

June 15, 1943.

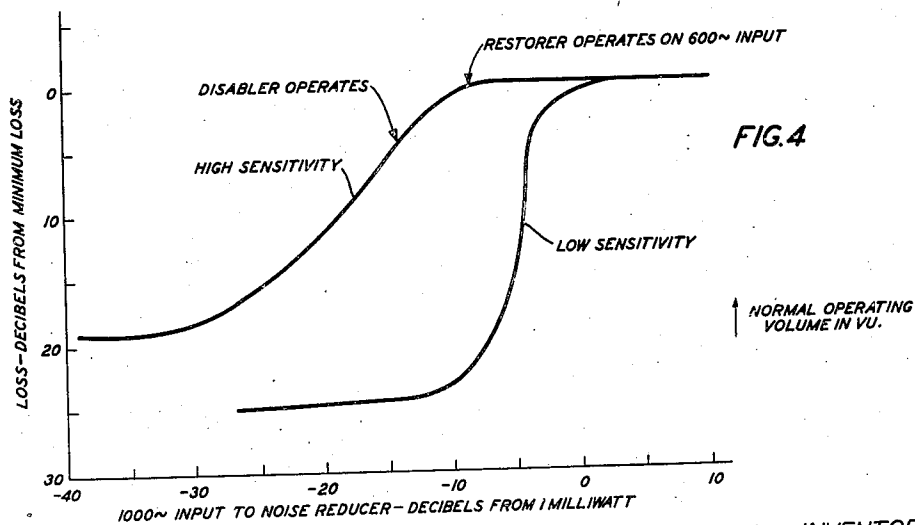
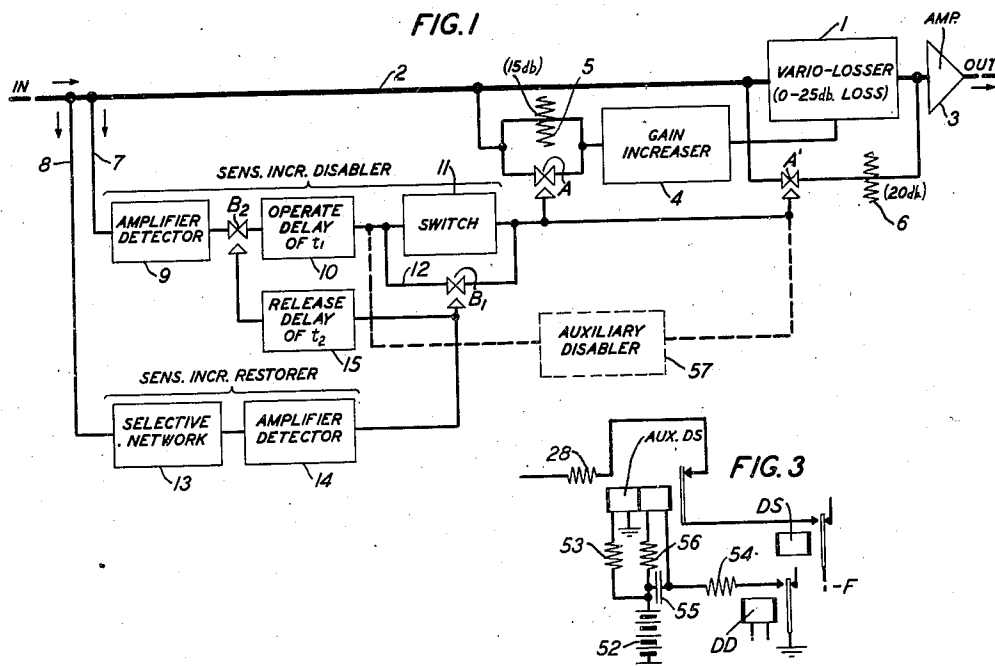
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2,321,986

