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TWO-WAY SIGNAL TRANSMISSION SYSTEM

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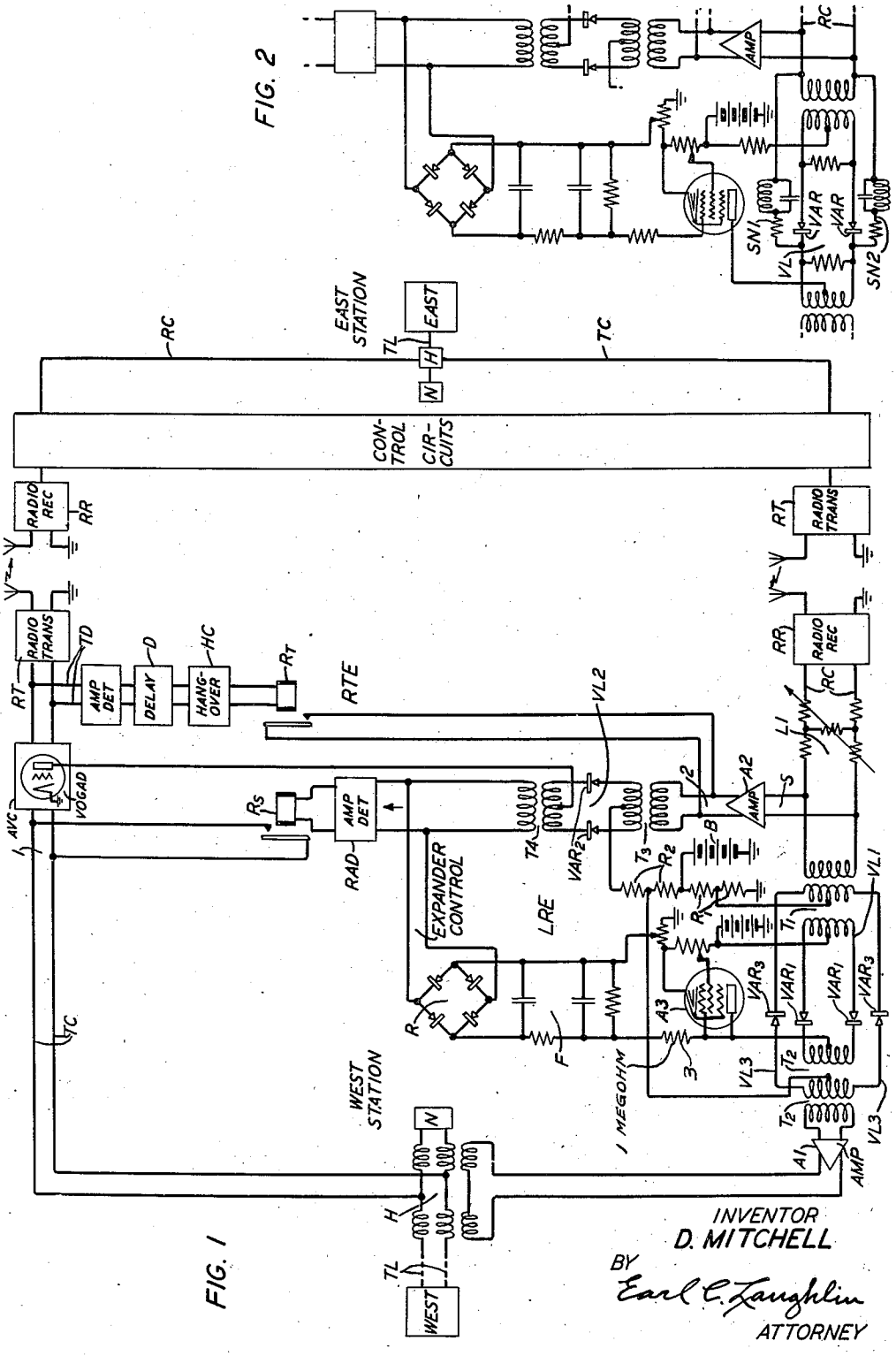


FIG. 2

FIG. 1

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## TWO-WAY SIGNAL TRANSMISSION SYSTEM

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6 Claims. (Cl. 178—44)

The invention relates to two-way signal transmission systems and particularly to the signal-controlled circuits for controlling transmission in such systems.

The invention is particularly applicable to, although not limited to, the voice-operated control circuits employed at the terminals of a two-way radio telephone system for controlling the direction and volume of signal transmission while suppressing echoes and preventing singing.

