumed that the receiving loss introduced in line L_2 is zero and that lamp S_2 is lighted as a result of the operation of relays R and R' . A circuit may now be traced from ground over the armature of relay R_6 , the armature and upper contact of relay R' , the armature of relay R and the left-hand armature of relay R_4 , over the winding of relay 12 to battery and ground. Relay 12 operates and this operation causes the operation of relay 11, the left-hand winding of which is connected in a circuit similar to that just traced. The closing of the left-hand contact of relay 11 (right of the electromagnet) completes a locking circuit through the right-hand winding, a back contact of relay 21 and the winding of relay R_4 , the ground being furnished over a switch labeled "Automatic cut-out key", to be discussed hereinafter. The closing of the right-hand contact of relay 11 connects ground to the second relay associated with the receiving loss potentiometer, and accordingly step "1" of the potentiometer becomes effective. When relays 12 and 11 operate, the operation of relay 13 is caused and a circuit is closed through the contact of relay 13 and the winding of relay R_5 . The operation of relay R_5 causes in turn the operation of relay R_6 . The winding of relay R_4 is included in the locking circuit of relay 11. Since this relay R_4 is made slow-operating, it will not operate until relay R_6 has operated. The operation of relay R_6 removes ground from the operating circuit of relay 12, causing the release of that relay, but the delay in the action of relay R_4 is not great enough to prevent the operation of that relay while relay 12 remains operated. The operation of relay R_4 disconnects ground from the zero relay of the potentiometer and permits relay 12 to release, also causing the release of relay 13, which is followed by the release of relay R_5 and the release of relay R_6 , in turn. The operation of relay R_5 has permitted relays R and R' to release. When relay R_5 releases, if no further receiving loss should be introduced, relay R' alone will operate, the operation of relay R being prevented by the biasing winding, and no further change will be made in the received loss. If, however, additional loss should be introduced, relay R as well as relay R' will again operate, and since relay 11 is locked in its operated position, ground will now be furnished over the left-hand armatures of relays 12 and 11 (left of the electromagnets) to relay 22. Relay 22 operates and is followed by the operation of relays 21, 23, R_5 and R_6 , this operation being similar to the operation of relays 12, 11, 13, R_5 and R_6 described above. When relay 21 operates, it breaks the locking circuit of relay 11, causing the release of that relay and the disconnection of ground from relay "1" of the potentiometer. The release of relays 22, 23, R_5 and R_6 is brought about by the release of relay 11. Should additional loss be required, relays 32, 31 and 33 are operated in conjunction with relays R_5 and R_6 , with the required dis-

connection of the No. 2 potentiometer-relay ground connection. It will be understood, of course, that while only three potentiometer steps are shown, any suitable number may be provided by the addition of the necessary resistances, control relays and relay chains corresponding to 31, 32 and 33, for instance.

Let it be assumed that relay 31 is operated with the resultant connection of step "3" of the potentiometer, and that relay R' releases, causing lamp S_1 to light and thereby indicating that the receiving loss should be decreased. It will readily be understood that the circuit provides in such a case for the operation of relays 22, 21, 23, R_5 and R_6 and the release of relay 31. In other words, the circuit arrangement provides for the cutting out of loss in suitable steps just as it provides for the connecting in of loss in suitable steps.

It will be noted that with the automatic cut-out key at the right of relay R_4 in the position shown in the drawings, ground is normally connected to the circuit of the zero relay associated with the receiving loss potentiometer and, upon operation of relay R_4 , is applied to certain relays of the control system. It may be desirable, under certain conditions, to switch from the automatic control of the received volume to manual control of that volume. With the circuit arrangements shown, this shift is made by simply throwing the automatic cutout key to the opposite position, ground thus being connected to the arm of the received-volume-control switch. It will be noted, further, that this switching from automatic to manual control does not affect the operation of the signal lamps S_1 and S_2 . These lamps still function to give the desired indications.