NOISE REDUCTION IN TELEPHONE TRANSMISSION SYSTEMS

Filed March 7, 1942

2 Sheets-Sheet 1



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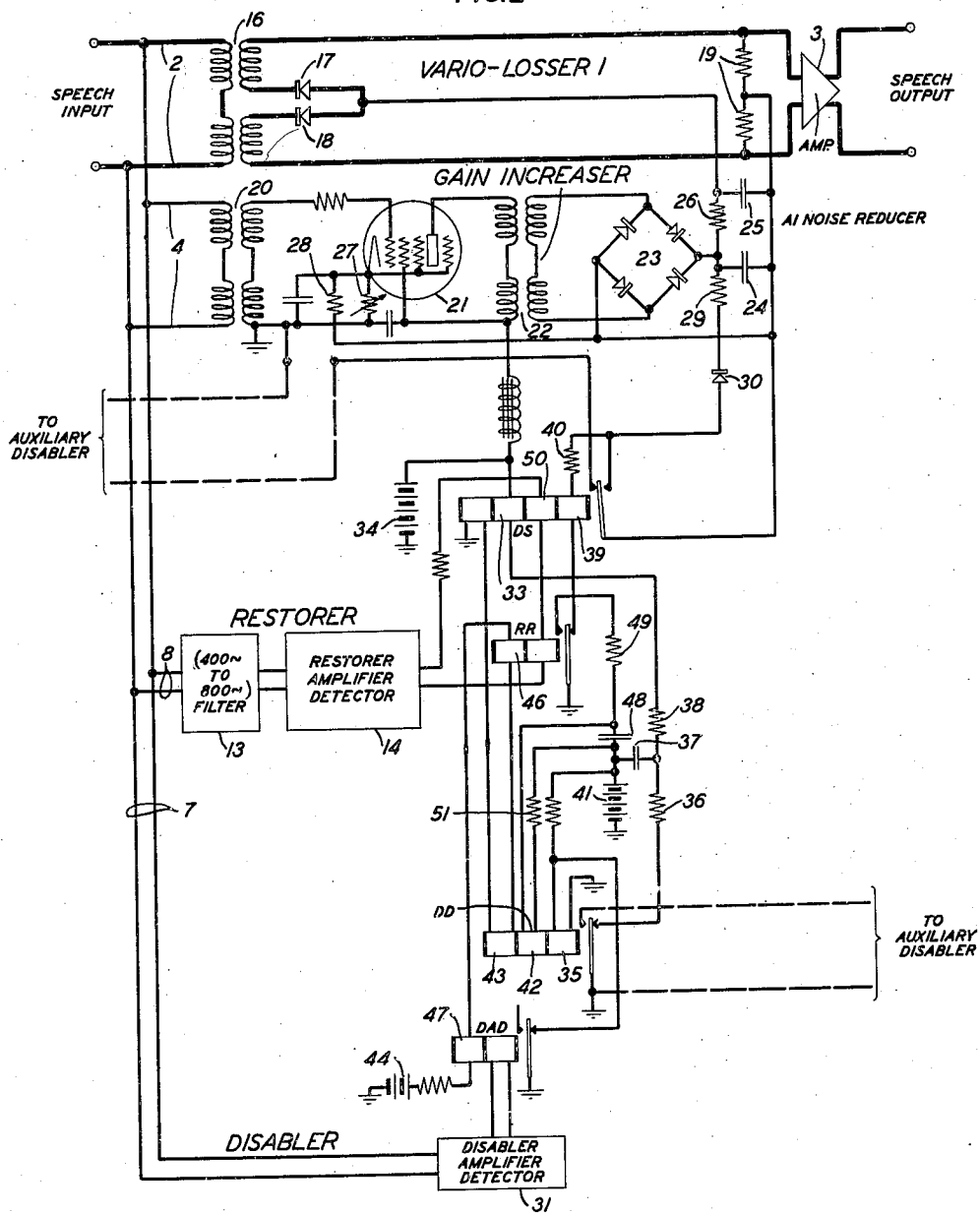
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2 Sheets-Sheet 2

FIG. 2



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NOISE REDUCTION IN TELEPHONE TRANSMISSION SYSTEMS

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The invention relates to telephone transmission systems and particularly to circuits for discriminating between waves of different amplitudes in such systems, such as between speech waves and interfering noise waves.

As is well known, wire and radio telephone circuits are subject to variable interference, such as circuit noise, cross-talk or static, tending to adversely affect the quality of telephone conversation while talking is taking place over the circuit and to produce an annoying effect during the pauses in conversation. To reduce the effects of such interference without producing undue distortion of speech, speech-controlled variable lossers have been used to introduce a fixed amount of loss into the transmission circuit except in the presence of speech waves when the loss is automatically reduced to a low value. By their use the background of noise is reduced during idle periods and also during the time the speech waves are below a value determined by the control setting.

One type of noise reduction circuit, disclosed for example, in the United States patent to E. R. Taylor No. 2,137,036, issued November 15, 1938, comprises a variable loss pad including copper-oxide rectifier elements, having a maximum loss value sufficient to reduce the normal transmitted noise to a negligible amount, inserted in the speech channel in front of an amplifier and a forward-acting amplifier-detector-filter control circuit, referred to as a "gain increaser," having a sensitivity set at a low enough value to avoid operation on noise. The control circuit is responsive to received speech waves to so control the alternating current impedance of the copper-oxide rectifier elements as to reduce the loss value of the pad and thus effectively increase the gain of the speech channel during the speech transmission intervals.

If such a noise reducer is employed in a radio telephone circuit, particularly a short wave radio telephone circuit, where the maximum levels of noise and cross-talk are fairly high, it is not feasible for the technical operator to vary the adjustment of the gain increaser sensitivity continuously as the noise varies. Consequently, the gain increaser sensitivity tends to be maintained at a relatively low value.

Because of the effects of fading, the received speech is subject to considerable variation in intensity even though signal-operated controls for maintaining speech volumes are provided at the radio transmitter and at the radio receiver. This variation appears principally as occasional

syllables of relatively low intensity which occur during rapid down fades. There may also be considerable distortion with respect to frequency, due to selective fading.

The maximum noise, which determines the setting of the gain increaser sensitivity, is usually sufficiently below the amplitude reached in most of the received speech syllables, so that complete removal of loss occurs on all but occasional syllables of relatively low intensity. This is due to the fact that practically all speech syllables contain at least one vowel, and vowels as a class are the highest intensity sounds of speech.

