Jan. 8, 1946. A. C. NORWINE 2,392,496

TRANSMISSION CONTROL IN TWO-WAY SIGNALING SYSTEM

Filed Sept. 5, 1942 3 Sheets-Sheet 1

FIG. 1

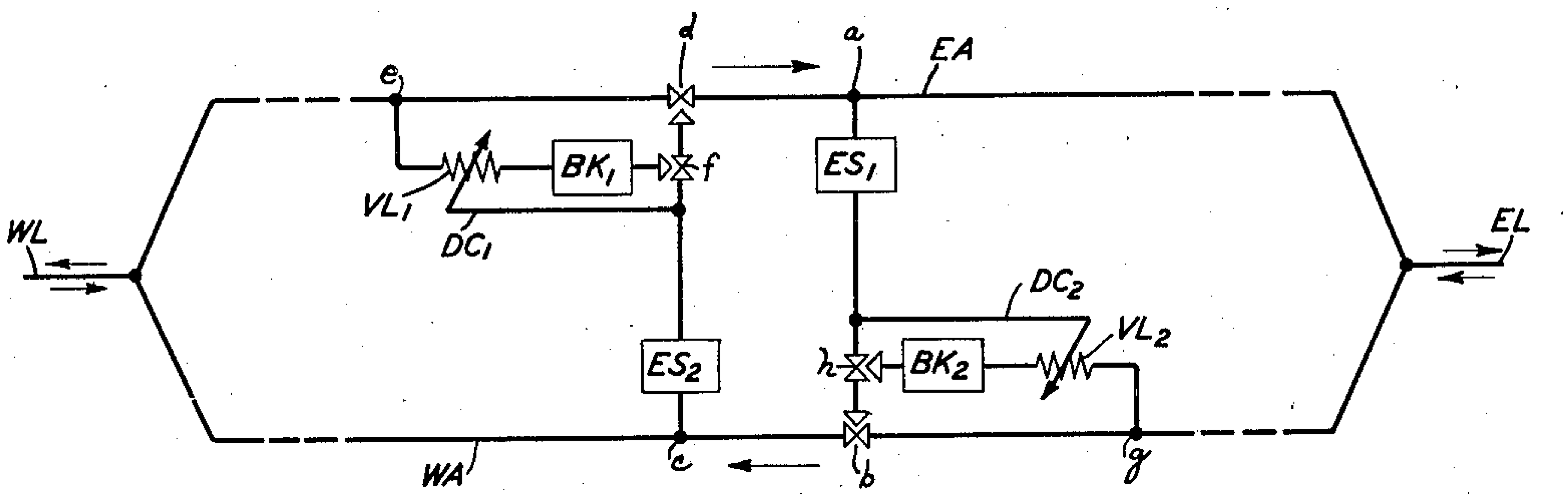
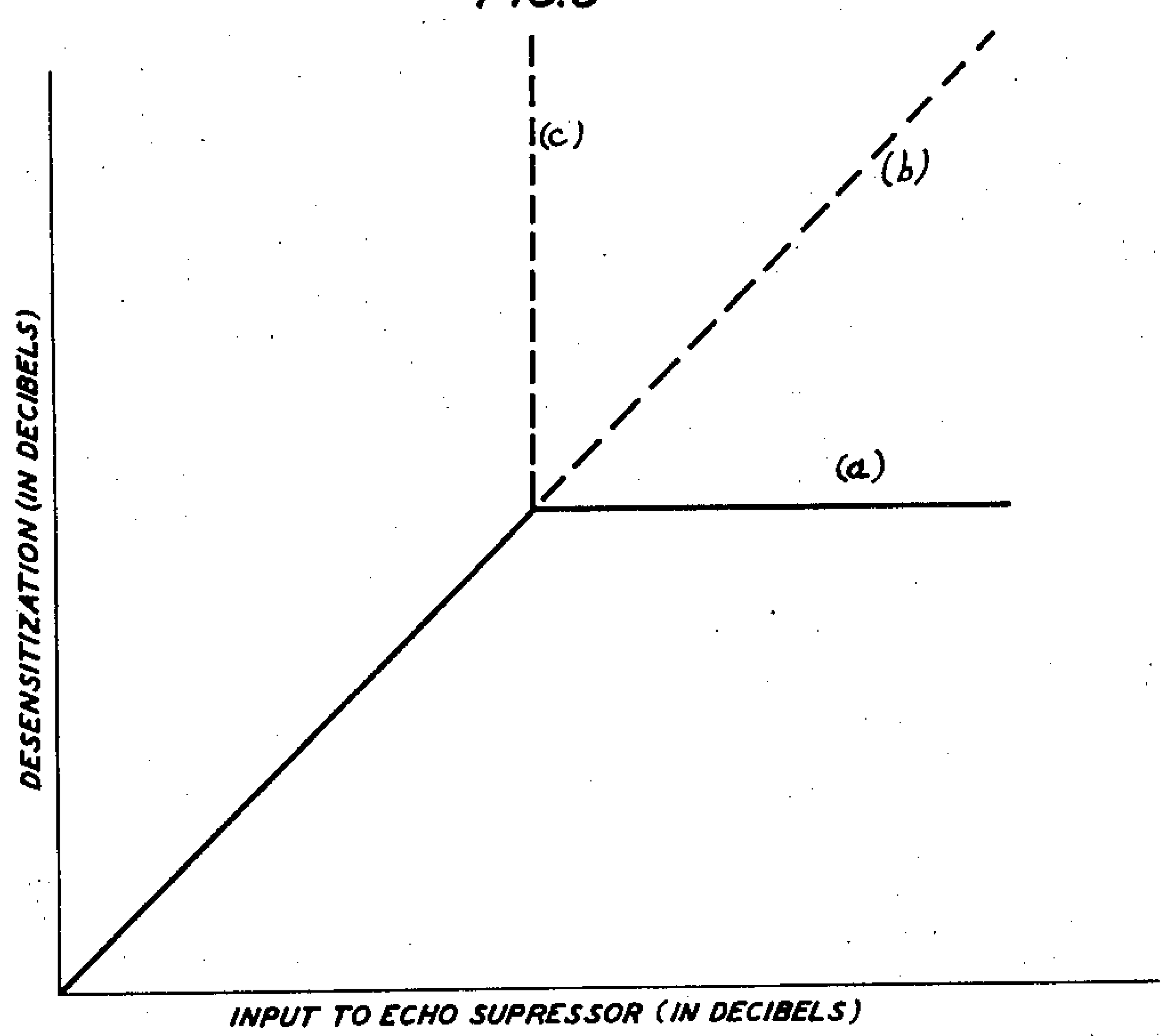


