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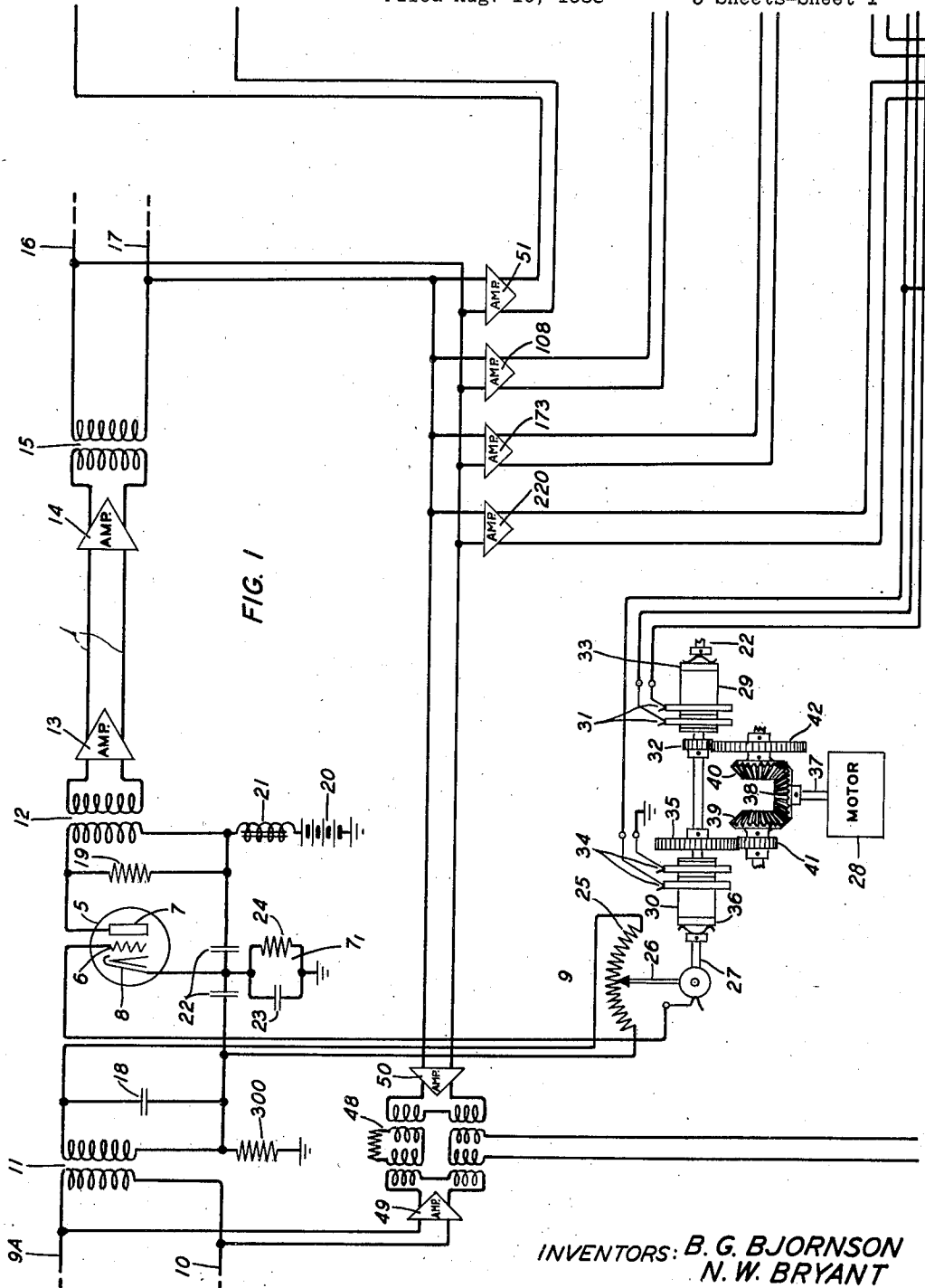
B. G. BJORNSON ET AL

2,170,397

SIGNAL TRANSMISSION SYSTEM

Filed Aug. 10, 1938

3 Sheets-Sheet 1



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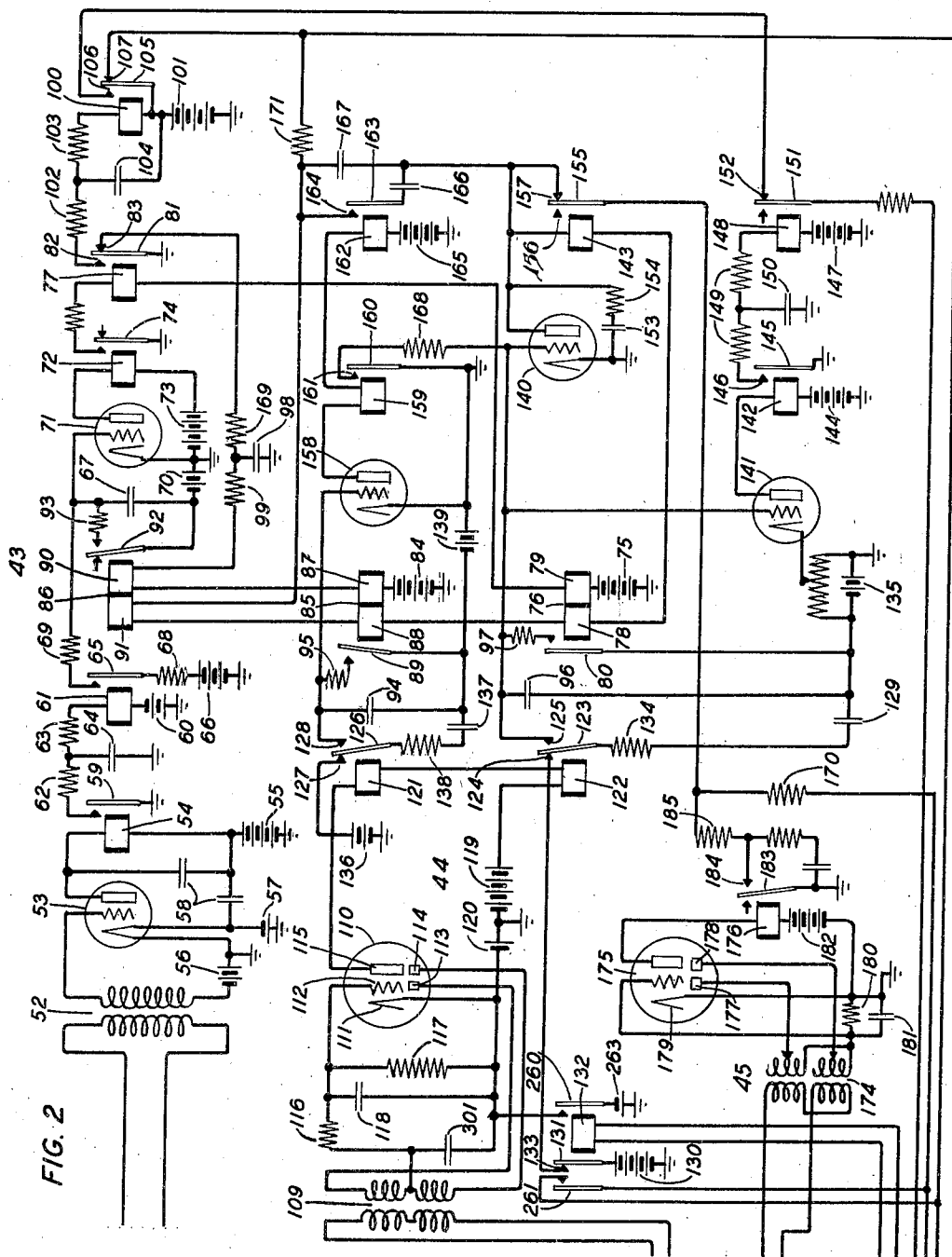
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SIGNAL TRANSMISSION SYSTEM