An object of the invention is to improve the operation of such circuits particularly from the standpoint of reducing signal clipping and breaking difficulties.

This object is attained in accordance with one embodiment of the invention by employing for the control circuits at each terminal of the system the combination of a transmitting vogad (volume-operated gain-adjusting device) with a receiving expander type singing suppressor and receiving terminal echo suppressor which are interlocked with the vogad in such manner that the amount of singing suppression provided by the singing suppressor and the sensitivity of the echo suppressor are both determined by the amount of gain in the vogad.

The various objects and features of the invention will be better understood from the following detailed description thereof when read in conjunction with the accompanying drawing, in which:

Fig. 1 shows schematically a two-way radio telephone system equipped with control circuits in accordance with the invention; and

Fig. 2 shows schematically an alternative modification of part of one of the control circuits employed in the system of Fig. 1.

In the radio telephone system of Fig. 1, the west and east terminal stations each comprises a one-way transmitting circuit TC leading to a radio transmitter RT and a one-way receiving circuit RC leading from a radio transmitter RR, which are coupled in substantially conjugate relation with each other and in energy-transmitting relation with a two-way telephone line TL leading to a telephone subscriber's station by the usual hybrid coil transformer H and associated balancing network N.

As the control circuits of the invention at the two stations are identical, only those at the west station have been illustrated in detail, those at the east station being represented by a suitably labeled box. As indicated, referring to the west station, these control circuits include, connected in the transmitting circuit TC between the hybrid coil H and the radio transmitter RT, an automatic volume control device AVC, known as a vogad, which may be of any of the well-known types, for example, such as disclosed in Hogg et al. Patent No. 1,853,974, Mitchell et al. Patent No. 2,019,577 or Wright et al. Patent No. 2,043,403; and in the receiving circuit RC, connected between the radio receiver RR and the hybrid coil H, a variable loss pad L1, and the vario-losser VL1 and one-way amplifier A1 of the limited volume range expander device LRE.

The control circuits at the west station include also a receiving terminal echo suppressor RTE including a receiving suppressor control branch S having its input bridged across the receiving circuit RC at a point between loss pad L1 and vario-losser VL1, and a transmitting disabler control branch TD having its input bridged across the transmitting circuit TC at a point between the vogad AVC and the radio transmitter RT. The suppressor control branch S comprises the one-way amplifying device A2; a sensitivity-adjusting vario-losser VL2 comprising the varistor elements $VAR_2$ connected effectively in series in the control branch S by transformers T3 and T4; the amplifier-detector RAD; and the suppressor relay $R_S$ connected across the output of the amplifier-detector RAD, the normally open contacts of which are connected across the circuit TC at a point 1 in front of the vogad AVC and are adapted to be closed to short-circuit the circuit TC by operation of relay $R_S$ when it is energized by the output currents of RAD. The transmitting disabler control branch TD comprises an amplifier-detector TAD, followed by a delay circuit D, a hang-over circuit HC and the transmitting disabler relay $R_T$ the normally open contacts of which are connected across the suppressor control branch S at a point 2 between the amplifying device A2 and the vario-losser VL2, and are adapted to be closed to short-circuit the input of branch S by operation of relay $R_T$ when it is energized by the output currents of TAD.

The limited volume range expander LRE, which is a vario-repeater similar to that disclosed in Fig. 5 of my Patent No. 2,213,991 issued September 10, 1940, includes in addition to the amplifier A1 and the vario-losser VL1 in the circuit RC, a forward-acting "expander control" circuit for the vario-losser. The vario-losser VL1 comprises the varistors $VAR_1$, which may be copper oxide rectifiers, connected effectively in series with the circuit RC in front of amplifier A1 by the transformer T1 and T2. The "ex-

pander control" includes an input amplifying and sensitivity-adjusting portion connected across the receiving circuit RC in front of transformer T1, which, as indicated, may comprise the amplifying device A2 and the vario-losser VL2 common also to the input portion of the suppressor control branch S of echo suppressor RTE, and an output portion comprising in order the full wave rectifier R, the filter F and a direct current amplifier A3 comprising a single amplifying vacuum tube of the pentode type, the control grid-cathode circuit of which is connected across the output of filter F and the plate-cathode circuit of which is connected across the mid-points of the inner windings of transformers T1 and T2 so that the plate current of the tube A3 will flow through the series varistors $VAR_1$ of the vario-losser VL1.