FIG. 3



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TRANSMISSION CONTROL IN TWO-WAY SIGNALING SYSTEM

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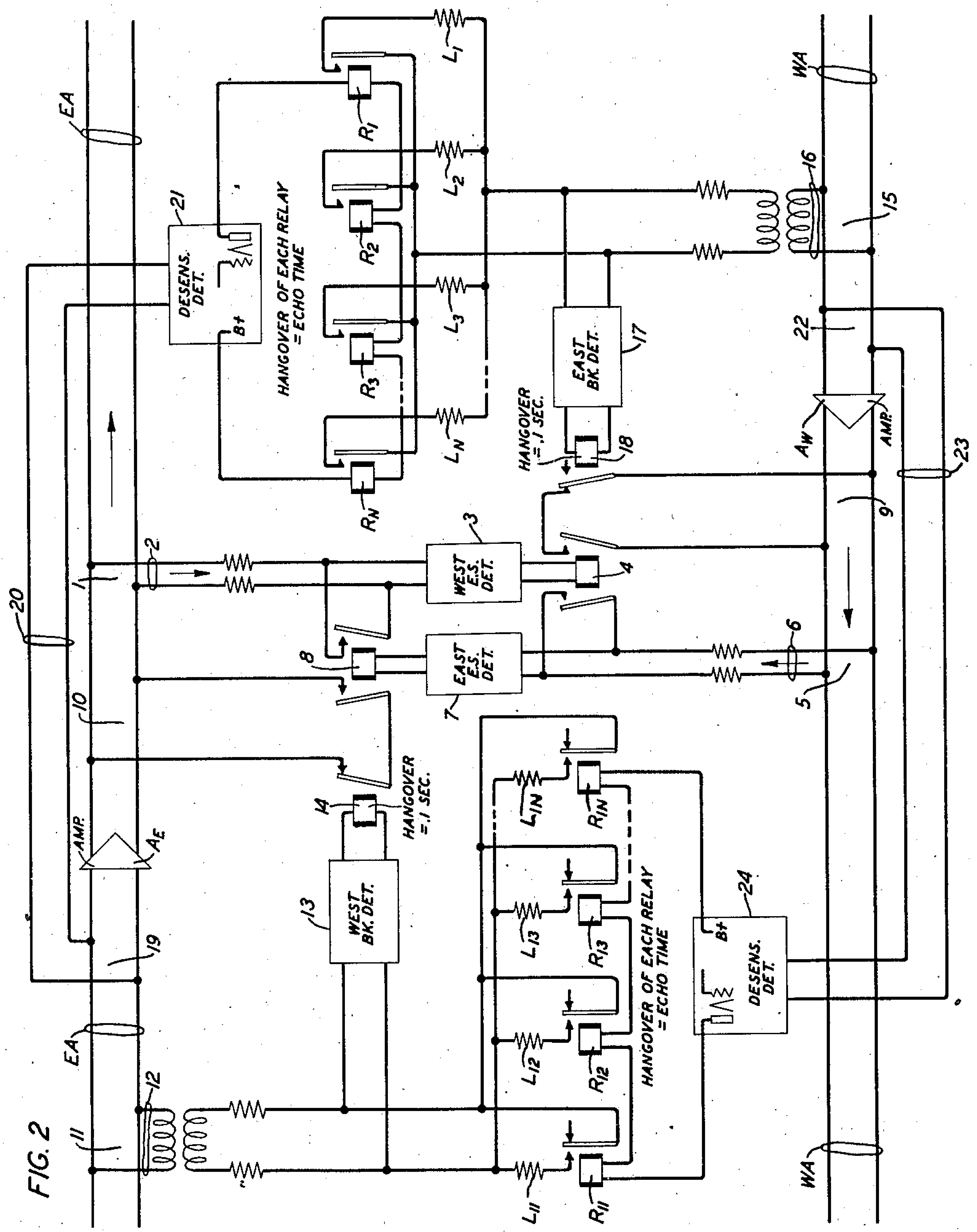