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3 Sheets-Sheet 2



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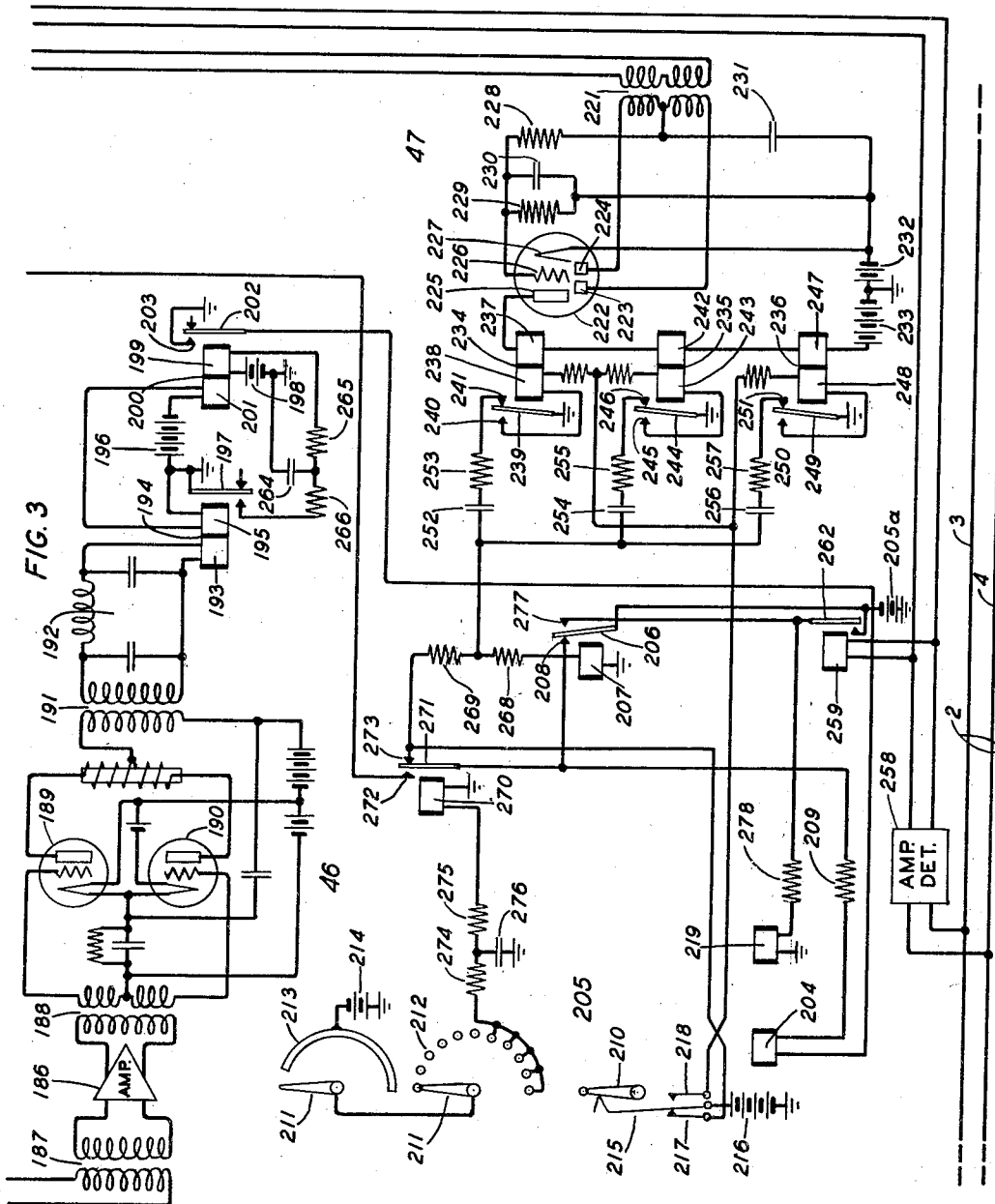
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SIGNAL TRANSMISSION SYSTEM

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,170,397

SIGNAL TRANSMISSION SYSTEM

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16 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to circuits for controlling the volume on signal transmission systems.

One object of the invention is to provide a signal transmission line with volume control circuits that shall be governed according to the operation of a volume indicator to maintain substantially constant volume on a transmission line.

Another object of the invention is to provide a signal transmission line with volume control circuits of the above-indicated character that shall effect gains and losses of different amounts according to the energy of the signals on the transmission line.

Another object of the invention is to provide a signal transmission line with a volume integrating detector circuit for counting the amplitude variations above a predetermined value and a cumulative timer for determining the time interval during which amplitude variations are counted by the volume detector circuit that shall effect a small increase in gain under control of the timer circuit in case a minimum number of amplitude variations are not counted by the volume detector circuit during a time interval and that shall effect no change in gain or different amounts of gain loss in case the minimum number or more than the minimum number of amplitude variations are counted during a time interval by said volume detector circuit.

A further object of the invention is to provide a signal transmission line with a syllable counter operated by signal syllables and a second volume integrating detector circuit that shall effect a substantial increase in gain under control of the syllable counter when the detector circuit is not operated by amplitude variations above normal value and a predetermined number of syllables are counted and that shall effect no gain or gain of varying amounts when the syllable counter is operated by a predetermined number of syllables and the volume detector circuit is operated by one or more amplitude variations above normal value.

In signal transmission systems it is desirable and in some cases essential to control the volume of the transmitted signals. In transmitting speech currents to radio transmitting stations it is desirable to hold the volume of the transmitted speech current at constant volume in order not to overload apparatus at the radio transmitting station. A system of this type is disclosed in the patent to S. Doba, Jr. 2,012,810, August 27, 1935.

In the present invention volume control cir-

cuits that operate according to the principal of operation of a volume indicator are employed to maintain substantially constant volume on a transmission line. A volume indicator is an instrument employed to read the volume of signals on a transmission line and essentially consists of a damped voltmeter. Volume readings are obtained by reading the number of swings of the instrument needle for a given time interval. The time interval is generally taken at ten seconds.

A four-wire system has been employed to describe the invention. The gain on the transmitting channel is controlled by an amplifier governed by a motor operated potentiometer. Essentially the circuits employed to control the motor operated potentiometer comprise a cumulative timer circuit, a first volume integrating detector circuit, a fast gain decreaser circuit and a large gain increaser circuit which employs a syllable counter and a second volume integrating detector circuit. The cumulative timer circuit measures the time interval during which the first volume integrating detector circuit counts amplitude variations above a predetermined value.

The cumulative timer circuit is provided with a timer relay which operates according to the peaks of the speech currents on the transmission line. The timer relay charges a condenser according to the operation thereof. The charge on the condenser measures the time interval during which the amplitude variations are counted. The cumulative timer circuit regulates the length of the time interval by integrating the time during which useful outgoing speech is present on the transmission line. When this time interval has become five seconds the interval is terminated. Since in connected conversation useful speech is present 65 to 75 per cent of the time the total elapsed time is usually about seven seconds. This time interval was arbitrarily chosen instead of the ten-second interval usually associated with volume indicator readings. It is to be understood that any other desired time interval may be chosen if so desired. A gain increaser relay is operated under control of the charge on the timer condenser at the end of the time interval.