With no signal input to the expander control circuit, only a fraction of a milliampere of direct current flows in the plate circuit of tube A3 through the series varistor elements $VAR_1$ of vario-losser VL1, with the result that the series resistance produced by the vario-losser in the circuit RC is high. By proper selection of the resistance values of varistors $VAR_1$, the vario-losser may be made to provide the desired amount of suppression loss in the circuit RC to prevent singing. Incoming speech signals applied to the "expander control" from the circuit RC pass through amplifier A2 and the sensitivity-adjusting vario-losser pad VL2 to the rectifier R. The direct current output of rectifier R passes through the resistance-condenser filter F and is applied as a bias to the control grid-cathode circuit of amplifier tube A3. As the signal input to the expander control circuit increases, the negative bias at the control grid of the tube A3 decreases, causing more plate current to flow through the series varistor elements $VAR_1$ in such direction as to decrease the resistance values of the varistors $VAR_1$. This proportionally reduces the insertion loss of the vario-losser VL1, and thereby effectively increases the gain of the vario-repeater so that the volume range of the received signals in the circuit RC is expanded. This expansion characteristic extends for only a limited range after which further increase of signal input to the expander control circuit results in no further increase in gain of the vario-repeater. This result is produced because of the limiting effect of the (1 megohm) resistance 3 in the control grid-cathode circuit of tube A3.

The control circuits at the west station in Fig. 1 also include a third vario-losser VL3 comprising the auxiliary varistors $VAR_3$ connected effectively in series with circuit RC and in shunt with the varistors $VAR_1$ of vario-losser VL1 through third (center) windings on the transformers T1 and T2, and a control circuit including potentiometer resistances $R_1$ and $R_2$ for adjusting the loss values of vario-losser VL3 to control the effective insertion loss of vario-losser VL1 in the circuit RC, and the insertion loss of the vario-losser VL2 common to the expander control circuit and the suppressor control branch S of the echo suppressor RTE, in accordance with the gain of the transmitting vogad AVC in the manner which will be described in connection with the following complete description of operation of the system of Fig. 1.

In the idle condition of the west terminal station with no telephone signals being transmitted or received, the echo suppressor control circuits are in the condition indicated in the drawing with the receiving switching relay $R_S$ of the suppressor branch S unoperated so that the transmitting circuit TC is unblocked at the point 1, and the transmitting switching relay $R_T$ of the transmitting disabler branch TD likewise unoperated so that the suppressor control branch S is operative. Also, as described above, with no signal input to the limited volume range expander LRE in the receiving circuit RC, the normal loss value of its vario-losser VL1 is sufficiently high to so reduce the gain of the expander as to prevent singing around the circuits TC and RC.

Let it be assumed that the west subscriber associated with the two-way line TL starts to talk. His speech waves received over the two-way line TL will be divided in the hybrid coil H, the portion entering the receiving circuit RC being dissipated in the output of the amplifying device A1 and the useful part passing over transmitting circuit TC, provided the echo suppressor receiving control branch S is not operated by previously received speech currents in the receiving circuit RC to block the circuit TC at the point 1, through the vogad AVC to the radio transmitter RT which will radiate them to the radio receiver RR at the distant east station. The speech waves passing through the vogad AVC will regulate the vogad gain so that they will be impressed on the radio transmitter RT with the greatest possible volume. The portion of west's speech waves diverted into the transmitting disabler branch TD of the echo suppressor RTE will be amplified and detected in TAD and after a certain delay provided by delay circuit D will cause operation of relay $R_T$ to short-circuit the common input for the receiving suppressor branch S and the "expander control" for the expander LRE in the receiving circuit, to prevent false operation of the receiving echo suppressor branch and maintain the normal singing loss in the receiving circuit RC.

The vogad AVC controls the sensitivity of the echo suppressors and the range of the limited volume range expander LRE at the west station in accordance with the gain of the former in the following manner.