Although the vowel amplitudes are normally well above the amplitude of the maximum noise, the amplitude of consonants which precede and follow the vowels may be of the same order of magnitude as the maximum noise. With the gain increaser circuit adjusted to discriminate against maximum noise, therefore, removal of loss on consonants may be incomplete. That is, even at the normal operating speech volume, there is noticeable initial and terminal clipping of speech syllables, and these effects are aggravated by the effects of fading. Terminal clipping, however, is mitigated by hangover in the variable loss associated with the gain-increaser function. These clipping effects are continuously present even though the noise levels on the circuit during an appreciable portion of the time are relatively low. It is fairly obvious that if the gain increaser sensitivity adjustment could be more continuously maintained at the highest value consistent with the noise present, the average grade of transmission could be improved.

An object of the invention is to reduce or to suppress circuit noise, static, cross-talk or other interference in telephone transmission systems, particularly short wave radio telephone circuits, during silent periods or pauses in the transmission of speech signals without unduly affecting the quality or volume of transmission during talking periods.

This object is attained in accordance with the invention by modification of a noise reducing circuit of the above-described type to provide automatic adjustment of gain increaser sensitivity in accordance with the amount of noise present. The adjustment provides two different values of gain increaser sensitivity, one of which is sufficiently low to discriminate against the maximum noise present and the other sufficiently high to avoid noticeable distortion of speech.

The modified circuit is so arranged that when the noise level is low—lower, for instance, than

the level of the ordinary consonants in speech—the high sensitivity condition of the gain increaser is sustained practically continuously, and when the noise level occurring between syllables is high—that is, of the same order of magnitude as the consonants in speech—switching from high to low sensitivity takes place. Such operation is obtained by the use, in addition to the usual gain increaser control, of two other wave-operated controls also connected to the speech transmission circuit in front of the vario-losser (variable loss pad). One of these additional controls, which may be called a “sensitivity increase disabler,” is arranged to operate in response to applied waves of a level as high as that of the consonants in speech to reduce the sensitivity of the gain increaser and to increase the maximum loss value of the vario-losser by a given fixed amount. The other, which may be called a “sensitivity increase restorer,” is arranged to operate in response to applied waves of a level as high as that of the vowels in speech to restore the sensitivity of the gain increaser and the maximum loss value of the vario-losser to their normal high and low values, respectively. In addition, the disabler control has a delay in operation of a given amount and the restorer control has a delay in release time (hangover) of a different amount, to cover the duration of initial and terminating consonants, respectively.

In one form of circuit, restoration of high gain increaser sensitivity occurs during every speech syllable, and in another form, additional means are provided for maintaining the low gain increaser sensitivity throughout a talk spurt if the noise is continuously of high level.

The noise reducing circuit of the invention recognizes three types of input which are capable of being separated from each other on an amplitude basis:

A. A level corresponding to voiced speech sounds as transmitted through a network designed to be selective with respect to the distribution of frequency components in voiced sounds. The occurrence of noise or cross-talk at this level has been found to be very infrequent, even under the worst conditions in which a short wave radio telephone system is used;

B. A level, normally of the order of 15 decibels below that of A, corresponding to that of unvoiced speech sounds and relatively high levels of noise and cross-talk, as transmitted through a circuit of uniform response with frequency; and

C. Noise levels below those of unvoiced speech sounds as transmitted by a circuit of uniform response with frequency.

The noise reducer provides limited volume range expansion at all times on inputs of type A, but never on inputs of type C.

Volume range expansion on inputs of type B is provided on a limited time basis, selectively between noise and unvoiced speech being obtained through the fact that practically all unvoiced speech sounds occur either in an interval of about 50 milliseconds immediately preceding a voice sound or in an interval of about 120 milliseconds immediately following a voiced (or type A) sound. Provision is therefore made for an input pulse of type A to set up a condition of increased sensitivity in the expansion control circuit, and for inputs of type B which exceed the duration of normal unvoiced sounds to disable this increased sensitivity condition.

The design of the circuit of the invention is based on the following considerations,

As indicated above, the vowel amplitude occurring in each syllable provides an input which restores or sustains the gain increaser circuit in the high sensitivity condition. In the most general case, the interval between two successive restoring impulses of this kind includes in order: a terminating consonant of the first syllable; a space, which may be occupied by noise; and the initial consonant of the second syllable.

In the circuit of the invention discrimination is on a time basis: that is, discrimination is based on the fact that consonants differ from noise in that they are practically always included in a short interval immediately before or after a vowel. Most initial consonants are included in an interval of 80 milliseconds before the vowel and most terminating consonants are included in an interval of 130 milliseconds after the vowel. The high sensitivity condition, having been set up by a vowel, is prevented from being switched to low sensitivity for a period of about 130 milliseconds. The input from the terminating consonant is therefore ordinarily sufficient to hold the gain increaser operated and maintain minimum loss in the speech channel throughout the length of the consonant.

The circuit is arranged so that a shift from high to low sensitivity can be initiated, but not necessarily completed, by any input of consonant amplitude (which may be defined as the whole amplitude range above an amplitude which is exceeded in most consonants) which occurs while the restoring operation caused by the vowel is not controlling. This is accomplished by introducing delay between the initiation and completion of a switch to low sensitivity.