The first volume integrating detector circuit is provided with two marginal relays. The first marginal relay is operated by syllables having a predetermined amplitude and the second marginal relay is 2 decibels less sensitive than the first marginal relay. The second marginal relay will only be operated when the output volume indicator overshoots at least 2 decibels.

If the first volume integrating detector circuit does not count a minimum number of syllables on the transmission line by means of the first marginal relay during a time interval measured by the cumulative timer circuit, the cumulative timer circuit governs the motor operated potentiometer to effect a small gain on the transmission line. The gain effected on the transmission line may be of the order of three-fourths decibel and two counted syllables may be taken as the minimum number counted by the first marginal relay. If at the end of a time interval there have been two, three or four operations of the first marginal relay in the time interval, then no gain change is made on the transmission line and a new time interval is started. If five operations of the first marginal relay take place in a time interval the gain on a transmission line is immediately decreased three-fourths decibel and a new time interval is started. Small gain changes or adjustments are continued up or down unless higher gain changes are required.

If during any given time interval as determined by the cumulative timer circuit there are three strong syllables which cause operation of the second marginal relay, then circuit modifications are made so that any gain decrease occurring during that time interval will be 3 decibels instead of the usual three-fourths decibel. The 3 decibel gain decrease occurs immediately after the fourth operation of the second marginal relay or the fifth operation of the first marginal relay. If within the time interval there are not four syllables strong enough to operate the second marginal relays or five syllables strong enough to operate the first marginal relay, the circuits are all returned to normal position without any gain change.

The fast gain decreaser circuit produces a gain decrease on any syllable with a peak that extends above the marginal operating level of the fast decreaser circuit. This circuit is nearly peak operated because very fast operation is desired. Since peak factors of various talkers vary over a wide range, this type of circuit by itself cannot be expected to give good regulation based on the readings of a volume indicator. The sensitivity of the circuit is adjusted so that it very seldom reduces the volume too low but generally leaves it a little high so that the circuits described above will make the more accurate volume adjustments.

The fast gain increaser circuit is made up of a syllable counter and a second volume integrating detecting circuit. Six successive low syllables must be counted before any gain increase can be effected by means of the large gain increaser circuit. After the sixth low syllable the gain on the transmission line is increased 15 decibels, 8 decibels, 3 decibels, or no decibels, according to the operation of the second volume integrating detector circuit. Three marginal relays are controlled by the second volume integrating detector circuit. If none of the marginal relays under consideration are operated during the operation of the syllable counter, then a gain increase of 15 decibels is effected under control of the syllable counter. If one or more syllables is strong enough to operate the most sensitive marginal relay, but not strong enough to operate the others, then the gain increase is reduced to 8 decibels. If one or more syllables is strong enough to operate the second marginal relay, which is more sensitive than the first, but not strong

enough to operate the third relay, the gain increase is reduced to 3 decibels. (In this case both the first and second marginal relays will have operated.) If one or more of the syllables is strong enough to operate the least sensitive marginal relay then all three marginal relays will have been operated and no gain increase is effected.

It should be noted that the fast decreaser circuit and the cumulative timer circuit are very nearly peak operated whereas the volume integrating detector circuit should require considerable power for operation. The cumulative timer circuit is set so sensitive that it will be operated a large part of the time during which speech is present. The sensitivity of the cumulative timer circuit is limited by the noise level. The fast gain decreaser circuit will operate only on exceptionally high peaks which seldom occur when gain adjustment is fairly correct.

In the accompanying drawings, Figs. 1, 2 and 3 disclose diagrammatic circuits constructed in accordance with the invention. The drawings are assembled to show the completed circuits by attaching Fig. 2 to the right side of Fig. 1 and by attaching Fig. 3 to the bottom of Fig. 1.

Referring to Figs. 1, 2 and 3 of the drawings, a transmission system is shown comprising a transmitting channel 1 and a receiving channel 2. The receiving channel comprises conductors 3 and 4. An amplifier space discharge device 5 comprising a grid 6, an anode 7 and a cathode 8 is effectively connected in series with the transmitting channel. A motor operated potentiometer 9 controls the device 5 to govern the gain on the transmission channel 1 so as to maintain the volume substantially constant. The portion of the transmitting channel 1 shown on the drawings comprises input conductors 9a and 10 which are connected by a transformer 11 to the potentiometer 9 adjacent to the device 5. The output circuit from the device 5 is connected by a transformer 12 to a suitable amplifier 13. The amplifier 13 is connected to a second amplifier 14. The output circuit from the amplifier 14 is connected by a transformer 15 to output conductors 16 and 17. A condenser 18 is connected across the secondary winding of the transformer 11 and a resistance 19 is connected across the primary winding of the transformer 12. Anode potential for the anode 7 is provided by a battery 20 in circuit with an inductance element 21. Two by-pass condensers 22 are associated with the device 5. A condenser 23 shunted by a resistance element 24 is connected to the cathode 8 for providing the biasing potential for the device 5. The plate current of device 5 flows through resistance 24 and the resulting voltage across it is in the grid circuit and biases the device properly. A resistance 300 and one of the condensers 22 provide some filtering action.

The potentiometer 9 is motor-operated and comprises a resistance element 25 controlled by a switch arm 26 mounted on a shaft 27. The shaft 27 is operated in a forward and in a reverse direction by a constantly operating motor 28 under control of two magnets 29 and 30. The magnet 29 is fixedly connected to slip rings 31 and a pinion 32. The pinion 32, the slip rings 31 and the magnet 29 are rotatably supported on the shaft 27. An armature 33 is slidably mounted on the shaft 27 to be rotated therewith and adapted to be engaged by the magnet 29 when energized. The magnet 30, slip rings 34 and a gear wheel 35, are rotatably mounted on the

shaft 27. The magnet 30 when energized is adapted to engage an armature 36 which is slidably mounted on and adapted to rotate with the shaft 27. A motor shaft 37 carries a beveled gear wheel 38 which meshes with two beveled gear wheels 39 and 40. The beveled gear wheel 39 has a pinion 41 fixed thereto which meshes with the gear wheel 35. The beveled gear wheel 40 has a gear wheel 42 fixed thereto which meshes with the pinion 32.

In the motor-operated potentiometer above described, the magnet 30 is constantly rotated at a slow rate of speed and the magnet 29 is constantly rotated at a faster rate of speed. Upon energization of the magnet 30 the contact arm 26 which is attached to the shaft 27 is moved toward the right as shown in Fig. 1 of the drawings to raise the gain on the transmitting channel. When the magnet 29 is energized, the contact arm 26 is moved toward the left as shown in Fig. 1 of the drawings to lower the gain on the transmitting channel. The raising of the gain is effected at a much lower speed than the lowering of the gain.