FIG. 2

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TRANSMISSION CONTROL IN TWO-WAY SIGNALING SYSTEM

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FIG. 4

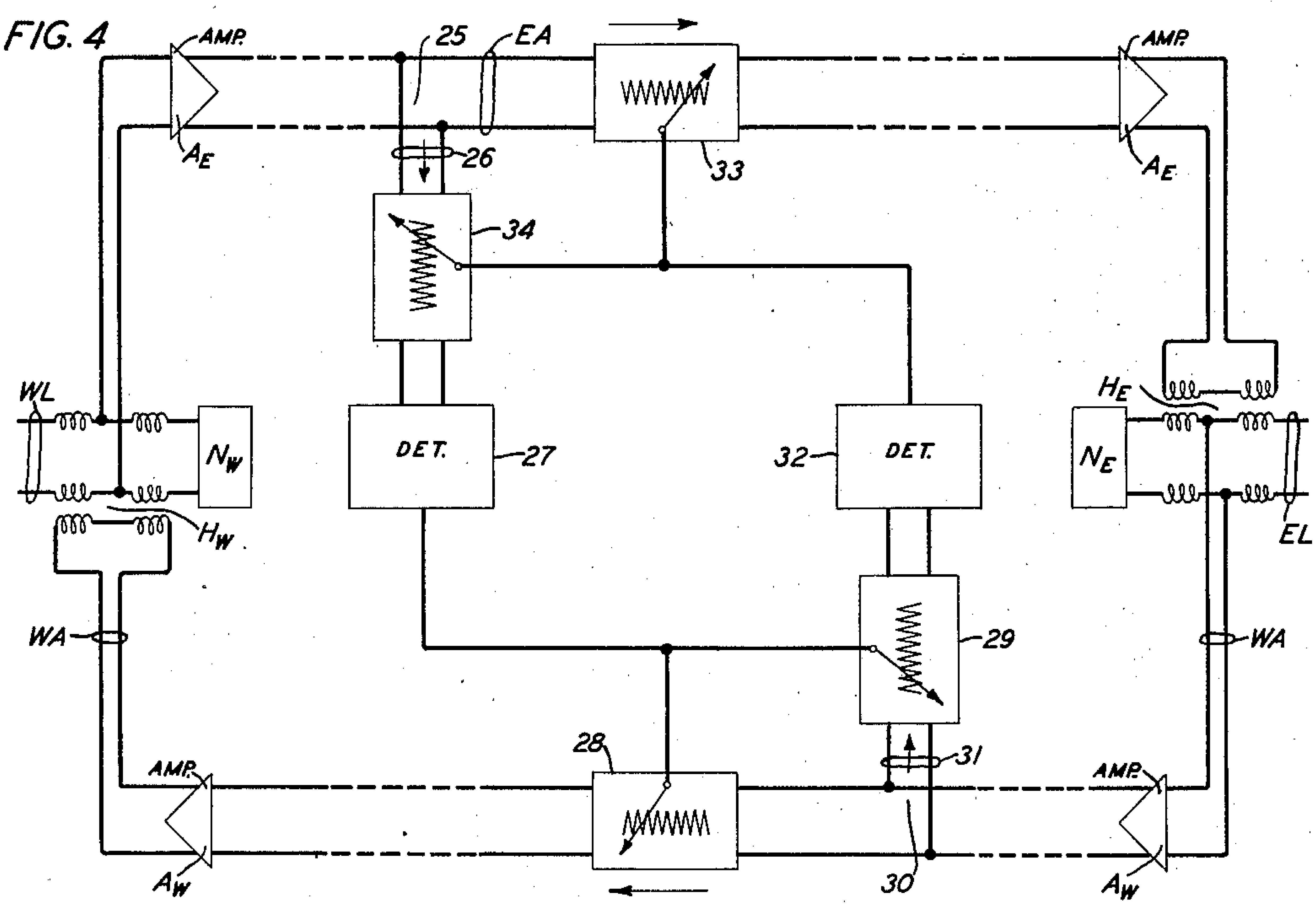
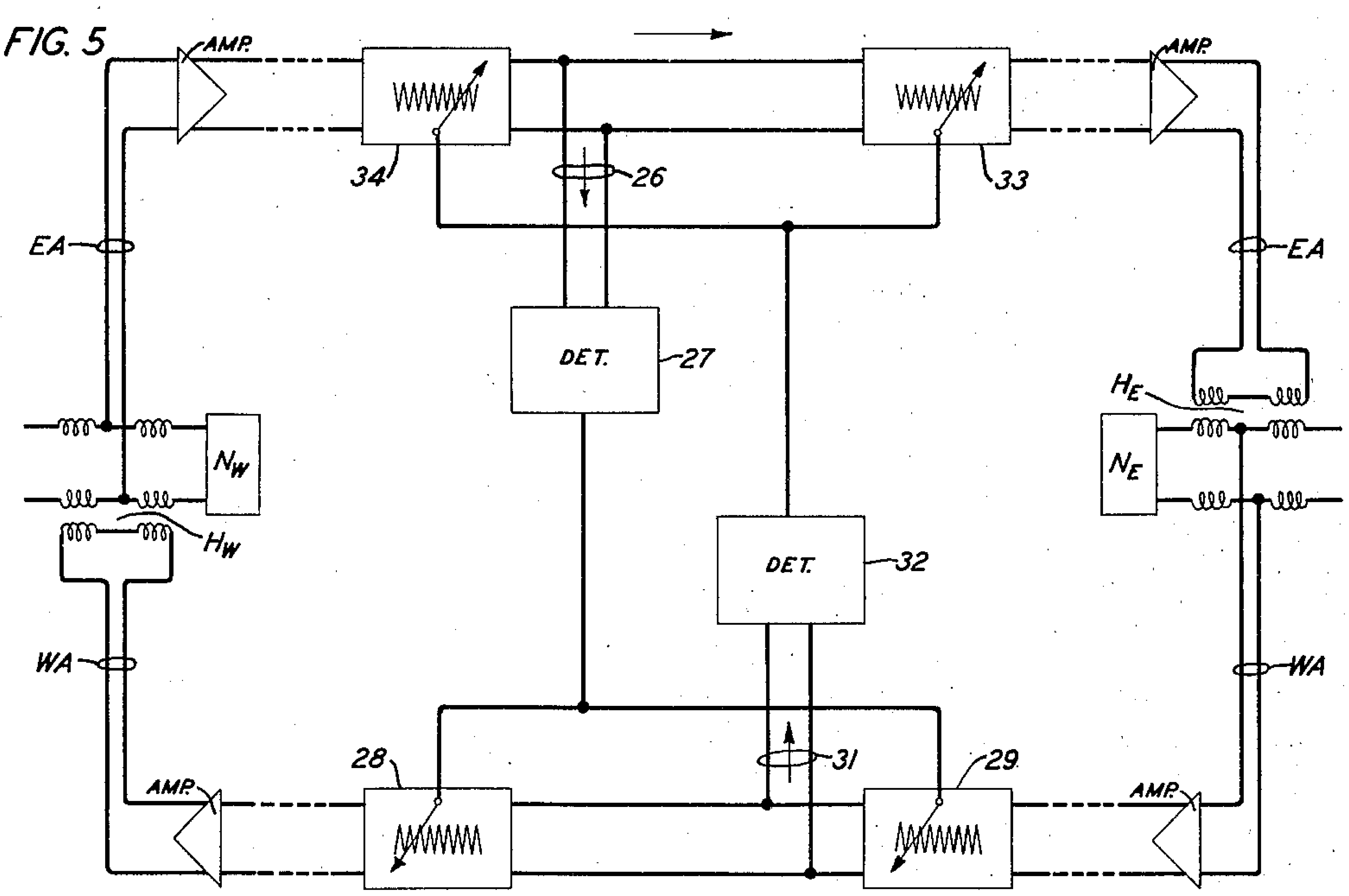


FIG. 5



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UNITED STATES PATENT OFFICE

2,392,496

TRANSMISSION CONTROL IN TWO-WAY SIGNALING SYSTEMS

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Application September 5, 1942, Serial No. 457,393

6 Claims. (Cl. 178—44)

The invention relates to two-way signaling systems, such as two-way telephone systems, and particularly to the signal-controlled switching circuits employed with such systems to directionally control signal transmission therein while suppressing echoes and preventing singing.

Such signal-controlled switching circuits, commonly called echo suppressors, usually comprise two switching branches respectively connected to each of the two oppositely directed one-way signal transmission paths at a terminal or intermediate point of the two-way system, each including a rectifier for rectifying the portion of the signal waves diverted into the switching branch, and electromagnetic relays or other switching devices operated by the rectified signals to suitably control the transmission efficiencies of the signal transmission paths and to disable the other switching branch, so as to provide the desired directional control of signal transmission while suppressing echoes and preventing singing.

The prior patent application of K. H. Davis and A. C. Norwine, Serial No. 421,704, filed December 5, 1941, which issued as Patent No. 2,306,689 on December 29, 1942, discloses such an echo suppressor applied to a four-wire telephone circuit, modified so as to enable a subscriber at one terminal of the system by talking loudly to break in on another who is talking and has obtained directional control of the circuit, without waiting for the latter to pause and regardless of how loudly the latter subscriber is talking. This is accomplished by the use of relatively insensitive auxiliary switching controls, properly located with respect to the echo suppressor controls, operating on an amplitude basis to disable the echo suppressor controls of the talking subscriber when the breaking subscriber talks with the required loudness. These auxiliary controls necessarily have to be relatively low in sensitivity to avoid false operation by echoes of loud speech.