The plate current of the tube shown in the vogad AVC is assumed to rise when the gain of the vogad increases as is common to most vogads. It is supplied from the battery B shown connected to a point between the potentiometer resistances $R_1$ and $R_2$ which are connected in series between ground and the mid-point of the secondary winding of the input transformer T3 for vario-losser VL2. The mid-taps of resistances $R_1$ and $R_2$ are respectively connected to the mid-points of the auxiliary (center) windings of the transformers T1 and T2, which connect the auxiliary varistor elements $VAR_3$ of vario-losser VL3 effectively in shunt with the varistors $VAR_1$ of vario-losser VL1. Plate current is supplied by battery B to the plate of the vogad AVC over a circuit extending from the positive terminal of that battery through potentiometer resistance $R_2$, in parallel through the varistors $VAR_2$ of the vario-losser VL2 to the plate of the vogad tube. Current is also supplied from battery B through portions of the potentiometer resistances $R_1$ and $R_2$ to the varistors $VAR_3$ of the vario-losser VL3. Let it be assumed that the plate current of the vogad tube is at a very low value. Since the current through $R_2$ is very low, this will mean that the current flowing through the auxiliary varistors $VAR_3$ of vario-losser VL3 will be in the forward

direction, that is, the voltage at the tap on $R_2$ will be more positive than the voltage at the tap on $R_1$. Current is also supplied through a portion of resistances $R_1$ and $R_2$ to the varistor elements $VAR_2$ of vario-losser VL2. The current flowing through the auxiliary varistors $VAR_3$ will make them of low resistance value so that they will effectively shunt out the normally high impedance of the varistors $VAR_1$ of the vario-losser VL1 effectively making the insertion loss of the latter vario-losser in the circuit RC comparatively low. Thus, when the gain of the vogad AVC is low, the range of the expander LRB will be practically nothing.

Since the current through varistors $VAR_2$ in vario-losser VL2 common to the receiving suppressor control branch S and the "expander control," is low for the same reason, the sensitivity of the echo suppressor control branch S and of the "expander control" will also be low for this low gain condition of the transmitting vogad. It will be apparent, therefore, that with the substantially zero insertion loss of the vario-losser VL1 and the low sensitivity of the range control therefor for the low gain condition of the transmitting vogad, the limited range expander LRE will operate as an ordinary amplifier to amplify any received speech signals. The low sensitivity of the receiving suppressor control branch S will be allowable since, due to the low gain of the vogad, echoes of received speech signals appearing in the transmitting circuit TC will be attenuated considerably and will therefore not be annoying. Also, due to the low gain of the transmitting vogad, there will be no need to suppress singing and therefore it will not be necessary to have any loss normally in the limited range expander.

Let it now be assumed that the speech currents received over the line TL from the west talker and transmitted into the transmitting circuit TC are weak, which will cause the gain of the vogad AVC to be increased. This will cause an increase in plate current to be drawn by the vogad tube indicated, and therefore will cause more current to pass through potentiometer resistance $R_2$ and also through the varistors $VAR_2$ in vario-losser VL2. The current through $R_2$ will cause the tap on $R_2$ to be progressively less positive with respect to ground and thus at some point, which by proper proportioning of the elements of the circuit may be made to occur at a desired value, the tap on $R_2$ will be at the same voltage as the tap on $R_1$. Any further increase in current through $R_2$ will cause the tap on $R_2$ to be negative with respect to the tap on $R_1$. The net result is that as the vogad gain increases, thus increasing the current through $R_2$, the current through the auxiliary varistors $VAR_3$ in vario-losser VL3 decreases in the forward direction and eventually reverses, so that such current as flows will be in the backward direction. This will cause the impedance of the elements $VAR_3$ to rise with increasing vogad plate current and thus accomplish the desirable result of increasing the range of the expander LRE. It is apparent that the operating range of the limited range expander device LRE will be increased since the reduction of current in the forward direction through the varistors $VAR_3$ increases their impedance and thus reduces their shunting effect on the varistors $VAR_1$ in the vario-losser VL1.

At the same time, the increase of current through the varistors $VAR_2$ in the vario-losser VL2 reduces the impedances of these varistors thus decreasing the insertion loss of vario-losser VL2 and increasing the sensitivity of the receiving echo suppressor control branch S and also of the "expander control" for vario-losser VL1. Thus, for the high gain condition of the transmitting vogad, the limited range expander LRE is conditioned to provide a comparatively large normal loss in the receiving circuit RC when no incoming signals are present, and a comparatively large range of expansion of any incoming speech signals, and the associated suppressor control S is conditioned to operate in response to fairly weak incoming speech signals and thus to operate relay $R_S$ to block the transmitting circuit TC at the point 1 to prevent singing and to suppress echoes of the received signals.

The operation of the control circuits at the east station in response to west's radiated signals when they arrive at the latter station will be explained by referring to the similar receiving control circuits at the west station illustrated in detail, referring to the east station circuits by the same identification characters as the corresponding circuits at the west station with the addition of a prime (') mark.