The magnets 29 and 30 of the motor-operated potentiometer are controlled by means of a cumulative timer circuit 43, a volume integrating detector circuit 44, a peak-operated large gain decrease circuit 45, a syllable counter circuit 46 and a second volume integrating detector circuit 47. The cumulative timer circuit 43, the volume integrating circuit 44, the large gain decrease circuit 45 and the second volume integrating detector circuit 47 are backward-acting and are connected to the output conductors 16 and 17 of the transmitting channel. The syllable counting circuit 46 is connected to a hybrid coil 48. The hybrid coil 48 is connected between the input conductors 9a and 10 and the output conductors 16 and 17 of the transmitting channel. A suitable amplifier 49 is connected between the input conductors 9a and 10 and the hybrid coil and a second suitable amplifier 50 is connected between the output conductors 16 and 17 and the hybrid coil 48. If the syllable counter-circuit 46 were connected only to the input conductors 9a and 10, the sensitivity of the circuit would be limited by noise operation to such a value that on low input volumes the counter would only be operated on very strong syllables. The rate of counting of weak input speech impulses would then be liable to be less than on strong speech. In order to reduce this difficulty, the syllable counter-circuit 46 is connected through the hybrid coil 48 to both the input conductors 9a and 10 and the output conductors 16 and 17. This enables speech currents to reach the syllable counter-circuit by two paths, one directly connected to the hybrid coil and the other through the variorepeater and line amplifiers. The sensitivity of the latter path is adjusted so that it is equal to the first path when the gain control circuits are about 30 decibels.

The volume integrating detector circuit 44 effectively counts the number of volume indicator deflections during a given period of time. The cumulative timer circuit 43 determines the time interval during which the deflections are counted. The cumulative timer circuit 43 comprises an amplifier 51 connected to the output conductors 16 and 17 of the transmitting channel. The output from the amplifier 51 is connected by a transformer 52 to a detector tube 53. The output circuit for the detector tube is connected to the coil of a relay 54. Plate potential for the de-

tector tube 53 is supplied by a battery 55 in series with the coil of the relay 54. A battery 56 supplies grid biasing potential and a battery 57 supplies filament heating current for the detector tube 53. Two by-pass condensers 58 are associated with the detector tube 53. An armature 59 of the relay 54 completes a circuit from a battery 60 for operating a relay 61 upon energization of the relay 54. Two resistance elements 62 and 63 and a condenser 64 are provided for effecting a hangover in the operation of the relay 61.

The relay 61 is preferably given a hangover of .015 second, so that it will hold over between the vocal peaks of speech. The relay 61 is provided with an armature 65 which completes a circuit from a battery 66 to charge a condenser 67 when the relay is operated. The circuit completed by the armature 65 extends from grounded battery 66 through a resistance element 68, armature 65, resistance element 69, condenser 67, a grid biasing battery 70 and ground return to the battery 66. The condenser 67 is connected in the grid circuit of a detector tube 71 which controls a relay 72. A battery 73 supplies anode potential to the detector tube 71 in series with the coil of the relay 72. The biasing battery 70 is connected to the grid of the tube 71 in circuit with the condenser 67.

Normally, sufficient plate current does not flow through the detector tube 71 to operate the relay 72 and no operation of the relay 72 can take place until a sufficient charge has been built on the condenser 67. The relay 72 is provided with an armature 74 which completes a circuit from a battery 75 for operating relays 76 and 77. The relay 76 is provided with two coils 78 and 79 and an armature 80 and is included in the integrating detector circuit 44. The relay 77 is provided with an armature 81 which operates between contact members 82 and 83. The relay 77, when released and the armature 81 is in engagement with the contact member 83, completes a circuit from battery 84 through coils 87 and 90 of polarized relays 85 and 86. The relay 85 is provided with the holding coil 87, a releasing coil 88 and an armature 89. The relay 86 is provided with the holding coil 90, a releasing coil 91 and an armature 92. The coil 90 of the relay 86 operates as a holding coil and the coil 91 opposes the action of coil 90. The coil 91 when energized releases the armature 92 to discharge the condenser 67 in circuit with a resistance element 93. The coil 87 of the relay 85 serves as a holding coil and the coil 88 opposes the action of the coil 87. The coil 88 when energized releases the armature 89 to discharge a condenser 94 through a circuit including a resistance element 95. Either coil 78 or 79 of the relay 76 serves to operate the armature 80 to discharge a condenser 96 in circuit with a resistance element 97.

When the relay 77 is energized and the armature 81 is moved from engagement with the contact member 83 and into engagement with contact member 82, the holding circuit from the battery 84 through the coils 87 and 90 of the relays 85 and 86 is broken. However, the relays 85 and 86 are held operated a predetermined time by a hangover circuit comprising condenser 98 and a resistance element 99. After the hangover time, relays 85 and 86 release and discharge condensers 94 and 67 through resistances 95 and 93, respectively. The armature 81 of the relay 77 when in engagement with the contact member

32 completes an operating circuit from the battery 101 for operating relay 100. The operating circuit for the relay 100 extends from ground through the armature 81, contact member 82, resistance elements 102 and 103, coil of relay 100, battery 101 and ground return to the armature 81. A condenser 104 provides a hangover in the operation of the relay 100 when the relay 77 is released. The relay 100 is provided with an armature 105 which operates between contact members 106 and 107. The armature 105 when in engagement with the contact member 107 completes a circuit from the battery 101 under certain conditions for energizing the gain lowering magnet 29. The armature 105 when moved into engagement with the contact member 106 completes a circuit from the battery 101 under certain conditions for energizing the gain raising magnet 30.

The first volume integrating detector circuit 44 comprises an amplifier 108 which is connected to the output conductors 16 and 17 of the transmitting channel 1. The amplifier 108 is connected by a transformer 109 to a rectifying amplifying tube 110. The tube 110 comprises a cathode 111, grid 112, two rectifying anodes 113 and 114 and an amplifying anode 115. The tube rectifying anodes 113 and 114 are connected to opposite terminals of the divided secondary winding for the transformer 109 and serve as a full wave rectifier. The rectifying circuit including the anode 113 may be traced from the anode 113 through the top portion of the secondary winding of the transformer 109, resistance element 116 and resistance element 117 to the cathode 111. A like circuit may be traced from the anode 114 to include the lower portion of the secondary winding of the transformer 109. The resistance element 117 which is shunted by a condenser 118 is connected between the grid and cathode of the triode portion of the rectifier-amplifier tube 110. The circuit consisting of the tube 110 and the condenser-resistance network including resistances 116 and 117 and condensers 118 and 301 is designed to simulate the action of a volume indicator for a fairly wide range. Battery 119 is provided for supplying potential to the anode 115 of the tube 110. A battery 120 is provided to increase the available plate potential over that obtained from battery 119, thereby increasing the range somewhat.

Two marginal relays 121 and 122 are provided in the output circuit of the amplifier portion of the tube 110. The relays 121 and 122 are normally operated. The relay 122 is released when the integrated amplitudes of the syllables of the transmitting channel are above a predetermined level. The relay 121 is released when the integrated amplitudes of the syllables of the transmitting channel are above a second predetermined level. Preferably the second marginal relay 121 is two decibels less sensitive than the relay 122. Normally, the plate current flowing through the amplifier portion of the tube 110 operates both relays 121 and 122. Negative grid bias for releasing the relays 121 and 122 is provided by the voltage drop across the resistance element 117. Condensers 118 and 301 in combination with the resistances 117 and 116 serve to integrate the signals over a period of time.

The relay 122 is provided with an armature 123 which operates between contact members 124 and 125. The relay 121 is provided with an armature 126 which operates between contact members 127 and 128. The relay 122 when in operative

position completes a circuit for charging a condenser 129 from battery 130. The circuit for charging the condenser 129 may be traced from the grounded battery 130, through armature 131 of relay 132, contact member 133, contact member 124, armature 123, resistance element 134, condenser 129, battery 135 and ground return to the battery 130. When the relay 122 is released and the armature 123 is moved into engagement with the contact member 125, the charge on the condenser 129 is impressed on a condenser 96. The condenser 129 is relatively small as compared with condenser 96.