An object of the invention is to improve the operation of break-in echo suppressor circuits of the above-described general type.

A more specific object is to reduce the difference between the "loudness" of two talkers at opposite terminals of a two-way telephone system equipped with break-in echo suppressors of the above-described type, required for break-in, without increasing the probability of false operation by echoes.

These objects are attained in accordance with one embodiment of the invention by adding means to desensitize the break-in controls connected to each one-way transmission path in proportion to the loudness of the speech signals in the oppositely directed one-way transmission path, so that a "loud" talker needs to talk only slightly louder than the echoes of a "weak" talker who has obtained directional control of the system, to break in immediately.

In other embodiments of the invention echo suppression is obtained and break-in facilitated by providing limited desensitizations of each one-way signal transmission path and the echo suppressor control branch controlled from that path, or, alternatively, of each signal transmission path on either side of the point of connection of the input of the associated echo suppressor control branch, which are different functions of the amplitude of the signals transmitted over the oppositely directed one-way signal transmission path controlling the other echo suppressor control branch.

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

Fig. 1 shows a functional schematic of a four-wire telephone circuit equipped with an echo suppressor of the amplitude break-in type embodying one modification of the invention;

Fig. 2 shows schematically one detailed circuit arrangement for accomplishing the functions diagrammatically illustrated in Fig. 1;

Fig. 3 shows curves used for explaining the different types of operation which may be obtained with circuit arrangements such as illustrated in Figs. 1 and 2; and

Figs. 4 and 5 show schematically, and in part diagrammatically, other modifications of the invention.

In the functional diagram of Fig. 1, each single line represents a two-wire signal transmission path. Contacting arrowheads at a point in a transmission path indicate that the path is normally enabled at that point, and an arrow pointing from a box towards the contacting arrowheads indicates that the path will be disabled at that point by operation of the apparatus represented by the box. An arrow through the representation of a resistance at a point in a transmission path, pointing from a box indicates that the sensitivity of the path at that point will be adjusted by operation of the apparatus represented by the box.

The four-wire telephone circuit of Fig. 1 comprises a one-way, two-wire transmission path EA normally conditioned to transmit telephone signals in the direction from west to east between the two-way line WL and the two-way line EL, and a one-way, two-wire transmission path WA normally conditioned to transmit telephone signals in the direction from east to west between the line EL and the line WL. Connected across the west-to-east signal transmission path EA at an intermediate point a is the input of an echo suppressor branch ES_1 operating in response to applied telephone signals from the path EA, when that path is operative, to disable the east-to-west transmission path WA at the intermediate point b. Similarly, connected across the path WA at a point c beyond the disabling point b in that path is the input of a second echo suppressor branch ES_2 operating in response to applied signals from the path WA, when that path is operative, to disable the path EA at a point d in front of the point a to which the echo suppressor ES_1 is connected. Thus, the echo suppressor branch connected to the one-way path of the four-wire circuit transmitting the signals of the subscriber at one terminal of the system, who is first to talk, operates to disable the oppositely directed one-way path and effectively the associated echo suppressor branch so as to give exclusive directional control of the system to the first talker.

Connected across the transmission path EA at a point e in front of the disabling point d in that path is the input of a break-in control circuit BK_1, relatively insensitive compared to the echo suppressor branch ES_1, operating in response to applied telephone signals from the path EA of sufficient amplitude to overcome its desensitization to disable the echo suppressor branch ES_2 controlled from the path WA, at the point f in its output. Similary, connected across the transmission path WA at a point g in front of the disabling point b is the input of a break-in control circuit BK_2, relatively insensitive compared to the echo suppressor branch ES_2, operating in response to telephone signals from the path WA of sufficient amplitude to overcome its desensitization to disable the echo suppressor branch ES_1 connected to the path EA at a point h in its output. As described in detail in the aforementioned Davis-Norwine patent application disclosing similar-in control circuits, after the subscriber at one terminal of the system who first starts to talk, has operated the echo suppressor branch associated with the one-way path EA or WA transmitting his signals, to seize directional control of the system in the manner described above, and while that subscriber continues to talk, a subscriber at the other terminal of the system by talking loudly enough to cause operation of the break-in control branch fed from the oppositely directed one-way path which transmits his signals, may disable the echo suppressor of the first subscriber to interrupt the directional control of the circuit by the latter so as to allow the signals of the second subscriber to get through to the first subscriber. If the first subscriber continues to talk with normal loudness, the second subscriber by operating his own echo suppressor branch may disable the oppositely directed transmission path to seize directional control of the system and cut off the first subscriber, but if the first subscriber also talks with sufficient loudness to operate his own break-in control branch to disable the echo suppressor branch of the other subscriber, both subscribers will be able to hear each other but there will be no echo suppression.

As noted above, a disadvantage of break-in control echo suppressors of the type just described is that the auxiliary break-in controls necessarily have to be relatively low in sensitivity to avoid false operation by echoes of the loudest possible speech. In accordance with the present invention the "loudness" of the second talker required for break-in is made substantially smaller without increasing the probability of false operation by echoes, thus improving the naturalness of conversation. This is accomplished, as indicated diagrammatically in Fig. 1, by adding means for causing the break-in control branch controlled from each one-way transmission path to be desensitized in proportion to the amplitude of the speech signals in the oppositely directed one-way transmission path. Thus a "loud" talker needs to talk only slightly louder than the echoes of the "weak" talker who has obtained directional control of the system to break in immediately. This desensitization may be accomplished as indicated diagrammatically in Fig. 1, by adding controls DC_1, DC_2 to adjust a vario-losser VL_1 or VL_2 in the input of the break-in control branch BK_1, BK_2 connected to each one-way transmission path in accordance with the amplitude of the rectified signals in the output of the echo suppressor branch ES_2 or ES_1 controlled from the oppositely directed one-way path, or, alternatively, the desensitization controls may be controlled by an auxiliary detector connected to the oppositely directed one-way path (as illustrated in Fig. 2). The hang-over of each vario-losser VL_1, VL_2 should be made such that the desensitization of the break-in control connected to each path in response to each controlling signal in the other path will be maintained for a sufficient time interval to prevent false operation of the control by the echo of that signal.