As stated hereinabove and as shown in the drawings, the pad associated with the switchboard, which, for the case under particular consideration, is a 6 decibel pad, is normally connected into the circuit. It has been found from tests made on the transatlantic circuit that with such a pad the conditions existing are approximately as follows:

If the connected circuit is a local circuit or a toll circuit equipped with four-wire echo suppressors, the receiving relay hangover time should be .02 second, and, since there is practically no difference between the return losses of those circuits, no special change from the normal is introduced in the loss ahead of the receiving amplifier-detector or the receiving loss. If a short toll line without echo suppressors is connected to the four-wire circuit, the receiving relay hangover should be increased to .05 second, the loss ahead of the receiving amplifier-detector is increased by 4.5 decibels, since the average return loss is now about 8 decibels less and the receiving loss is increased by 12.5 decibels. If the toll circuit connected is a long circuit, the receiving relay hangover should be increased to .1 second, the loss ahead of the receiving amplifier-detector is increased by 9 decibels, the return loss is decreased by 8 decibels and the receiving loss is increased by 17 decibels.

To make adjustments to meet the above conditions, the applicants provide certain circuit arrangements shown in Fig. 2. The sleeve lead, it will be understood from the discussion contained hereinabove, is connected to battery when a toll connection is made. Such a connection thus results in the operation of relay R_7 , which disconnects the pad (immediately to the right of that

relay) from the circuit, reducing the loss by 6 decibels, for instance. Likewise, battery is connected to the winding of relay R_3 , which operates and adjusts the loss introduced ahead of the receiving sensitivity control, increases the hangover time of the receiving relay (see R_3 of Fig. 1) from .02 second to .05 second and cuts out of the received-volume-control circuit the resistance r' . In addition, a receiving hangover adjustment key is provided by which the operator may make further adjustment for the long toll circuit connection. As indicated in the drawings, he may close the key contact shown at the right to place ground on the winding of relay R_3 and on the hangover control wire to the voice-operated relays. The operation of relay R_3 adjusts the loss introduced ahead of the receiving-sensitivity-control, and the ground connection on the hangover control wire increases the hangover time of the receiving relay (see R_3 of Fig. 1) by .05 second; the operation of relay R_3 also cuts out of the received-volume-control circuit the resistance r . The key contact at the left can be opened to remove ground from the winding of relay R_3 if no increase of hangover time is desired, as in the case of the connection of a four-wire circuit equipped with echo suppressors.

There may be connected to the four-wire circuit a circuit which introduces conditions slightly different from those considered above and for which adjustment is provided, as described above. With such a circuit connected, minor adjustment should be made in the received volume. This adjustment may be made by the operation of the control shown and labeled "Return loss compensator". It will be understood that with the switch arm in contact with point "0", no extra resistance is connected into the control circuit; if contact is made at point "1", an extra resistance of $3x$ ohms is included in the control circuit; if contact is made at point "2", a resistance of $6x$ ohms is added, and so on, the arrow indicating the movement of the switch arm to adjust for higher return loss. For the purpose of illustration, a resistance of $3x$ ohms is added for each increase of 3 decibels in the return loss, as compared with the case of a typical connected circuit.

It has been deemed desirable to give a somewhat detailed description of the applicants' invention in a specific form as applied to a certain transmission system, namely, a transoceanic radio telephone system, for the purpose of clear illustration. In this form, the various controls other than the control of received volume are made manually, for the greater part, and these various adjustments are caused to control jointly and automatically the adjustment of the received volume. It will be understood, however, that the applicants' invention might well be applied to widely different circuits and for the purpose of obtaining automatic adjustment of a control other than that of the received volume. For instance, it is conceivable that it might be desirable to cause various controls of volume and sensitivity to join in the automatic control of the transmitting volume rather than the received volume. It will be clear from an examination of Fig. 2 that the simplest of circuit changes would bring about such a result. Accordingly, it is to be understood that the scope of the invention is not limited by the specific disclosure but is to be determined by the appended claims.