The relay 121 when in operative position and when the armature 126 is in engagement with the contact member 127 completes a circuit from the battery 136 for charging a condenser 137. The circuit for charging the condenser 137 may be traced from grounded battery 136 through contact member 127, armature 126, resistance element 138, condenser 137, battery 139 and ground return to the battery 136.

Two three-element space discharge tubes 140 and 141 are controlled according to the charge on the condenser 96. The condenser 96 impresses positive potential on the grids of the tubes 140 and 141 in opposition to the biasing battery 135. A relay 142 is included in the output circuit of the tube 141 and a relay 143 is included in the output circuit of the tube 140. Plate potential for the tube 141 is supplied by a battery 144. Plate potential for the tube 140 is supplied by the battery 101. The plate current of tube 141 increases as the charge on the condenser 96 increases and when the marginal relay 122 has been released twice the relay 142 is operated. The tube 140 is operated in a manner to be hereinafter described when the relay 122 has been released five times or when the relay 121 has been released four times. The relay 142 is provided with an armature 145 which is adapted to engage a contact member 146. Upon operation of the relay 142, a circuit is completed from a battery 147 for operating a relay 148. Resistance elements 149 in combination with the condenser 150 establish a hangover circuit for the relay 148. The relay 148 is provided with an armature 151, which is adapted to engage a contact member 152 in the released position. The armature 151 of the relay 148 is included in the operating circuit of the gain raising magnet 30 and no increase in the gain can take place in response to action of the cumulative timer circuit 43 unless the relay 148 is in released position.

The space discharge device 140 is gas-filled and triggers off when a predetermined potential is impressed on the grid. The output circuit of the device 140 is shunted by condenser 153 and a resistance 154 for providing an oscillatory circuit which assists in extinguishing the arc. The relay 143 which is controlled by the device 140 is provided with an armature 155 which operates between contact members 156 and 157. Upon operation of the device 140, either $\frac{3}{4}$ decibel or 3 decibels reduction in gain is effected.

The charge on the condenser 94 controls the grid of a space discharge device 158. A relay 159 having an armature 160 which engages a contact 161 and a relay 162 having an armature 163 which engages a contact member 164 are controlled by the device 158. Anode potential for the device 158 is supplied from a battery 165 in series with the coils of the relays 162 and 159. Upon operation of the relay 162 and an engage-

ment between the armature 163 and contact 164 condensers 166 and 167 are connected in parallel for a purpose to be later explained. The relay 159 when operated grounds the grid of the device 140 through a resistance element 168.

The cumulative timer circuit 43 initiates a gain increase of $\frac{3}{4}$ decibel whenever the gain is so low in the time interval that there have not been two operations of the relay 122 in the volume integrating detector circuit 44. The cumulative timer circuit, the same as the large gain decrease circuit 45, is peak-operated. Syllables of speech on the transmitting channel 1 are amplified by the amplifier 51 and supplied to the detector tube 53. The relay 54 is operated according to the detected signals. The relay 61 is operated by relay 54 on each syllable of speech that reaches above the marginal operating value of the relay. The relay 61 has a .015 second hangover, which causes it to remain operated throughout the syllable as long as the peaks exceed the marginal operating requirement. During the time the relay 61 is held operated, the condenser 67 is charged from the battery 66 through the high resistance 69 and resistance 68. The condenser 67 is in the grid circuit of the space discharge device 71 and therefore controls the space current of the device 71.

At the start of each time interval which is measured by the cumulative timer circuit 43, the charge on the condenser 67 is zero and the tube or device 71 is biased by the battery 70 so that no plate current flows. Upon operation of the relay 61 and charging of the condenser 67 the grid of the device 71 becomes more positive and current flows in the plate circuit through the coil of the relay 72. Upon a predetermined plate current flow through the tube 71 the relay 72 is operated. The time interval to effect operation of the relay 72 is generally taken as five seconds. In connected conversational speech this usually requires a lapse of time of about seven seconds. Upon operation of the relay 72 a circuit is completed by the armature 74 for energizing coils of the relays 76 and 77 from the battery 75. Operation of the relay 76 completes a circuit for discharging the condenser 96 through the resistance element 97.

Operation of the relay 77 breaks the holding circuit through the coil 90 of the relay 86 and the coil 87 of the relay 85. This holding circuit extends from grounded battery 84 through coil 87, coil 90, resistance 99, resistance 169, contact member 83, armature 81 and ground return to the battery 84. The relays 86 and 85 are held operated for a predetermined length of time by reason of the hangover produced by the condenser 98. When the armature 81 of the relay 77 engages the contact member 82, a circuit is completed from the battery 101 for operating the relay 100. Upon operation of the relay 100 a circuit is completed from the battery 101 for energizing the gain increase magnet 30. The circuit for energizing the gain increase magnet 30 may be traced from grounded battery 101 through armature 105, contact member 106, contact member 152, armature 151 of the relay 148, slip ring 34, magnet 30, slip ring 34, and ground return to the battery 101.

The amount of gain increase is proportional to the length of time the clutch magnet 30 is held energized. The time the clutch magnet is held energized is determined by the hangover of the relay 86 and the hangover of the relay 100. The hangover time of these relays has been adjusted

so that the total increase in gain is about $\frac{3}{4}$ decibel. The hangover of the relays 86 and 85 becomes effective when the relay 77 operates and removes ground from the resistance element 169. The operation of the relay 77 permits the condenser 98 to charge and when the charging current becomes small the relays 86 and 85 are released. The release of the relay 86 discharges the condenser 67. The release of the relay 85 discharges the condenser 94. When the condenser 67 is discharged, the grid of the tube 71 is again made negative, the plate current is reduced to zero and the relays 72, 77 and 76 are released. The release of the relay 76 removes the shunt across the condenser 96. The release of the relay 77 removes the ground from the operating circuit of relay 100 and applies it to the holding circuit of relays 86 and 85. The relays 86 and 85 when operated remove the shunts across the condensers 67 and 94 and a new timed interval is started.

If in a time interval as measured by the cumulative timer circuit 43, two, three or four operations of the relay 122 have taken place, then the relays 142 and 148 are operated, as will be explained. Operation of the relay 148 opens the circuit of the gain increase magnet 30 and therefore no gain increase can be effected by operation of the cumulative timer circuit 43 as above described.

The marginal relays 121 and 122 in the volume integrating circuit 144 are operated according to the strength of the syllables on the transmission channel 1. The amplified signals supplied from the transmitting channel are rectified by the diode portion of the tube 110, integrated by condensers 118 and 301 and the resistances 117 and 116, and amplified by the triode portion of the tube 110 for operating the relays 121 and 122 according to the strength of the syllables. If in any given time interval five syllables are strong enough to operate the relay 122 or four syllables are strong enough to operate the relay 121 which is 2 decibels less sensitive than the relay 122, a gain decrease is made and a new integrating interval is started. Upon each release of the relay 122 the condenser 96 is charged by the charge of the condenser 129. The condenser 129 is charged from the battery 130 when the relay 122 is in operative position. The condenser 96 is in the grid circuit of the tubes 140 and 141.