Various types of operation which may be obtained with the desensitizing arrangements of the invention as shown in Fig. 1 (or the alternative arrangements of Fig. 2) depending on the adjustment of the desensitizing gain controls are illustrated in the curves of Fig. 3, in which the desensitization (in decibels) of a break-in control branch controlled from one side of the four-wire circuit is plotted against the input (in decibels) to the echo suppressor branch controlled from the oppositely directed side of the four-wire circuit. Curve a shows limited range desensitization, that is, the break-in control operated from one side of the four-wire circuit is desensitized in direct proportion to the loudness of signal input to the echo suppressor branch operated from the other side, up to the knee of the curve; beyond that, the desensitization (and thus the break-in control sensitivity) is constant. With this adjustment, echo suppressor characteristics which may be identified by the code letters NBE are obtained. The first code letter N of the three means that the echo suppressor provides normal echo suppression if both talkers are weak or only one talker is speaking. The second letter B of the code means that if only one of the talkers is loud enough to operate his break-in control a normal break-in occurs and he gains directional control of the system. The third letter E in the code means that if both talkers talk loudly enough to operate their break-in control both echo suppressors are lifted off so that both talkers hear each other, and double talking echoes occur. With this adjustment, the initial breaking sensitivity can be increased by the range of desensitization, if the desensitization controls are provided with sufficient hang-over in operation by any suitable means to prevent false break-ins by echoes. Thus, the "loud" talker would need to talk only a little louder than the echo of the "weak" talker to be able to break in immediately.

The range of input over which desensitization is changing determines the range for which the middle letter "B" of the code will hold. That is, both talkers will have to talk louder than the input defining the knee of the curve *a* to reach the condition referred to by the last code letter E. In the case of curve *b*, there is no range where this condition can be reached, so that we have an NB echo suppressor which is similar to the ordinary differential echo suppressor except that breaking will be faster because the hang-over of differential is applied to desensitize, not to disable, the opposite side of the four-wire circuit. With the adjustment of curve *c*, the break-in controls are disabled for inputs higher than the knee of the curve, so that the suppressor is changed to what may be called the NBN type, that is, one that provides normal suppression for weak talkers or only one talker; if one of the talkers is loud enough to operate his break-in control, a normal break-in occurs and he gains control of the echo suppressor; and when both talkers talk loudly enough to operate their break-in controls, the echo suppressor functions normally to give directional control to the first talker to speak.

To make the above-described types of break-in effective, it is necessary that the relative sensitivities of the various echo suppressor controls and the relative normal sensitivities of the break-in controls be properly proportioned.

Fig. 2 shows in more detail the circuits and apparatus which could be used to accomplish the echo suppressing, break-in control and desensitizing control functions more diagrammatically illustrated in Fig. 1. The four-wire telephone circuit of Fig. 2 includes the one-way transmission circuit EA including the amplifier A_E, normally conditioned to transmit in the direction from east to west, and the one-way transmission circuit WA including the one-way amplifier A_W, normally conditioned to transmit in the direction from east to west. The input of the circuit EA and the output of the circuit WA may be coupled at the west terminal of the four-wire circuit by the usual hybrid coil and associated line balancing network (not shown) to a west two-way line leading to subscribers' stations, and the output of the circuit EA and the input of the circuit WA may be coupled at the east terminal of the four-wire circuit by the usual hybrid coil and associated line balancing network (not shown) to an east two-way line leading to subscribers' stations.

Connected across the circuit EA at an intermediate point **1** is the input of an echo suppressor branch circuit **2**, to be referred to hereinafter as the west echo suppressor, including the wave detector **3** and the electromagnetic relay **4** adapted to be operated in response to the rectified voice signal output of the detector **3**. Similarly, connected across the east-to-west circuit WA at an intermediate point **5** is the input of an echo suppressor branch circuit **6**, to be referred to hereinafter as the east echo suppressor, including the wave detector **7** and the electromagnetic relay **8** adapted to be operated by the rectified voice signal output of the detector **7**. The relay **4** in the west echo suppressor **2** operates to close a short-circuiting connection across the circuit WA at a point **9** in front of the point **5** to which the input of the east echo suppressor **6** is connected, to disable that circuit, and simultaneously to close a short-circuiting connection across the input of the detector **7** in the echo suppressor **6** to disable that echo suppressor. Similarly, the relay **8** of the east echo suppressor **6** operates to close a short-circuiting connection across the circuit EA at the point **10** in front of the point **1** to which the input of the west echo suppressor **2** is connected to disable that circuit, and simultaneously to close a short-circuiting connection across the input of detector **3** in the west echo suppressor **2** to disable that echo suppressor.

Connected across the west-to-east transmission circuit EA at a point **11** in front of the disabling point **10** therein is the input of a third control circuit **12** relatively insensitive compared to the west echo suppressor **2**, which will be referred to hereinafter as the west break-in control, including the wave detector **13** and electromagnetic relay **14** adapted to be operated in response to operation of the detector **13** by applied voice signals of sufficient amplitude to overcome the desensitizing loss in its input, to put a disabling break in the short-circuiting connection across the circuit EA at the point **10**, and thus to effectively disable the echo suppressing function of the east echo suppressor **6**.

Similarly, connected across the east-to-west circuit WA at a point **15** in front of the disabling point **9** is the input of a control circuit **16** relatively insensitive as compared to the west echo suppressor **6**, which will be referred to hereinafter as the east break-in control, including the wave detector **17** and the electromagnetic relay **18** adapted to be operated by operation of the detector **17** in response to applied voice signals of sufficient amplitude to overcome the desensitization loss in the input of the circuit **16** to put a disabling break in the short-circuiting connection across the circuit WA at the point **9**, and thus to effectively disable the echo suppressing function of the west echo suppressor **2**.