In a period immediately following a vowel this delay has the value t (130 milliseconds). The first part of the delay t is the period t_2 (50 milliseconds), corresponding to the hangover of the restoring operation, and the last part is the delay t_1 (80 milliseconds), corresponding to the delay in operation of the sensitivity increase disabler control. The delay t_1 applies during any part of the period in which the restoring device is released. The effects of a spaced succession of inputs during this period are not cumulative.

That is, while the restoring device is released, a shift to low sensitivity will take place on any input which is sustained for a period exceeding t_1 but will not take place on any single input or spaced succession of inputs, no one of which is sustained longer than the time t_1 . The delay t , therefore, applies in all cases to terminating consonants in the form of a “sensitivity hangover.” The delay t_1 applies to initial consonants, except in cases where noise of consonant amplitude is present or when the previous terminating consonant has exceeded t in duration.

The interval during which noise can be applied to the circuit in the high sensitivity condition while no speech is present is in general limited to the time t_1 (80 milliseconds). An important exception to this is when the noise is in effect a continuation of the terminating consonant. The corresponding interval in this case is the amount by which the fixed circuit time t (130 milliseconds) exceeds the actual length of the terminating consonant, and may have any value from zero to t . The latter situation occurs after practically every syllable if the noise is continuously high.

The maximum loss of the vario-losser in the high sensitivity condition of gain increase is adjusted to 20 decibels, but when the gain increaser is switched to the low sensitivity condition the

maximum loss value of the vario-losser is changed to 25 decibels, for the purpose of aiding in attenuating loud cross-talk, particularly in long pauses.

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

Fig. 1 is a functional schematic diagram showing the general arrangement of apparatus in a circuit embodying the invention and illustrating the important operating characteristics;

Fig. 2 shows schematically the detailed circuits of the apparatus for producing the operating characteristics diagrammatically illustrated in Fig. 1 in accordance with one embodiment of the invention;

Fig. 3 shows schematically a detailed circuit of the alternative auxiliary disabler shown in dashed lines in the circuit arrangement of Fig. 1; and

Fig. 4 shows characteristic curves illustrating the operating characteristics of the circuits of Figs. 1 and 2.

In the functional schematic of Fig. 1, the single heavy line represents a two-wire speech transmission channel and the other lighter single lines are two-wire transmission paths forming with the associated boxes having labels indicating their functions, the noise reducer of the invention. The contacting arrow-heads in the transmission paths indicate that the paths at those points are normally enabled, and an arrow pointing toward contacting arrow-heads in a path indicates that the path will be disabled at that point by operation of the apparatus in the box from which the arrow points. A representation of a resistance in a transmission path indicates a normal loss in that path.

In the system of Fig. 1, the vario-losser 1 is inserted in the main speech channel 2 in front of the amplifier 3, the loss of vario-losser 1 being controlled by a forward-acting amplifier-detector 4, designated as a gain increaser, which is tapped on the speech input to the vario-losser 1. The provision for selecting between high and low values of gain increaser sensitivity is indicated diagrammatically as a resistance loss pad 5, normally of 15 decibels value, connected in the input circuit of the gain increaser 4, and a by-pass around the pad 5 including the normally closed switch contacts A which when opened will effectively cut the loss pad 5 into the gain increaser circuit to reduce its sensitivity by 15 decibels. The normally closed switch contacts A' in a second by-pass circuit including the resistance loss pad 6, around the vario-losser 1 in the speech channel 2 normally hold the maximum vario-losser loss at 20 decibels and when opened effectively increase the maximum loss value of vario-losser 1 to 25 decibels.

The switching control includes two additional forward-acting control circuits designated 7 and 8, respectively, also tapped on the voice channel 2 in front of the vario-losser 1. The control circuit 7, designated as the "sensitivity increase disabler," including in order the amplifier-detector 9, the delay circuit 10 and switch 11, operates in response to input waves of amplitudes corresponding to the consonants in speech to simultaneously open the sensitivity control contacts A for the gain increaser 4 and the maximum loss control contacts A' for vario-losser 1 after a delay of t_1 (80 milliseconds), to reduce

the gain increaser sensitivity 15 decibels and to increase the maximum loss of the vario-losser from 20 to 25 decibels. When the sensitivity increase disabler 7 operates it is maintained operated by the lock circuit 12, shown simply as a connection from the output to the input of the disabler switch 11, including the normally closed contacts B₁.

The second control circuit 8, designated as a "sensitivity increase restorer," including an amplifier-detector 14 and the preceding selective network 14, operates in response to the applied waves of amplitudes corresponding to the vowels occurring in each speech syllable to open contacts B₂ in the circuit in the output of amplifier-detector 9 and contacts B₁, to disable the sensitivity increase disabler 7 and its locking circuit 12, respectively. The contacts B₂ remain open to disable the sensitivity increase disabler circuit 7 for a hangover interval of t_2 (50 milliseconds) after the release of the amplifier-detector 14 in the sensitivity increase restorer circuit 8, as indicated by the box 15 labeled "release delay of t_2 " connected between the output of amplifier-detector 14 and the switch contacts B₂. The selective network 13 in the input of the "sensitivity increase restorer" has a characteristic such that the sensitivity of the latter is a maximum at about 600 cycles per second and falls off to about 7 decibels lower at 400 and 800 cycles per second. The discrimination obtained in favor of vowels over atmospheric noise with this circuit would be about 5 decibels.