When the relay 122 is released twice and two charges are transferred from the condenser 129 to the condenser 96, then the grid bias on the tube 141 is reduced so that the plate current of the battery 144 operates the relay 142. The armature 145 of the relay 142 completes a circuit from battery 147 for operating the relay 148. The armature 151 of the relay 148 breaks the operating circuit of the gain increase clutch magnet 30 so that no increase in gain can take place under control of the cumulative timer circuit 43 when the relay 148 is operated. No further circuit change occurs until the fifth release of the relay 122. The fifth charge transferred from the condenser 129 to the condenser 96 causes ionization of the gas tube 140. Upon breakdown or triggering off of the tube 140, a circuit is completed for energizing the gain decrease magnet 29. This circuit may be traced from ground battery 101 through the armature 105 of relay 100, contact member 107, slip ring 31, magnet 29, second slip ring 31, resistance 170, armature 155 of the relay 143, contact member 157, space discharge device 140 and ground return to the battery 101. At the

same time current flows from the grounded battery 101 through armature 105, contact member 107, resistance element 171, coil 91 of the relay 86, coil 88 of the relay 85, coil 78 of the relay 76, coil of relay 143, device 140, and ground return to the battery 101. The building up of current in the windings of the relays 86, 85, 76 and 143 is retarded by the shunting effect of condenser 167. When the condenser 167 has become sufficiently charged relays 143 and 76 operate while the relays 85 and 86 are released.

Operation of the relay 143 interrupts the current flowing through the gain decrease magnet 29. The gain decrease magnet 29 is operated about .002 second in order to effect a gain decrease of about $\frac{3}{4}$ decibel. Operation of the relay 76 discharges the condenser 96, permitting release of the relays 142 and 148 and extinguishing the ionization of the gas-filled device 140. The relay 143 and the relay 76 are then released. The releasing of the relays 86 and 85 discharge the condensers 67 and 94, so that a new integrating interval can be started.

If the volume on the transmitting channel 1 is somewhat higher so that the relay 121 is frequently operated, the gain decrease may become 3 decibels instead of $\frac{3}{4}$ decibel. The relay 121 when released transfers charge from the condenser 137 to the condenser 94 in the same manner as the relay 122 transfers charge from the condenser 129 to the condenser 96. The charge on the condenser 94 controls the potential on the grid of the tube 158. When three charges from the condenser 127 have been impressed on the condenser 94, the plate current of the tube 158 is raised sufficiently to effect operation of the relay 162. Operation of the relay 162 connects the condenser 166 in shunt to the condenser 167. Connecting the condenser 166 in shunt to the condenser 167 decreases the rate at which current builds up in the coil 91 of the relay 86, coil 88 of the relay 85, coil 78 of the relay 76 and the coil of the relay 143 when the device 140 ionizes. The device 140 does not ionize, however, until the relay 122 operates the fifth time or the relay 121 releases the fourth time within the same time interval as measured by the cumulative timer circuit 43. If the relay 122 releases the fifth time within the interval, the action is identical to that described above for the condition of five operations of the relay 122 and no operation of the relay 121 except that the amount of gain decrease is 3 decibels. The change in the amount of gain decrease is effected by the condenser 166 in shunt to the condenser 167. The condenser 166 connected in shunt to the condenser 167 delays the release of the relays 86 and 85 and the operation of the relays 76 and 143.

If before the relay 122 operates the fifth time, the relay 121 operates a fourth time within the time interval, the plate current of the device 158 becomes great enough to operate the relay 159. Operation of the relay 159 connects the grid of the tube 140 to ground through the resistance element 168 and the tube immediately ionizes, causing a 3-decibel gain decrease as above set forth and a new interval is started. Grounding of the grid of the tube 140 by the relay 159 reduces the negative bias on the tube.

The fast or large gain decrease circuit 45 comprises an amplifier 173 connected to the output conductors 16 and 17 of the transmission channel. The amplifier 173 is connected by a transformer 174 to diode triode space discharge de-

vice 175. The amplifier portion or triode portion of the device 175 is connected to a relay 176. The anodes 177 and 178 of the device 175 are connected to terminals of separate secondary windings for the transformer 174. The cathode 179 of the device 175 is connected through a resistance 180 shunted by condenser 181 to a common terminal of the secondary windings of the transformer 174. The anode of the triode portion of the device 175 is supplied with potential from a battery 182 in circuit with the coil of the relay 176. The relay 176 is normally operated and is released only when sufficient negative potential is impressed on the grid of the triode portion of the device 175.

The fast deceiver circuit 45 produces a gain decrease on any syllable with a peak that extends above the marginal operating level of the fast deceiver circuit. The syllables build up a charge on the condenser 181 and this biases the grid of the triode portion of the device 175 negatively to reduce the plate current. When the plate current falls sufficiently the relay 176 is released. Release of the relay 176 completes a circuit for energizing the gain decrease magnet 29. The circuit completed by the release of the relay 176 may be traced from ground through armature 183, contact member 184, resistance 185, resistance 170, one slip ring 31, magnet 29, the other slip ring 31, contact member 107, armature 105 and grounded battery 101. The amount of gain decrease is determined by the length of time the relay 176 is released. This is determined by the length of time the syllable peaks remain above the marginal operating value. When the gain has been decreased so that the peaks are no longer high enough to hold the relay 176 released, the relay pulls up and prevents further gain decrease.

The syllable counter circuit 46 comprises an amplifier 186 which is connected to the hybrid coil 48 by transformer 187. The hybrid coil 48 as above set forth is connected between the input conductors 9a and 10 and the output conductors 16 and 17 of the transmitting channel 1 but is isolated by amplifiers 49 and 50. The output circuit of the amplifier 186 is connected by transformer 188 to two detector tubes 189 and 190. The detector tubes 189 and 190 are connected by a transformer 191 to a filter 192 which selects syllable frequencies. The filter 192 is connected to a coil 193 of a relay 194. The relay 194 which is a polarized relay is provided with a second coil 195 which is energized from a battery 196. The relay 194 is provided with an armature 197 for completing a circuit from battery 198 to energize a coil 199 of a relay 200. The relay 200 is provided with a second coil 201 which is energized from the battery 196 and an armature 202 which engages the contact member 203 upon operation of the relay 200 for completing a circuit through a stepping magnet 204 of a counting device 205. The circuit to the stepping magnet 204 may be traced from a grounded battery 205a, armature 206 of relay 207, contact member 208, resistance 209, stepping magnet 204, armature 202 of relay 200, contact member 203 and ground return to the battery 205a.

The counting device 205 comprises two switch arms 210 and 211 which are given a rotative movement under control of the stepping magnet 204. The arm 211 bridges contact elements 212 and a contact segment 213. A battery 214 is connected to the segment 213. The arm 210 75

engages a switch member 215 in the initial position of the counter 205 to connect a battery 216 to a contact member 217. Upon starting of the counting device the member 215 connects the battery 216 to a contact member 218. A release magnet 219 under control of the relay 207 is provided for the releasing of the switch arms 211 and 210.

The second volume integrating detector circuit 47 which cooperates with the syllable counting circuit 46 to effect a large gain increase comprises an amplifier 220, which is connected to the output conductors 16 and 17 of the transmitting channel 1. The amplifier 220 is connected by a transformer 221 to an integrating detecting circuit including a diode triode space discharge device 222. The diode portion of the device 222 comprises two anodes 223 and 224, which are connected to opposite terminals of the divided secondary winding of the transformer 221. The triode portion of the device 222 comprises an anode 225, a grid 226 and a cathode 227. One rectifying circuit for the diode may be traced from the anode 224 through the upper portion of the secondary winding for the transformer 221, resistance element 228, resistance element 229 and the cathode 227. The circuit through the anode 223 may be traced in a like manner. Condensers 230 and 231 are provided for effecting an integrating operation. Batteries 232 and 233 are provided for supplying plate potential to the anode 225.