Connected across the circuit EA at a point **19** in front of the disabling point **10** is the input of a fifth control circuit **20**, to be referred to hereinafter as the east break-in control desensitizer, including the wave detector **21**, which may be of the electron discharge tube type as indicated, and a plurality of marginal electromagnetic relays R_1, R_2, R_3 . . . R_N of different sensitivities ranging from a high sensitivity for relay R_1 to a low sensitivity for the relay R_N, connected in series across the output of the detector **21**. The highest sensitivity relay R_1 is adapted to be operated by the rectified signal output of the detector **21** in response to the amplitude of voice signals applied to the input of the detector **21** which would be produced by the weakest direct voice signal (not echoes) passing over the circuit EA; the lowest sensitivity relay R_N is adapted to be operated by the rectified voice signal output of the detector **21** in response to an amplitude of the voice signals applied to the input of the detector **21** which would be produced by the loudest received voice signals passing over the path EA; and the other relays, R_2, R_3 . . . are adapted to be respectively operated by different rectified signal outputs of the detector **21** in response to amplitudes of the voice signal inputs to that detector produced by voice signals of different intermediate stages of loudness passing over the circuit EA. The relays R_1, R_2, R_3 . . . R_N when operated respectively connect the losses L_1, L_2, L_3 . . . L_N across the input of the detector **17** in the west break-in control **16**. The value of the loss L_1 is selected such that when it is connected across the input of the west break-in- control **16** it will reduce the sensitivity of that control by an amount sufficient to just prevent false operation of that control by echoes applied from the path WA of the signals causing operation of the relay R_1. Similarly, the value of each of the other losses $L_2, L_3 \ldots L_N$ is selected so that when each in turn is connected across the input of the break-in control 16 the total loss in the input of that control will reduce its sensitivity by an amount just sufficient to prevent false operation of the control by echoes of the signals of the amplitude causing the operation of the respective relays which are operated. Also, each of the relays $R_1, R_2, R_3 \ldots R_N$ is provided with the same hang-over in operation, which is sufficient to maintain the loss which it controls connected in the input of the west break-in control 16 for just sufficient time to prevent false operation of that control by the echo of the signal causing the operation of the relay. The number of relays used in the chain $R_1 \ldots R_N$ will depend on the range of speech volumes for which desensitization is required and the decibel loss inserted per relay.

Similarly, connected across the circuit WA at a point 22 in front of the disabling point 9 is the input of a sixth control circuit 23, to be referred to hereinafter as the west break-in control desensitizer, including a wave detector 24, like detector 21, and a plurality of marginal relays R_{11}, R_{12}, $R_{13} \ldots R_{1N}$ of different sensitivities covering the same range as the relays $R_1 \ldots R_N$ in the west break-in control desensitizer 20 and with hang-overs computed in the same way, connected in series across the output of the wave detector 24 and operating in response to applied voice signals from the circuit WA of different amplitudes over the desired range of control, respectively insert the losses L_{11}, L_{12}, $L_{13} \ldots L_{1N}$, equivalent to the losses $L_1, L_2, L_3 \ldots L_N$ in the west break-in control desensitizer 20, across the input of the detector 13 of the west break-in control 12, to prevent false operation of the west break-in control 12 by the echoes of the signals controlling the operated relays.

The circuit arrangement of Fig. 2 operates as follows:

Let it be assumed that a west telephone subscriber at the west terminal of the four-wire circuit starts to talk, and at that time the east subscriber at the east terminal of the four-wire circuit is silent. West's speech waves will pass over the circuit EA to the east subscriber being amplified en route by the amplifier A_E. A portion of West's signals will be diverted from the circuit EA at the point 11 into the input of the west break-in control 12, which, at the time, with no speech waves being received from the east subscriber over the circuit WA, will be in its most sensitive condition so that at least a portion of West's speech signals may be of high enough amplitude to momentarily cause operation of the break-in detector 13 and thus of relay 14 to put a break in the short-circuiting connection across the circuit EA at the point 10. This will have no effect on the directional control of transmission because that short-circuiting connection is broken at another point with the east echo suppressor unoperated.

Another portion of West's speech signals will be diverted from the circuit EA at the point 19 into the east break-in control desensitizer 20 and will cause operation of the detector 21 therein to operatively energize one or more of the chain of relays $R_1 \ldots R_N$ in its output, depending on the loudness of West's speech, to cause one or more of the losses $L_1 \ldots L_N$ to be inserted into the input of the detector 17 of the east break-in control 16 to just sufficiently desensitize that control so as to prevent its false operation by applied echoes from the circuit WA of West's signals causing the operation of the operated relays in the chain $R_1 \ldots R_N$.

Another portion of West's speech waves will be diverted from the circuit EA at the point 1 into the west echo suppressor 2 and will cause the operation of the detector 3 and thus of the electromagnetic relay 4 to close the short-circuiting connection across the circuit WA at the point 9 to disable that circuit, and to close a second short-circuiting connection across the input of the east echo suppressor 6 to disable that echo suppressor. This will give West directional control of the circuit and will cause the echoes of his signals reflected at the east terminal of the four-wire circuit into the circuit WA to be suppressed at the point 9.

Now, if the east subscriber desired to break in on West, the former will raise his voice so that at least a portion of his speech signals transmitted over the circuit WA and diverted into the east break-in control 16 will be of sufficient amplitude to overcome the desensitization of that control produced by West by operation of the east break-in control desensitizer 20 in a manner which has been described. As the desensitization of the east break-in control 16 is only that which will just prevent false operation by the echoes of West's speech signals, it will be apparent that East need only talk slightly louder than the echoes of West's speech signals to accomplish this. If East does so, his speech waves will cause operation of the detector 17 and thus of the electromagnetic relay 18 in the east break-in control 16, to put a break in the short-circuiting connection which has been placed across the circuit WA at the point 9 by West by operating the west echo suppressor 2, thus causing the circuit WA to be reenabled at that point, so that East's speech waves may be transmitted out over that circuit to the west subscriber.

While West continues to talk, however, his voice signals will maintain the relay 4 in the west echo suppressor 2 operated to hold the east echo suppressor 6 disabled in its input. Thus, both transmission circuits WA and EA will be operative to respectively transmit the signals of the west and east subscribers to the other subscriber, but there will be no suppression of echoes.

Another portion of East's speech waves will be diverted at the point 22 into the west break-in control desensitizer 23 and will cause the operation of the detector 24 and thus of one or more of the relays $R_{11} \ldots R_{1N}$ in its output, depending upon the amplitude of East's signals, to connect one or more of the losses $L_{11} \ldots L_{1N}$ into the input of the west break-in control 12. The losses thus inserted into that control will desensitize that control just sufficiently to prevent its false operation by echoes from the path EA of East's signals which produce the operation of the operated relays of the chain $R_{11} \ldots R_{1N}$.

Now, if West also raises his voice sufficiently to overcome the desensitization produced in West's break-in control 12 his voice signals will cause operation of the detector 13 and thus of relay 14 to put a break in the short-circuiting connection across the circuit EA at the point 10, but this will be ineffective to cause any change in the operation of the circuit for that short-circuiting connection is already opened because of the non-operation of relay 8 of the east echo suppressor 6 held disabled in its input by the west echo suppressor 2.

This condition of the circuits will continue until one of the subscribers stops talking so as to release his echo suppressor and his break-in control. This will allow the other talker by operating his suppressor to block the echo path and disable the first subscriber's echo suppressor, to seize directional control of transmission in the system, and by continuing to operate the desensitization control for the first subscriber's break-in control making it possible for the latter to interrupt by talking just slightly louder than the first subscriber's echoes.