West's speech currents detected by the radio receiver RR at the east station will pass over the receiving circuit RC through the variable loss pad L1' to the vario-losser VL1' of the receiving expander LRE', and to the common input of the "expander control" for that vario-losser and the receiving echo suppressor control branch S', connected across the circuit RC in front of the vario-losser VL1'. West's speech waves will pass through the limited range expander LRE', and either receive plain amplification if the vogad AVC' in the transmitting circuit TC of the east station is at low gain, or will have their volume range expanded by operation of LRE' as an expander if the transmitting vogad AVC' is at high gain, in the manner which has been described for the similar apparatus at the west station, before being transmitted over the output of the circuit RC' through the hybrid coil H' and line TL to the east subscriber. A portion of west's speech currents passing into the common input for the "expander control" for VL1' and receiving echo suppressor control branch S', will be amplified and detected in the amplifier-detector RAD' of the latter and cause the operation of the switching relay $R_S'$ to insert a singing and echo suppressing loss in the transmitting circuit TC' at the point 1' in front of the transmitting vogad AVC'. The sensitivity of the receiving suppressor control S', of course, will be affected by the existing gain condition of the transmitting vogad AVC' at the east station in the manner similar to that previously described for the similar circuits at the west station, so that the sensitivity is high, if necessary, in order to suppress echoes satisfactorily.

It will be apparent that the circuits of the invention illustrated in Fig. 1 and described above will greatly reduce the possibility of clipping and breaking difficulties. The use of the limited range expander to switch loss in this circuit, because of its smooth, gradual action, will be effective to reduce the annoyance of clipping even if it does occur. An improvement from the standpoint of reducing such difficulties will be attained even without the use of the transmitting disabler portion TD or TD' of the echo suppressor circuits at the two terminal stations, so that for some

types of systems the transmitting disabler branches may be eliminated. However, under some conditions of operation the use of the latter is desirable. For example, if the gain of the transmitting vogad were very high at one terminal station and low at the other terminal station, it is probable that the receiving controls at the end at which the gain is high would be operated by echoes which were unsuppressed at the other end where the sensitivities were low. This would be readily prevented by the use of the transmitting control branch of the suppressor indicated. At each terminal station the transmitting disabler control TD or TD' would preferably be connected across the transmitting circuit TC just beyond the output of the vogad AVC, AVC'. The delay time of the delay circuit D or D' in the transmitting disabler branch at each station should be made approximately equal to the one-way transmission time T over the system between terminal stations, whereas the hang-over time provided by the hang-over circuit HC or HC' therein, which may be of any of the well-known types, would be made approximately equal to the one-way transmission time T over the system between terminal stations, plus a slight time increment $t$ to take care of weak word endings. With these added transmitting controls, if west started speaking, after time T his speech waves would reach the east terminal and at that time his transmitting disabler TD at the west station would disable both the receiving echo suppressor branch S and the operating "expander control" of the limited range expander LRE at the west station. Any echoes of west's speech currents produced in the transmitting circuit TC at the east station due to improper hybrid coil balance at the latter station, and radiated back to the west station and picked up by its radio receiver RR, due to the low sensitivities of the receiving echo suppressor control branch S and the "expander control" for the receiving expander device LRE with the transmitting disabler TD operated at the west station would be unable to falsely operate west's receiving controls and cut off further speech from him. The position of the transmitting controls TD and TD' is such that their sensitivities referred to the two-way line associated with the respective terminals would only be high when the talker was a very weak one. Thus, the use of the transmitting disabler devices should not add greatly to breaking difficulties.

Another possible difficulty might occur if static in the intermediate radio link were high and the talker volume were low. In this case, the echo suppressor sensitivity might become high enough so that false operation could occur. Proper adjustment of the variable loss pads L1 and L1' in the receiving circuits RC at the two terminals should prevent such false operation. Thus, loss would be inserted in these controls if static were high, and this would serve the double purpose of reducing received signal volume which is desirable with high static, and also reducing the chance of false operation of the receiving controls.