Three marginal polarized relays 234, 235 and 236 are controlled by the diode triode device 222. The relay 234 comprises an operating winding 237, a biasing winding 238 and an armature 239 which operates between contact members 240 and 241. The relay 235 comprises an operating winding 242, a biasing winding 243 and an armature 244 which operates between contact members 245 and 246. The relay 236 comprises an operating winding 247, a biasing winding 248 and an armature 249, which operates between contact members 250 and 251. The relay 234 controls the hangover of relay 207 as determined by discharging of a condenser 252 in circuit with a resistance element 253. The relay 235 controls the hangover of relay 207 as determined by discharging of condenser 254 in circuit with a resistance element 255. The relay 236 controls the hangover of relay 207 as determined by discharging of a condenser 256 in circuit with the relay 257.

In case of low volume on the transmitting channel 1, the gain changes effected by the cumulative timer circuit 43 and the volume integrating detector circuit 44 may be too small and infrequent to raise the volume in the required time. The syllable counter 46 and the volume integrating detector circuit 47 operate to produce much larger gain increases. The input voltage of audio frequency is amplified by the amplifier 185 and is detected by the tubes 189 and 190. The variations of syllable frequencies are selected by the filter 192. The relay 194 is operated by the impulses of syllable frequency for completing a circuit from the battery 198 to effect operation of the relay 200. The circuit for operating the relay 200 may be traced from the battery 198 through the coil 199 of the relay 200, resistance elements 205 and 266, armature 197 and ground return to the battery 198. The condenser 264 which is connected between ground and the two resistance elements 265 and 266 serves to effect a hangover in the operation of the relay 200. The relay 200 upon operation by a strong syllable completes a

circuit for energizing the stepping magnet 204. The circuit for operating the stepping magnet 204 may be traced from grounded battery 205a through the armature 206 of the relay 207, contact member 208, resistance 209, stepping magnet 204, armature 202 of the relay 200, contact member 203 and ground return to battery 205a. The relay 207 at this time is held in operative position by a circuit which extends from grounded battery 205a through armature 206 of relay 207, contact member 208, armature 271 of relay 270, contact member 273, resistance elements 268 and 269, coil of relay 207 and ground return to battery 205a.

Upon operation of the stepping magnet 204, the arms 211 and 210 of the counter mechanism 205 are operated one step. On each succeeding operation of the relay 200, the counter steps another step. When the counter reaches the sixth position the operating circuit of the relay 270 is energized. The energizing circuit for the coil of the relay 270 extends from grounded battery 214, through switch segment 213, arm 211, sixth contact member on the counter, resistance elements 274 and 275, coil of relay 270 and ground return to battery 214. The relay 270 operates with sufficient hangover by reason of a condenser 276 to hold over during latter stepping movements of the counter so that it remains in operative position until the counter is released and returned to zero. Operation of the relay 270 removes the battery 205a from the holding circuit of the relay 207.

The relay 207 has a hangover the amount of which is determined by the position of the relays 234, 235 and 236. The relays 234, 235 and 236 are normally held in operative position by the plate current flow through the triode of the device 222. When the above-mentioned relays are in operative position the armatures 239, 244 and 249 apply ground to the condensers 252, 254 and 256. The condensers 252, 254 and 256 are also connected to the battery 205a by a circuit which extends from the grounded battery 205a through armature 206 of relay 207, contact member 208, armature 271 of relay 270 and resistance element 269 to the condensers 252, 254 and 256. The total hangover time of the relay 207 depends on the number of condensers 252, 254 and 256 which are charged and connected to ground when the energizing circuit of relay 270 is broken. The release of any of the relays 234, 235 and 236 removes the ground from the condenser 252, 254 and 256 and therefore changes the hangover time of the relay 207. When the output volume on the transmitting channel is very low all three relays 234, 235 and 236 will remain operated and relay 207 will have a maximum hangover time.

Operation of the relay 270 energizes the increase gain clutch magnet 30 by a circuit which extends from grounded battery 205a through the armature 206 of relay 207, contact member 208, armature 271 of relay 270, contact member 272, one of the slip rings 34, gain increase magnet 30, the other slip ring 34 and ground return to the battery 205a. When all three hangover condensers 252, 254 and 256 are effective the relay 207 remains operated for a time which will permit the gain to increase a large amount, for example 15 decibels.

If only the condensers 252 and 254 are effective the relay 207 will remain operated a sufficient time to effect 8 decibels gain. If only the relay 252 is effective the relay 207 will remain operative a sufficient time to effect 3 decibels

gain. If none of the condensers 252, 254 and 256 is effective, no gain will take place.

Upon release of the relay 207 the circuit from the battery 205a through the gain increase magnet 30 is broken. When the armature 206 of the relay 207 engages the contact member 277 the release magnet 219 is energized by a circuit which extends from the grounded battery 205a through armature 206 of relay 207, contact member 277, resistance element 278, coil of release magnet 219 and ground return to the battery 205a. The release magnet 219 causes the arms 210 and 211 to return to zero position. The arm 211 upon return to zero position removes battery 15 from the operating circuit of the relay 279. When the counter arm 210 reaches zero position the switch member 215 is separated from the contact member 218 and is moved into engagement with contact member 217. The separating of the switch arm 215 from contact member 218 disconnects the battery 216 from any of the biasing coils 238, 243 and 248 of the relays 234, 235 and 236. The engagement between the switch arm 215 and the contact member 217 serves 25 to energize the relay 207 from the battery 216. At this time operation of relay 207 applies potential from the battery 205a through the resistance element 269 and the coil of the relay 207. The relay 207 will again be held in operative position by current supplied by the battery 205a.

When the output volume on the transmitting channel is not very low one or more of the speech syllables will build up a sufficient charge on the condenser 230 of the volume integrating detector circuit 47 to reduce the plate current through the triode of the device 222 sufficient to release one or more of the relays 234, 235 and 236. Whenever one of the relays 234, 235 and 236 is released, ground is applied to the biasing winding associated therewith. The circuit of the biasing winding 248 for the relay 236 may be traced from grounded battery 216 through contact arm 215, contact member 218, coil 248, contact member 250, armature 249 and ground return to the battery 216. When one of the relays 234, 235 and 236 has been released and held by its biasing winding the relay cannot pull out and be operated until the syllable counter circuit is returned to zero position.

When the volume control circuits are used as a part of a four-wire circuit the echoes of the received speech may operate in the various control circuits unless provision is taken to prevent such operation. An amplifier detector 258 is connected to the receiving channel 2 for operating relays 259 and 132 whenever the receiving channel is in service. The relay 259 when operated completes a circuit from the battery 205a through the armature 262 and resistance 278 for operating release magnet 219. This insures that the syllable counter would be in zero position and that the relays 234, 235 and 236 will be in normal position. The relay 132 is provided with an armature 231 which short-circuits the gain decrease magnet 29 to prevent any operation thereof when speech is on the receiving channel. Armature 131 of the relay 132 disconnects the battery 130 from the condenser 129 and prevents any charging thereof. The condenser 129 charges the condenser 96 which in turn controls the gain decrease by means of the space discharge devices 140 and 141. The armature 260 operated by the relay 132 impresses negative potential on the grid 112 in the triode of the space discharge de-

vice 110 so as to prevent operation of either marginal relay 121 and 122.