An echo suppressor of the proportional losser type, for example, such as shown in A. B. Clark Patent No. 1,821,928, issued September 8, 1931, can be made to suppress echoes well by inserting losses in the echo path which increase several decibels for each decibel increase in signal in the oppositely directed path, or it can be made to permit the signal in one path, if loud enough, to interrupt the signals in the other path if the inserted losses increase but slowly with increases in signal amplitude. In such an echo suppressor, the requirement of good echo suppression is incompatible with the requirement that break-in be easy.

Fig. 4 shows a proportional losser type of echo suppressor in accordance with the invention which meets both break-in and echo suppressing requirements. Referring to Fig. 4, the four-wire telephone circuit consists of one one-way, two-wire transmission path EA including the one-way amplifiers A_E, normally conditioned for transmitting voice signals from west to east, and a second one-way, two-wire transmission path WA including the amplifiers A_W for transmitting voice signals in the direction from east to west. These paths are associated at their terminals with a west two-way line WL and an east two-way line EL by the usual hybrid coil and associated line balancing network.

Connected across the transmission path EA at an intermediate point 25 is the input of a combined echo suppressor and break-in control circuit 26 including the wave detector 27 and connected in parallel across the output of the latter, the variable loss devices 28 and 29, the loss values of which are adjusted in accordance with the amplitude of the signal output of the detector 27, as shown diagrammatically. Similarly, connected across the transmission path WA at an intermediate point 30 is the input of a combined echo suppressor and break-in control circuit 31 including the wave detector 32 and the variable loss devices 33 and 34 connected in parallel across the output of the latter, the loss values of which are adjusted in accordance with the amplitude of the signal output of the detector 32, as illustrated diagrammatically. The variable loss device 28 controlled from the output of detector 27 is inserted in the path WA beyond the point 30 to which the control circuit 31 is connected so that its loss is effective in that path only and the variable loss device 29 controlled from the output of detector 27 is connected in the input of the control circuit 31 in front of the wave detector 32 so that its loss determines the sensitivity of the latter circuit. Similarly, the variable loss device 33 controlled from the output of detector 32 is connected in the path EA beyond the point 25 of connection of the control circuit 26 so that its loss is effective in that path only, and the variable loss device 34 is connected in the input of the control circuit 26 in front of the wave-detector 27 so that its loss determines the sensitivity of that circuit.

The normal loss values of the variable loss devices 28 and 33 in the paths WA and EA, respectively, are made very low so that the normal transmission efficiencies of those paths are high. Also, the normal loss values of the variable loss devices 34 and 29 in the inputs of the control circuits 26 and 31, respectively, are also made very low being only large enough to prevent false operation of the detectors in those circuits in response to line noise from the associated signal transmission paths.

Now, let it be supposed that a west telephone subscriber associated with the line WL starts to talk first. Because of the normal low loss condition of the variable loss device 33 in the path EA the west subscriber's speech waves will be transmitted over that path to the line EL leading to the east subscriber with maximum transmission efficiency being amplified by the amplifiers A_E en route. A portion of West's speech waves will be diverted from the path EA into the control circuit 26 and, the variable loss device 34 therein being in its normal low loss condition, with no speech signals of the east subscriber being passed over the path WA, will quickly cause the operation of the detector 27 to produce an increase in loss of the variable loss device 28 in the path WA, to reduce transmitted echoes of West's speech waves reflected into that path at the east terminal of the four-wire circuit. The operation of detector 27 will also cause an increase in the loss of the variable loss device 29 in the input of control circuit 31 to desensitize that circuit, so as to prevent its subsequent operation by applied speech waves of the east subscriber of normal loudness subsequently received from the line EL to reverse directional control of the circuit. Similarly, if the east subscriber associated with the line EL starts to talk first, the variable loss device 28 being in its normal low loss condition, his speech waves will be transmitted over the path WA to the line WL leading to the west subscriber with maximum efficiency. The portion of West's speech waves diverted into the control circuit 31, the variable loss device 29 therein being in its low loss condition, will quickly operate the detector 32 which in turn will cause the loss of the variable loss device 33 in the path EA to be increased so as to reduce the transmitted echoes of East's speech waves reflected from the west terminal of the four-wire circuit into the path EA. The operation of detector 32 will also cause the loss of the variable loss device 34 in the control circuit 26 to be increased thereby desensitizing that circuit so as to prevent its false operation by subsequently applied speech waves of the west subscriber of normal loudness subsequently received over the line WL and the path EA.

The variable loss devices 28 and 33 in the transmission paths WA and EA, respectively, would preferably be arranged so that the losses introduced by them in the respective transmission paths WA and EA in response to operation of the control circuit 26 and the control circuit 31, respectively, will be just large enough so that for each value of input signal applied to the controlling circuit the echo of that signal will be reduced to a commercial amount. On some commercial four-wire telephone circuits this may require so large a loss for all inputs that we have simply a proportionally desensitized echo suppressor. However, if the loss introduced by the variable loss device 28 or 33 in response to operation of the associated control circuit can be limited and still suppress echoes, or if it is made to follow the syllabic variations of the speech signals and these variations are delayed in application to match the delay of echoes, a loud talker could be heard through it even before his speech signals sufficiently desensitize the other talker's control detector so as to reduce the loss in the loud talker's transmission path to a low value. As the loss inserted by the variable loss device 28 or 33 in the transmission path is reduced, the continuing break-in speech becomes gradually louder, as heard by the talker being interrupted. For this reason, it may be less annoying than abrupt break-in, such as that afforded by relay type break-in arrangements.

The variable loss devices 34 and 29 in the control circuits 26 and 31, respectively, may be arranged so that when they are adjusted by the control detector 32 or the control detector 27, respectively, their losses do not increase faster than the input to the opposite side of the circuit, for this amount of desensitization will protect against false operation on echoes. Also, the losses inserted need not exceed the value which will protect against the highest amplitude echo. This assumes, of course, that there is effective hang-over in the desensitizing control equal to the delay time of the worst echo to be protected against.

Just as in the case of the desensitization applied to amplitude break-in controls, it is important to designate the point at which hang-over is applied. It is intended that the hang-over of proportional sensitivity reduction should mean the maintenance during the hang-over period of a desensitizing loss sufficient to prevent false operation on echo. Two things are to be noted about this definition: first, that the desensitizing loss reduces the sensitivity of the oppositely directed device rather than totally disabling it, and, second, that an input louder than the postulated echo can operate the reduced-sensitivity device immediately.