Fig. 2 shows a modified form of vario-losser VL which may be used in place of the vario-losser VL1, VL1' in the receiving limited volume range expander LRE, LRE' at the west and east stations, respectively, in the system of Fig. 1, to give a shaped frequency characteristic to the loss switched to provide the desired expansion, for the purpose of minimizing speech signal impairment due to the loss switching. The desired shaping of the loss with frequency is obtained, as indicated, by connecting a by-pass circuit around the series varistors VAR in the two sides of the receiving circuit RC, each including an identical network section SN1, SN2, consisting of resistance, inductance and capacitance elements in suitable configuration and with such relative values, for example, antiresonant networks, as to by-pass frequencies in the voice frequency range having the minimum signal energy content around the vario-losser. The network sections SN1, SN2 are preferably designed to make the loss inserted in the receiving circuit RC by the vario-losser VL when the system is in the idle condition the inverse of that of the coupling loss between the transmitting circuit TC and the receiving circuit RC at the terminal which normally has a peak in the general neighborhood of 1200 cycles but may fall off to quite low values on either side of this peak. This will reduce the amount of loss which must be switched at speech frequencies other than the one at which peak coupling loss exists, while leaving the singing margin for the over-all system practically unchanged. This type of vario-losser is adapted for use for a similar purpose in connection with limited volume range expanders in other types of systems, for example, in loud-speaker conference telephone systems.

Various other modifications of the circuits and apparatus illustrated and described which are within the spirit and scope of the invention will be apparent to persons skilled in the art.

What is claimed is:

1. In a terminal of a two-way telephone system including a signal transmitting path and a signal receiving path, a volume-operated gain-adjusting device in said transmitting path, a limited volume range expander in said receiving path, operating as a combined singing suppressor and received signal amplifier, an echo suppressor device connected to said receiving path normally responsive to received signals of a given level to insert an echo suppression loss in said transmitting path in front of said gain-adjusting device, and means to reduce signal clipping and facilitate breaking comprising means for making the amount of singing suppression provided by said expander and the sensitivity of said echo suppressor device vary as a function of the transmitting path gain provided by said gain-adjusting device.

2. A control terminal for a two-way telephone system comprising a signal transmitting path, a signal receiving path, a volume-operated gain-adjusting device in said transmitting path, a limited volume range expander with an associated expander control in said receiving path, operating to provide a singing suppression loss therein in the absence of received signals, and to increase the gain of said receiving path in response to received signals, an echo suppressor including a receiving branch normally responsive to incoming signals of a given level in said receiving path, in the absence of prior outgoing signals in said transmitting path, to disable said transmitting path in front of said gain-adjusting device and means to reduce signal clipping and facilitate break-ins comprising control means responsive to a given low gain adjustment by said gain-adjusting device to reduce the expansion range of said expander and to desensitize said expander control and said receiving branch of said echo suppressor.

3. The control terminal of claim 2 in which said gain-adjusting device includes an electron discharge amplifying device, the amplitude of the space current of which is proportional to the gain adjustment, and said control means comprises means responsive to a decrease in the amplitude of the space current of said electron discharge device to a given value to reduce the amount of singing suppression loss provided by said expander and to insert loss in the expander control therefor and in said receiving branch of said echo suppressor.

4. The control terminal of claim 2, in which said echo suppressor includes a transmitting branch responsive to outgoing signals in said transmitting path operating in the absence of prior received signals in said receiving path, with a delay approximately equal to the one-way transmission time over said system between terminals to disable the control for said expander and said receiving branch of said echo suppressor.

5. In a two-way telephone system including at each terminal thereof a signal transmitting path and a signal receiving path, means for controlling the direction and volume of telephone signal transmission, comprising at each terminal a volume-operated gain-adjusting device in the transmitting path, a limited volume range expander with an associated expander control in the receiving path providing a singing suppression loss therein in the absence of received signals and operating in response to received signals to expand the volume range of said signals, an echo suppressor comprising a receiving branch connected to said receiving path, responsive to received signals, when operative, to disable said transmitting path in front of said gain-adjusting device, and a transmitting branch connected to said transmitting path, beyond the disabling point therein, responsive to applied outgoing signals to disable said receiving branch of said echo suppressor and the expander control for said expander, and means controlled by said gain-adjusting device for adjusting the range of said expander and for desensitizing the receiving branch of said echo suppressor and the expander control for said limited range expander in accordance with the gain adjustment produced by said gain-adjusting device in said transmitting path so as to provide only the amount of singing and echo suppression necessary.

6. The system of claim 5, in which the transmitting branch of said echo suppressor includes means for delaying its operation in response to applied outgoing signals for a time interval approximately equal to the one-way transmission time between terminals of said system and means for prolonging its operation after cessation of the controlling signals for a hang-over time interval equal to said one-way transmission plus a small time increment to take care of weak word endings.

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