The sensitivity of the "sensitivity increase disabler" 7 is adjusted to be approximately the same as that of the "gain increaser" 4 in the high sensitivity condition, that is, with contacts A closed so that the 15 decibel pad 5 is effectively out of the latter circuit. The effective sensitivity of the "sensitivity increase restorer" 8 for input waves of amplitudes corresponding to that of noise or the consonants in speech is about 15 decibels lower, corresponding to the sensitivity of the "gain increaser" 4 in the lower sensitivity condition, that is, with contacts A open so that the 15 decibel pad 5 is included in the latter circuit. The effective sensitivity of the "sensitivity increase restorer" 8 for input waves of amplitudes corresponding to the vowels in speech is about 5 decibels higher than its effective sensitivity for waves of the amplitude of noise or the consonants of speech.

The "auxiliary disabler" 15 indicated by the dashed lines, when used, which is operatively controlled by operation of the amplifier-detector 9 in the "sensitivity increase disabler" 7 with a delay of t_1 , is arranged to open contacts A and A' in response to noise of continuously high level in the speech transmission circuit 2 to maintain the low sensitivity condition of gain increaser 4 and to increase the maximum loss of vario-losser 1 throughout a talk spurt, in a manner which will be described in connection with the description of operation of the detailed circuit of the auxiliary disabler in connection with Fig. 3.

The arrangement of Fig. 1 operates as follows: Assume that a typical sequence A comprising in order a vowel, a terminating consonant shorter than $t_2 + t_1$, a space in which the noise level is low, an initial consonant shorter than t_1 and a second vowel, be applied to the speech channel 2. The first vowel operates the sensitivity increase restorer 8 to open the contacts B₁ and B₂

to disengage both the locking and operating input to the sensitivity increase disabler 7 insuring that contacts A and A' remain in or are restored to the normally closed position corresponding to high sensitivity, and 20 decibels maximum loss, respectively. At a time t_2 after the vowel amplitude falls below the release point of the restorer 8, contacts B₂ close (contacts B₁ having been previously closed) connecting the operating input corresponding to the terminal consonant to the disabler 7. This input ceases at some time less than t_1 after contacts B₂ close. As this is less than the operating time t_1 of the disabler 7, contacts A and A' remain closed. The effect of the operating input which is received from the terminal consonant is not stored in the disabler 7 but is immediately dissipated when the input ceases. When the initial consonant input is subsequently applied, therefore, the full operating delay t_1 is again involved in the operation of the disabler 7. As the initial consonant is shorter than the time t_1 , contacts A and A' still remain closed. The input of the disabler 7 is then removed when contacts B₂ are reopened by input to the restorer 8 from the second vowel. The high sensitivity condition is therefore maintained throughout this sequence.

Assume now another typical sequence B comprising in order a vowel, a consonant shorter than t_2+t_1 , a space completely taken up by noise of consonant amplitude, an initial consonant shorter than t_1 and a second vowel, is applied to the circuit 2. This case differs from the first sequence (A) referred to above in that, because of the presence of noise, the operating input to the disabler 7 is not removed before a time t_1 after the contacts B₂ first close. The disabler 7, therefore, operates at the end of this interval, opening contacts A and A' and thereby shifting the gain increaser 4 circuit to low sensitivity and the vario-losser 1 to 25 decibels maximum loss. The lock circuit 12 maintains this operation until contacts B₁ again open. This occurs when the second vowel is applied to the restorer circuit 8. It will be noted that the same series of operations would take place if, instead of noise being present, the terminal consonant persists longer than the time t_2+t_1 after the contacts B₁ open.

Assume now that a third sequence C comprising in order a vowel, a terminating consonant shorter than t_2+t_1 , a space with low noise followed by a space longer than 80 milliseconds with noise of consonant amplitude, an initial consonant shorter than t_1 and a second vowel, is applied to the speech channel 2. In this case the situation is the same as in case A referred to above, until the noise of consonant amplitude is applied, contacts A, A' and B₁, B₂ at that instant being closed. At a time t_1 after the noise is applied, the disabler 7 operates and locks contacts A and A' in the open or low sensitivity, in 25-decibel maximum loss position, in which condition the circuit remains until contacts B₁ are opened by the succeeding vowel.

Fig. 2 shows schematically a noise reducer circuit with detailed circuit arrangements for accomplishing the functions illustrated diagrammatically in Fig. 1, certain of the corresponding elements in the two figures bearing the same identification characters.

In Fig. 1, the vario-losser 1 inserted in the telephone channel 2 in front of amplifier 3 includes a transformer 16 having a primary winding connecting to the input portion of the tele-

phone channel 2 and a secondary winding connecting to the input of amplifier 3, two oppositely poled copper-oxide rectifiers 17 and 18 connected in series between the two halves of the secondary winding of the transformer 16, and a mid-tapped resistance 19 shunting the transmission circuit between the secondary winding of transformer 16 and the input of amplifier 3.