The theory underlying the design of echo suppressors of the amplitude break-in type is that loud echo might be permissible if one or both talkers on a circuit are talking loudly. In a somewhat similar way, it may be said that the divided function proportional losser echo suppressors of Figs. 4 and 5 are based upon the theory that echo suppressing losses may be reduced during the period when both talkers are talking. Theoretically, if both talkers produce the same signal amplitude, each side of the echo suppressor would desensitize the other by half the normal amount for one talker only, and the echo suppressing losses would also be half normal. Each talker therefore would hear the other at reduced amplitude, but with very little echo. If the difference in loudness of the two talkers became greater, the louder one would desensitize the weaker input side more than half of normal, would be heard louder, and would suppress his own echoes better.

The circuit arrangement of Fig. 5 differs from that of Fig. 4 only in that the desensitizing variable loss device 34 for the control circuit 26 is placed in the path EA in front of the point to which the control circuit 26 is connected, instead of in the control circuit 26, and the desensitizing variable loss device 29 for the control circuit 31 connected to the path WA, is placed in the path WA in front of the point to which the control circuit 31 is connected, instead of in the input of the control circuit 31; and, as these desensitizing losses operate as echo suppression losses in the transmission path also, the variable loss devices 33 and 28 operating to insert echo suppressing losses in the path EA and WA, respectively, may be arranged to insert an echo suppressing loss in these paths smaller than that which would be necessary in the circuit of Fig. 4, by the amount of the desensitizing loss for the associated control circuit.

The variable loss devices 28, 29, 33 and 34 in the circuits of Figs. 4 and 5 may be of the relay-resistance type used for desensitizing the break-in control circuit in the circuit of Fig. 2.

Various modifications of the circuits 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 in a two-way telephone transmission system, two oppositely directed one-way signal transmission paths, one switching device connected to each path responsive to voice signal transmission therein, in the absence of prior voice signal transmission in the other path, to insert an echo suppression loss in the other path, and to effectively disable said one switching device connected to said other path, a second relatively insensitive switching device connected to each path in front of the echo suppression point therein, operating in response to applied voice signals from the connected path of sufficient amplitude to overcome its desensitization, to render said one switching device connected to the other path ineffective to disable the first path, so as to allow break-in, and means to desensitize said second switching device connected to each path in proportion to the amplitude over a given range of amplitudes of the voice signals transmitted over the other path, to enable operation of the latter device by the lowest amplitude voice signals in the connected path consistent with preventing its false operation by echoes of the voice signals in said other path.

2. In combination in a two-way telephone system including oppositely directed one-way transmission paths for the signals for opposite directions, one echo suppressor device connected to each path, responsive to voice signal transmission of the subscriber at one end of the system transmitted over that path, in the absence of prior voice signal transmission of a subscriber at the other end of the system in the other path, to disable said other path and said one echo suppressor device connected thereto, a relatively insensitive break-in control device connected to each path at a point in front of the disabling point therein, responsive to applied voice signal transmission of sufficient amplitude, to effectively disable the transmission path-disabling function of the echo suppressor device controlled from the other path, and means to desensitize the break-in control device connected to each path in accordance with the amplitude level of the voice signal transmission, over a given range of amplitudes, applied to the echo suppressor device controlled from the other path, so as to allow operation of the break-in control device connected to each path by the lowest level of applied voice signals above normal level consistent with preventing false operation thereof by applied echoes of the signals transmitted over

said other path in the absence of direct voice signal transmission in the first path.

3. The system cf claim 2 in which the ranges of densitization of said break-in control devices are selected so that if the voice signals of the talking subscribers at both ends of the system are weak or if the subscriber at one end only is talking, signal transmission over the system is effected only in one direction with the echoes of that signal transmission in the opposite direction suppressed; if the signals of one talking subscriber are loud and those of the other weak, the loud talker will obtain directional control with suppression of his signal echoes; and if both talkers are loud the signals of each will be transmitted to the other subscriber but there will be no echo suppression until one subscriber stops talking.

4. In combination in a two-way telephone system, two oppositely directed one-way transmission paths for respectively transmitting the oppositely directed signals of the subscribers at opposite terminals of the system, one switching device connected to each path, operating in response to voice signal transmission therein, in the absence of prior voice signal transmission in the other path, to insert an echo suppression loss in said other path and to desensitize said one switching device controlled therefrom, so as to give directional control of the system to the subscriber who first starts to talk, and means to facilitate break-in by the subscriber at one terminal of the system when the subscriber at the other terminal is talking and has obtained directional control of the system, and to avoid undesirable operation characteristics otherwise obtained with loud talking by the subscribers, comprising means to make the echo suppression loss inserted in each transmission path by operation of the switching device connected to the other path, to vary in proportion to the amplitude of the voice signals in said other path controlling the operation of that switching device, and to make the desensitization of the switching device connected to each path, by operation of the other switching device connected to the other path to vary in accordance with another function of the amplitude of the signals in said other path controlling the operation of said other switching device, such as to allow operation of the first switching device by voice signals applied from the first path of the lowest amplitude consistent with preventing its false operation by applied echoes of the voice signals transmitted over said other path.

5. In combination with a two-way telephone transmission system including two two-way line sections terminating at widely separated points in said system and two oppositely directed one-way transmission paths for respectively repeating voice signals in opposite directions between said two-way line sections, two voice-operated switching devices respectively connected to a different one of said paths at points in said system relatively close together, means responsive to operation of the switching device connected to each path under control of voice signals transmitted over the path to which it is connected, in the absence of prior voice signal transmission in the opposite direction in the other path, to insert a variable loss in said other path beyond the point of connection thereto of the other switching device, which is at any time just sufficient to reduce in said other path the transmitted echoes of the controlling signals to a predetermined tolerable amount, and other means responsive to operation of the switching device connected to each path to provide a desensitization of the other switching device varying with the level of the voice signals in the first path controlling the first switching device, and such as to permit operation of said other switching device by applied voice signals from said other path, of the lowest amplitude level consistent with preventing its false operation by echoes of the signals transmitted over said first path, so as to facilitate break-in.

6. In combination with a two-way telephone transmission system including two two-way line sections terminating at separated points in said system and two oppositely directed one-way transmission paths for respectively repeating voice signals in opposite directions between said two-way line sections, two voice-operated switching devices respectively connected to different ones of said two paths and means responsive to operation of either switching device under control of voice signals transmitted over the path to which it is connected, in the absence of prior voice signal transmission in the other path, to insert a variable loss in said other path on each side of the point of connection of the other switching device thereto, which losses are different functions of the amplitude level of the signals in the first path controlling the operation of the first switching device connected thereto, the sum of the losses thus inserted in said other path being limited to that value which will reduce the transmitted signal echoes therein to a predetermined tolerable amount, and the loss inserted in said other path in front of the point of connection of said other switching device thereto being limited to that value which will effectively produce just sufficient desensitization of the latter device to prevent its false operation by applied signal echoes.

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