What is claimed is:

1. In a transmission system including a four-wire circuit having two paths adapted for trans-

mission in opposite directions and connected in approximately conjugate relation and control apparatus responsive to currents in said transmission paths, said four-wire circuit being adapted for connection to any one of several types of extending circuit introducing different return characteristics, the method of transmission regulation which consists in adjusting the operating characteristics of said control apparatus, adjusting the volume in one of said transmission paths, causing the connection of said four-wire circuit to an extending circuit to introduce suitable extra adjustment of the operating characteristics of said control apparatus, and causing each of said adjustments to contribute directly to the control of the volume in the other of said transmission paths.

2. In a two-way transmission system including a four-wire circuit having two paths adapted for transmission in opposite directions and connected in approximately conjugate relation and switching devices responsive to currents in said transmission paths and adapted for sustained operation during a hangover period of variable length, said four-wire circuit being adapted for connection to any one of several types of extending circuit introducing different return characteristics, the method of transmission regulation which consists in causing the connection of an extending circuit to said four-wire circuit to contribute to the control of the sensitivity of said switching devices and to the control of the hangover period of said devices, and producing a contribution to the control of the received volume as the direct effect of each of said aforementioned control contributions.

3. In a two-way transmission system including a four-wire circuit having two paths adapted for transmission in opposite directions and connected in approximately conjugate relation and control apparatus responsive to currents in said transmission paths, said four-wire circuit being adapted for connection to any one of several types of extending circuit introducing different return characteristics, means for adjusting the volume in one of said transmission paths, means for adjusting the sensitivities of said control apparatus, means responsive to the connection of said four-wire circuit with an extending circuit for adjusting the operating characteristics of said control apparatus, and means for controlling the volume in the other of said transmission paths in accordance with the algebraic sum of the effects of the operation of said several adjusting means.

4. In a two-way transmission system including a four-wire circuit having two paths adapted for transmission in opposite directions and connected in approximately conjugate relation and control apparatus responsive to currents in said transmission paths, said four-wire circuit being adapted for connection to various types of extending circuit, means for adjusting the loss at a plurality of points in the four-wire circuit, means responsive to the connection of said four-wire circuit with an extending circuit for adjusting the operating characteristics of said control apparatus, and means for controlling the loss at another point in the four-wire circuit in accordance with the algebraic sum of the effects of the operations of said several adjusting means.

5. In a two-way transmission circuit, transmission paths adapted for transmission in opposite directions, circuit control apparatus associated with each of said paths and responsive to

currents therein, a potentiometer associated with each transmission path and a potentiometer associated with each set of control apparatus, several switching means each designed to adjust one of the potentiometers, and means for causing the operation of any one of a plurality of said switching means to contribute to the control of the operation of another of said switching means, said last named operation thus depending on the algebraic sum of the effects of the first mentioned operations.

6. In a two-way transmission circuit, transmission paths adapted for transmission in opposite directions, circuit control apparatus associated with each of said paths and responsive to currents therein, a potentiometer associated with each transmission path and a potentiometer associated with each set of control apparatus, several switching means each designed to adjust one of the potentiometers, a control circuit associated with one of said potentiometers, several resistances each associated with one of said potentiometers and adapted to be varied simultaneously therewith, said variable resistances

being connected in series in said control circuit, and switching means responsive to changes in the series resistance of said control circuit for adjusting the potentiometer associated therewith.

7. In a two-way transmission circuit, transmission paths adapted for transmission in opposite directions, circuit control apparatus associated with each of said paths and responsive to currents therein, a potentiometer associated with each transmission path and a potentiometer associated with each set of control apparatus, several switching means each designed to adjust one of the potentiometers, a control circuit associated with one of said potentiometers, several resistances each associated with one of said potentiometers and adapted to be varied simultaneously therewith, said variable resistances being connected in series in said control circuit, and switching means responsive to changes beyond predetermined values in the series resistance of said control circuit for adjusting the potentiometer associated therewith.

SUMNER B. WRIGHT.
EDMUND R. TAYLOR.

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