Bridged on the input of the telephone channel 2 in front of transformer 16 is the gain increaser circuit 4. A portion of the input signal diverted into the circuit 4 passes through the input transformer 20, is amplified by the "variable-mu" pentode tube amplifier 21 and passes from the plate-cathode circuit of the amplifier 21 through the transformer 22 to the copper-oxide full-wave rectifier 23. The direct current and low frequency output of the rectifier 23 is applied through the filter made up of the shunt condensers 24 and 25 and a series resistance 26, to the vario-losser 1 in the speech channel 2, by connections to the mid-tap of shunt resistance 19 and the mid-point between the copper-oxide rectifiers 17 and 18. The initial sensitivity of gain increaser 4 is adjusted by rheostat 27 in the cathode return circuit of amplifier tube 21, to prevent operation by the maximum amount of normal noise in circuit 2.

When no signal is being received, no rectified current is flowing through the rectifiers 17 and 18 of the vario-losser 1, and their alternating current resistance, in series with the transmission circuit 2, is high, with the result that the vario-losser 1 inserts a relatively high loss (about 20 decibels) in the circuit. As input is applied to the gain increaser circuit 4, rectified current flowing from the output of rectifier 23 through the filter 24, 25, 26 and the copper-oxide rectifiers 17 and 18 causes the alternating current resistances of the latter rectifiers to be decreased cutting down the loss of the vario-losser 1 in proportion to the increase in amplitude of that current, up to a given minimum loss value after which the loss is maintained constant.

The change in sensitivity of the gain increaser 4, corresponding to operation of contacts A, in the corresponding gain increaser circuit of Fig. 1, is obtained by connecting the resistance 28 in shunt with the rheostat 27 and disconnecting it therefrom. The input loss characteristics for the two sensitivities thus obtained for the vario-losser 1 are shown by the curves of Fig. 4. As indicated, the high sensitivity characteristic of the circuit differs from its low sensitivity characteristic by an amount ranging from about 10 decibels in input at high input levels to about 20 decibels at low input levels.

The change in maximum loss of the vario-losser 1, corresponding to operation of contacts A' in Fig. 1, is obtained by placing a direct current bias on the copper-oxide rectifier elements 17, 18 of the vario-losser 1 through resistance 29 and varistor 30. The varistor 30 is used to prevent the gain increaser output current from feeding back into this circuit. The amount of hang-over of the vario-losser 1 is determined by the selection of values for the condensers 24 and 25 in the gain increaser filter. The value selected for this particular circuit was 4 microfarads.

The inputs of the sensitivity restorer 8 and of the sensitivity increase disabler circuit 7 are also

bridged across the speech channel 2 in front of transformer 16.

The sensitivity increase disabler circuit 7 includes amplifier-detector 31 and a chain of three relays, the disabler amplifier-detector relay DAD, the disabler delay relay DD and the disabler switch relay DS, for providing the delay and switching operations of delay circuit 10 and switch 11 in the disabler switching arrangement 7 of Fig. 1.

The gain increaser circuit 4 is normally maintained in the "high sensitivity" condition by connection of the resistor 28 in shunt to the rheostat 27 in the cathode return of the amplifier 21 of the gain increaser circuit through the normally closed front contacts of the disabler switch relay DS and connection 56 (if the auxiliary disabler circuit is not used). The latter relay is normally held operated by current through its winding 33 from battery 34 over a circuit which is normally closed through the back contacts of the disabler delay relay DD. The release of the disabler switch relay DS, to remove resistance 28 from in shunt with the rheostat 27, resulting in a 15 decibel reduction in the sensitivity of the gain increaser 4, takes place when the circuit of the winding 33 of that relay is opened by operation of the disabler delay relay DD. This occurs when the disabler amplifier-detector relay DAD is operated in response to the output current of the disabler amplifier-detector 31, opening the normal short-circuit on the winding 35 of the disabler delay relay DD. The required delay t_1 in the disabling action is controlled primarily by the action of the resistance 36 and condenser 37 of suitably selected values, the condenser 37 being normally charged by current from battery 41. The condenser 37 discharges relatively quickly through the contact protecting resistance 38 when the disabler delay relay DD releases to break the charging circuit through its back contacts. This tends to prevent the effect of successive operations of the disabler delay relay from being cumulative.

When the disabler switch relay DS releases to close its back contacts, it is held in that position through the action of its locking winding 39 which is short-circuited by a connection extending from ground through the normally made back contacts of the restorer relay RR of the restorer circuit 8, winding 39, resistance 40 and made back contacts of relay DS to ground. The release of the disabler switch relay DS to its back contact also short-circuits the direct current bias applied to the rectifiers 17, 18 of the vario-losser 1 thereby increasing the maximum loss condition of that vario-losser to 25 decibels.