Modifications in the circuits and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. The method of controlling the volume of signals on a transmission line which consists in detecting and counting the number of amplitude variations above a predetermined value on the transmission line, in determining time intervals during which amplitude variations are counted, and in varying the gain on the transmission line according to the number and value of the amplitude variations above a predetermined value detected during a time interval.

2. The method of controlling the volume of signals on a transmission line which consists in detecting and counting the number of amplitude variations above a predetermined value on the transmission line, in determining according to the speed of amplitude variations on the line the time intervals during which amplitude variations are counted, in raising the gain on the transmission line when less than a minimum number of volume variations above a predetermined value are detected in one time interval, and in preventing raising of the gain on the line when a predetermined minimum number of volume variations above a predetermined value are detected in one time interval.

3. The method of controlling the volume of signals on a transmission line which consists in detecting and counting the number of amplitude variations above a predetermined value on the transmission line, in determining according to the speed of amplitude variations on the line the time intervals during which amplitude variations are counted, in raising the gain on the transmission line when less than a minimum number of amplitude variations above a predetermined value are detected in one time interval, and in lowering the gain on the transmission line when a predetermined number of variations more than a minimum number of volume variations above a predetermined value are detected in one time interval.

4. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for counting the number of amplitude variations above a predetermined value on the transmission line, a timer circuit operated according to the speed of the amplitude variations on the line for determining the time interval during which the amplitude variations are counted, and means governed by said timer circuit at the end of a time interval for operating said gain device to increase the gain a small amount when the volume indicating detector circuit has not received a predetermined minimum number of amplitude variations above the predetermined value.

5. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for counting the number of amplitude variations above a predetermined value on the transmission line, a timer circuit controlled according to the speed of the amplitude variations on the line for determining the time interval during which the amplitude variations are counted, means controlled by said volume indicating circuit when only a predetermined minimum number of amplitude variations above the

predetermined value occur for preventing operation of said device, and means governed by said timer circuit at the end of a time interval when less than the minimum number of amplitude variations above the predetermined value occur for operating said device to increase the gain on the line a small amount.

6. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for counting the number of amplitude variations above a predetermined value on the transmission line, a timer circuit governed according to the speed of the amplitude variations on the line for determining the time interval during which the amplitude variations are counted, means governed by said timer circuit for operating said gain device to increase the gain on the line a small amount if the amplitudes on the line in a time interval are a small amount below normal, and means controlled by said volume indicating detector circuit for operating said gain device to lower the gain on the line a small amount when the amplitudes on the line in a time interval are a small amount above normal.

7. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for counting the number of amplitude variations above a predetermined value on the transmission line, a timer circuit for determining the time interval during which the amplitude variations are counted, marginal means controlled by said volume indicating circuit, means controlled by said marginal means for effecting different amounts of gain reduction by said device according to the value of the amplitude variations counted, and means controlled by said timer circuit for operating said device to effect a small increase in gain upon failure of a predetermined minimum operation of said marginal means.

8. A signal transmission line having a gain varying device therein, timing means for measuring the time the signals on the transmission line are above a certain level to determine a time interval, indicating means for detecting the number of amplitude variations above a predetermined value in a time interval, means governed by said timing means for operating said device to increase the gain on the line when a predetermined minimum number of amplitude variations are not detected by said indicating means in a time interval, and means governed by said indicating means for preventing operation of said device by said timing means when a minimum number of amplitude variations above a predetermined value are detected, and for operating said device to lower the gain on the line according to the number and the value of the detected amplitude variations above the predetermined value when more than a minimum number of variations are detected.

9. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for counting the number of amplitude variations above a predetermined value on the transmission line, a timer circuit for determining the time interval during which amplitude variations are counted, marginal relays selectively operated by said indicating circuit, means governed by said timing circuit at the end of a time interval when less than a predetermined minimum number of amplitude variations have been detected by said indicating circuit for operating said device to increase the gain on the line, means operated by one of said relays for

preventing operation of said device by the timing circuit when a minimum number of amplitude variations are detected by said indicating circuit and for operating said device to lower the gain on the line a small amount when a predetermined number of amplitude variations above the minimum number of amplitude variations are detected by said indicating circuit, and means operated by another one of said relays for operating said device to effect a greater loss in the gain on said line when a number of amplitude variations of greater value are detected by said indicating circuit.

10. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for integrating and counting the number of amplitude variations above a predetermined value on the transmission line, a time circuit for determining the time interval during which the amplitude variations are counted, means governed by said time circuit and said indicating circuit according to the amplitude variations above a predetermined value for operating said device to effect small decreases and increases in gain on the line, and fast decreaser means for operating said device at a fast rate to lower the gain on the line when syllable peaks go above a predetermined upper level.

11. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for integrating and counting the number of amplitude variations above a predetermined value on the transmission line, a timer circuit for determining the time interval during which the amplitude variations are counted, means governed by said timer circuit at the end of a time interval for operating said device to increase the gain a small amount when the volume indicating detector circuit has not received a predetermined minimum number of amplitude variations above the predetermined value, means operated by said indicating circuit for operating said device to lower the gain on the line by varying amounts according to the value and number of amplitude variations detected above the predetermined minimum number, and fast decreaser means for operating said device at a fast rate to decrease the gain on the line when syllable peaks go above a predetermined upper level.

12. A signal transmission line having a gain varying device therein, means comprising a syllable counter operated by syllables on the line, gain increaser means operated by said counter when a predetermined number of syllables have been counted for operating said device to increase the gain on said line by a substantial amount, and marginal means operated according to the energy values of the syllables on the line to vary the amount of increase in gain effected by said gain increaser means.

13. A signal transmission line having a gain varying device therein, means comprising a syllable counter operated by syllables on the line, gain increaser means operated by said syllable counter when a predetermined number of syllables have been counted and the syllables are below a predetermined energy level for operating said device to increase the gain on the line by a substantial amount, and means for selectively varying the increase in gain caused by said gain increaser means according to the energy value of the syllables and for preventing operation of the gain increaser means when the syllables are above a predetermined energy value.

14. A signal transmission line having a gain

varying device therein, means comprising a syllable counter operated according to the number of syllables on the line, gain increaser means operated by said syllable counter when a predetermined number of syllables have been counted and the syllables are below a predetermined energy level for operating said device to increase the gain on the line by a substantial amount, means for selectively varying the increase in gain caused by said gain increaser means according to the energy value of the syllables and for preventing change in gain by the gain increaser means when the syllables are above a predetermined energy level and auxiliary means for controlling said device according to amplitude of the signals to effect small changes in gain on the line.

15. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for integrating and counting the number of amplitude variations above a predetermined value on the transmission line, a time circuit for determining the time interval during which the amplitude variations are counted, means comprising a syllable counter operated according to the number of syllables on the line, gain increaser means operated by said syllable

counter when a predetermined number of syllables have been counted for operating said device to increase the gain on the line by a substantial amount, marginal means operated according to the energy values of the syllables on the line for varying the amount of increase in gain by said increaser means and for preventing change in gain by the increaser means when the syllables are above a predetermined value, and means governed by said time circuit and said indicating circuit according to the amplitude variations above a predetermined value for operating said device to effect small decreases and increases in gain on the line.

16. A signal transmission line having a gain varying device therein, a volume indicating detector circuit for counting the number of amplitude variations on the transmission line above a predetermined value, and means governed by said detector circuit for controlling said device to lower the gain on the transmission line according to the number and strength of the amplitude variations above the predetermined value.

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