The restorer circuit includes the input filter 13 (400-800 cycles), the amplifier-detector 14 and the restorer relay RR. The restoration of high sensitivity to the gain increaser 4 upon application of vowel input from the circuit 2 and the low maximum loss condition (20 decibels) to vario-losser 1 involves three operations as follows:

1. The locking circuit for the gain increaser through the action of the locking winding 39 of the disabler switch relay DS, is disabled by the break of the armature of relay RR from its back contact when that relay is operated by the output current of the restorer amplifier-detector 14 by the vowels in the applied speech waves which, as stated above, occur in each speech

syllable. This is equivalent to operation of the control B_1 in the system of Fig. 1;

2. Operation of the restorer relay RR to close its front contact completes a circuit from battery 41 through the winding 42 of the disabler delay relay DD and resistances 49 and 51, of a polarity which is the opposite to that of the bias produced on that relay by biasing winding 43 by the current from battery 44 passing through the latter winding, the biasing winding 46 of relay RR, the biasing winding 47 of relay DAD in series. Condenser 48, connected across the circuit for winding 42 of relay DD, is charged quickly from the battery 41 through the contact protecting resistance 49. This input is sufficient to prevent operation of the disabler delay relay DD even though the winding 35 thereof is energized by operation of the disabler amplifier-detector relay DAD. It should be pointed out that in most cases when the restorer operates, the disabler amplifier-detector relay DAD will be operated since the disabler amplifier-detector 31 is more sensitive than the restorer amplifier-detector 14. The release of the restorer relay RR resulting in operation of the disabler switch relay DS by reclosing the back contact of the former relay to complete an energizing circuit for winding 39 of the latter relay, is equivalent to operation of contacts B_2 in the system of Fig. 1.

3. An operating input is applied directly to the winding 50 of the disabler switch relay DS from the output of the rectifier of the restorer amplifier-detector 14. The purpose of this is primarily to minimize the delay associated with restoration of high sensitivity upon application of vowel input.

When the vowel input to restore circuit 8 from the circuit 2 is removed, causing the restoring relay RR to release, the releasing input to winding 42 of the disabler delay relay DD is sustained for the period t_2 determined primarily by the values of the capacity of condenser 48 and the resistance of resistor 51.

In the circuit of Fig. 2 it will be noted that the disabler delay relay DD is held in operated condition when the input level to circuits 7 and 8 from the speech circuit 2 is maintained between the operating levels of the disabler amplifier-detector 31 and the restorer amplifier-detector 14. The operation of the disabler circuit is also delayed, as noted above, for the time t_2 when the restorer circuit releases. When no noise is present, therefore, the disabler delay relay DD tends to be operated only during the initial consonants of the applied speech waves and in the intervals by which terminating consonants exceed the value t_2 . If continuous noise of high level is present, the disabler delay relay DD is operated during these unusually short intervals and also during the usually longer intervals when no speech is present. The auxiliary disabler circuit indicated by the dotted box 15 so labeled, connected around the switch 7 in the diagrammatic showing of the noise reducer in Fig. 1, and illustrated in detail in Fig. 3, makes use of this difference in the operation of the disabler delay relay DD in the circuit arrangement of Fig. 2 to distinguish when noise of high level is continuously present.

As shown in Fig. 3, the auxiliary disabler consists of an auxiliary disabler relay AUX.DS having a biasing winding energized from battery 52 through resistance 53, and an opposing operating winding which is energized to cause opera-

tion of that relay from battery 52 through the series resistances 56 and 54 and the front contacts of the disabler delay relay DD when the latter operates in response to operation of the disabler amplifier-detector relay DAD (Fig. 2) by the output current of the disabler amplifier-detector 31. The operation of relay AUX.DS to open its back contacts causes the connection of resistance 28 in shunt with the cathode return sensitivity control rheostat 27 of the gain increaser tube 21 (Fig. 2) to be opened, so as to change the gain increaser circuit 4 to its low sensitivity condition, and simultaneously to short circuit the direct current bias applied to the vario-losser 1 in the speech channel to increase its maximum loss value to 25 decibels. The operating delay and sensitivity of the auxiliary disabler circuit, by suitable design of the relays and associated battery, resistances and condenser, are adjusted so that operation can occur in an ordinary pause between talk spurts—that is, in about 200 milli-seconds. The hangover is adjusted to about 500 milliseconds to cover the duration of several ordinary syllables. Upon application of noise of continuous high level the circuit ordinarily shifts to low sensitivity during the first pause between talk spurts and remains in that condition until the noise is removed. The shift does not occur, however unless the noise between two syllables lasts for 200 milliseconds or more. This tends to discriminate against operation on cross-talk.

Various modifications of the circuits of the invention as 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 combination with a transmission circuit transmitting speech signals and subject to cross-talk or other noise waves of relatively low amplitudes, a noise reducer comprising a variable loss network in said circuit normally providing sufficient loss therein to substantially suppress waves of said low amplitudes, a wave-operated control circuit connected to said transmission circuit, operating in response to applied speech waves to reduce the loss value of said network in proportion to the increase in amplitude of the applied waves up to a given minimum loss value, and means controlled by noise of a given level occurring in said transmission circuit between speech syllables to reduce the sensitivity of said control circuit.

2. In combination with a transmission circuit transmitting speech signals and subject to noise waves of relatively low amplitudes, a noise reducer comprising a variable loss pad in said circuit having a normal loss value sufficient to suppress waves of said low amplitudes, a wave-operated control circuit connected to said transmission circuit, responsive to applied speech waves to reduce the loss value of said pad in proportion to the increase in amplitude of said applied waves up to a given minimum loss value, said control circuit having a normal higher value of sensitivity sufficiently low to discriminate against the maximum amount of noise of said low amplitudes present in said transmission circuit, and means responsive to the noise waves appearing in said circuit between syllables of the transmitted speech wave, of a level corresponding to that of the consonants in speech to reduce the sensitivity of said control circuit to a lower value sufficiently high to avoid noticeable distortion in the transmitted speech waves.

3. In combination with a circuit transmitting speech waves, and subject to noise waves of low amplitude, a normal loss on said circuit of value sufficient to reduce the transmission of waves of said low amplitudes to an unobjectionable amount, a voice-operated control circuit connected to said channel, operating in response to the application of speech waves thereto to reduce said loss in the transmission circuit to a low value, the sensitivity of said control circuit being initially adjusted to prevent its operation on the maximum levels of said noise waves and means responsive to the presence in said transmission circuit of noise waves between syllables of transmitted speech waves, of a level as high as that of the consonants in speech, to reduce the sensitivity of said control circuit to a lower value sufficiently high to avoid noticeable distortion in the transmitted speech waves by the loss inserted in said transmission circuit.

4. In combination with a wave transmission circuit transmitting voice signal waves and subject to disturbing noise waves of low amplitudes, a variable loss device in said circuit normally providing sufficient loss therein to substantially suppress waves of said low amplitudes, a wave-operated control device connected to said circuit, responsive to waves therein only of amplitudes above said low amplitudes to reduce the loss value of said loss device in proportion to the amplitude of the applied waves, up to a given minimum loss, a second wave-operated control device responsive to noise waves appearing in said transmission circuit between syllables of the transmitted speech signal waves, of a level corresponding to that of the consonants in speech, to decrease the sensitivity of the first control device by a given amount, and a third control device responsive to the waves in said transmission circuit of a relatively higher level corresponding to that of the vowels in speech signals to restore the sensitivity of said first control circuit to its normal high value.

5. In combination with a speech wave transmission circuit subject to interfering noise waves of low amplitudes, a variable loss network in said circuit, having a given maximum loss value sufficient to substantially prevent transmission of waves of said low amplitudes, a wave-operated control circuit connected to said transmission circuit responsive only to applied waves of amplitudes above said low amplitudes to reduce the loss value of said network in proportion to the increase in amplitude of said applied waves, up to a given minimum loss value, a second wave-operated control circuit operating with a given amount of delay in response to waves in said transmission circuit of amplitude corresponding to that of the consonants in speech to reduce the sensitivity of the first control circuit by a given amount, to increase the maximum loss value of said network by a given amount, and to lock said first control circuit in the reduced sensitivity condition and said network in the increased maximum loss condition, and a third wave-operated control circuit selectively responsive to the vowels in the speech waves transmitted over said transmission circuit to restore said first control circuit to its normal higher sensitivity condition and said variable loss network to its normal reduced maximum loss condition, said third control circuit having a given amount of hangover in operation, the value of said given amount of delay and the value of said given amount of hangover being determined by

the duration of initial and terminating consonants in speech, respectively.

6. The combination of claim 5, in which said given amounts of delay in the operation of said second control circuit is in the order of 80 milliseconds, and in which said hangover of said third control circuit is in the order of 50 milliseconds.

7. The combination of claim 5, in which said variable loss network includes a series of non-linear impedance elements, said first control circuit comprising a forward-acting amplifier-rectifier-filter circuit supplying biasing direct current varying in accordance with the amplitude of the applied speech waves, to said non-linear impedance elements to control their alternating current loss value in said transmission circuit, said second control circuit comprising an amplifier-rectifier-relay circuit which operates to reduce the gain of the amplifier in said first control circuit, and to apply a fixed direct current bias to said non-linear impedance elements in said network to increase their maximum alternating current impedance values, said third control circuit comprises a filter-amplifier-detector-relay circuit operating to increase the gain of the amplifier in said first control circuit to its normal higher value and to remove said fixed direct current bias from the non-linear impedance elements of said variable loss network, and the delay in operation of said second control circuit and the hangover in operation of said third control circuit being obtained by suitable resistance-condenser circuits associated

with the relays of the respective control circuits.

8. The combination of claim 5, in which said second control circuit operating to reduce the sensitivity of the said first control circuit and to increase the maximum loss value of said network maintains said sensitivity so reduced throughout a talk spurt if the noise on said transmission circuit remains continuously higher than a given level for a period of 200 milliseconds or more.

9. The combination of claim 5, in which said variable loss network has a normal maximum loss value of about 20 decibels which is increased to about 25 decibels by operation of said second control circuit.

10. The combination of claim 5, in which the sensitivity of said first control circuit is reduced by about 15 decibels when said second control circuit operates.

11. The combination of claim 5, in which said variable loss network has a normal maximum loss value in the order of 20 decibels, the operation of said second control circuit causing the sensitivity of said first control circuit to be reduced by about 15 decibels and the maximum loss value of said network to be increased to about 25 decibels, said given amount of delay in the operation of said second control circuit being in the order of 80 milliseconds, and said given amount of hangover in the operation of said third control circuit being in the order of 50 milliseconds.

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