CIRCUIT FOR CONTROLLING TRANSMISSION IN SIGNALING SYSTEMS

Filed July 28, 1933 2 Sheets-Sheet 1

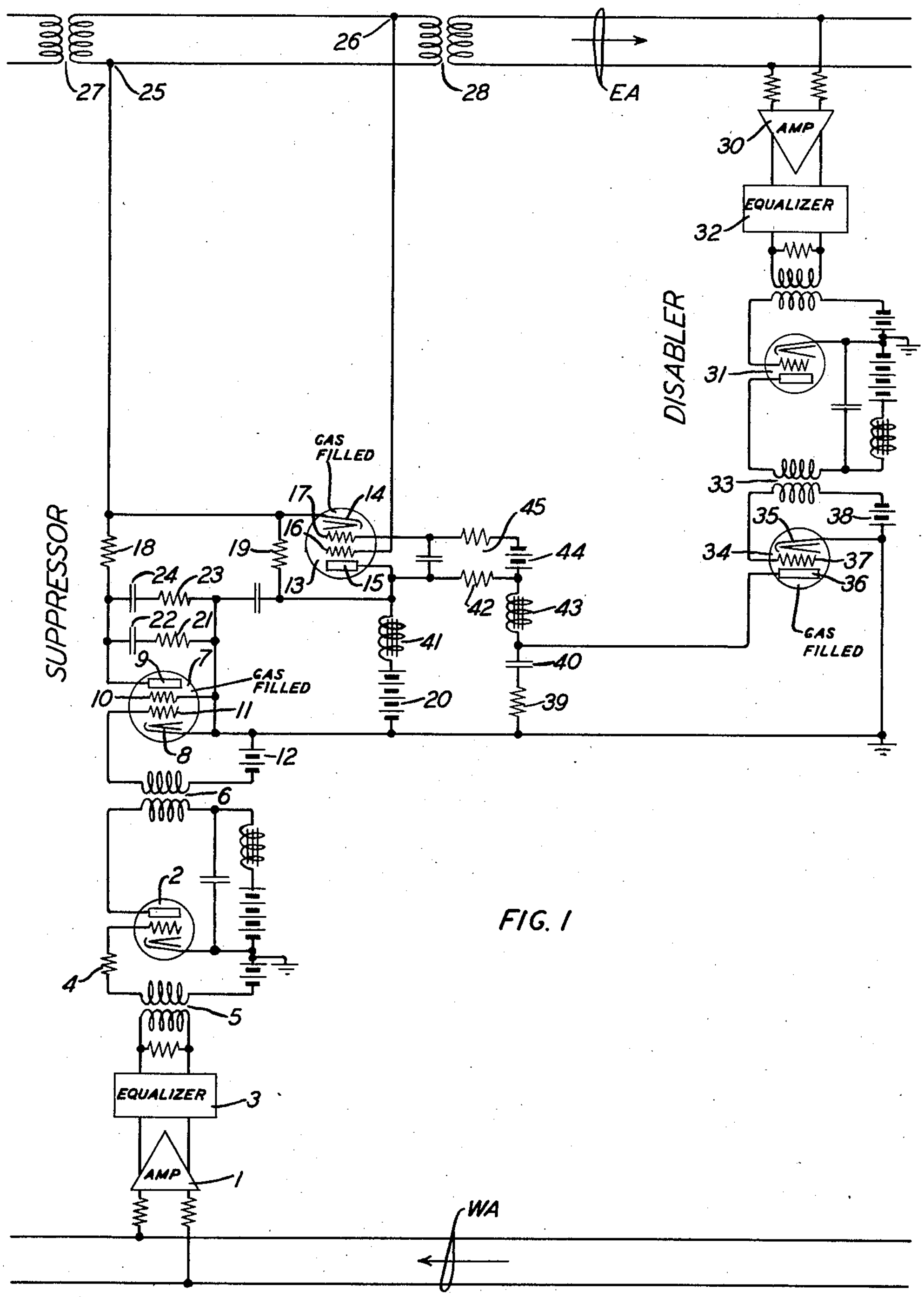

FIG. 1

INVENTORS B. G. BJORNSON
Q. E. GREENWOOD
BY H. A. Burgess
ATTORNEY

Sept. 10, 1935. B. G. BJORNSON ET AL 2,014,223

CIRCUIT FOR CONTROLLING TRANSMISSION IN SIGNALING SYSTEMS

Filed July 28, 1933 2 Sheets-Sheet 2

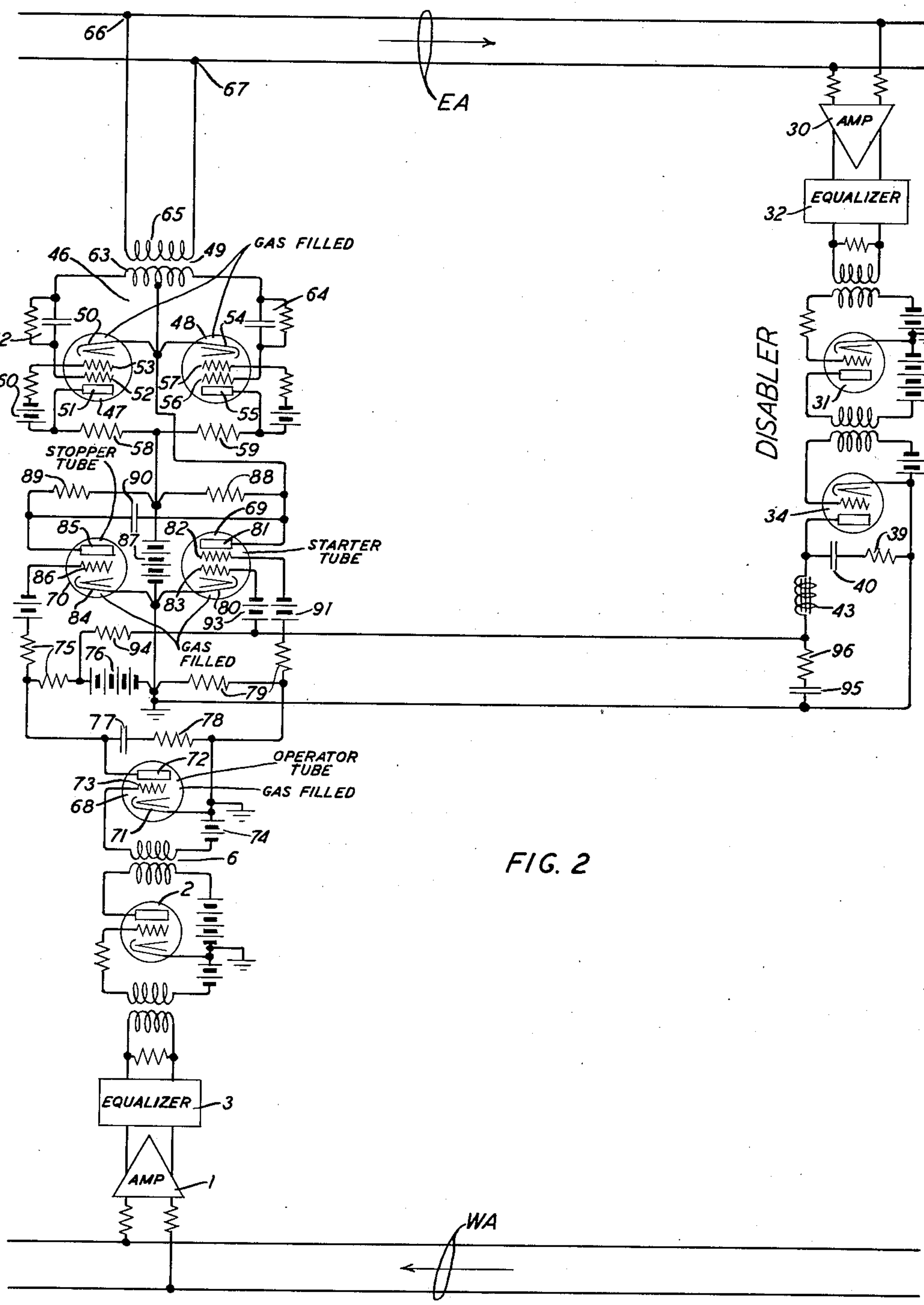

FIG. 2

INVENTORS B. G. BJORNSON
Q. E. GREENWOOD

BY H. A. Burgess

ATTORNEY

Patented Sept. 10, 1935

UNITED STATES PATENT OFFICE

2,014,223

CIRCUIT FOR CONTROLLING TRANSMISSION IN SIGNALING SYSTEMS

Bjorn G. Bjornson, Wyoming, N. J., and Quentin E. Greenwood, Flushing, N. Y., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application July 28, 1933, Serial No. 682,580

9 Claims. (Cl. 178—44)

The present invention relates to circuits for controlling transmission in a signal transmission system, and particularly to signal-controlled circuits for suppressing echoes and preventing singing in two-way signal transmission systems.

An object of the invention is to improve the operating characteristics of signal-controlled circuits for suppressing echoes and preventing singing in two-way signal transmission systems.

Signal-controlled, circuit-control apparatus, commonly called echo suppressors or anti-singing devices, are usually employed in connection with the repeating circuits of a long two-way signaling system, to insure that the system transmits in only one direction at a time so as to suppress echoes and prevent singing. This is usually accomplished by making the circuit-control apparatus responsive to signal transmission in either direction over the system to disable the transmission path for the opposite direction by increasing the attenuation therein, or to render operative the transmission path for the direction of signal transmission by reducing the attenuation therein, or to do both.

Certain circuits of the above mentioned type in the prior art have been designed to operate in response to transmitted signals to properly control the attenuation in the transmission paths by varying the output impedance of a vacuum tube or tubes connected effectively in parallel with the repeating paths. By this means the attenuation in the repeating path transmitting signals is made or maintained small so that it transmits the signals freely, while the attenuation of the oppositely directed repeating path is increased to the point where disturbing echoes or reflected currents are substantially suppressed. A difficulty encountered in prior art echo suppressor circuits of this type is the production of unbalance currents or transients in the transmission paths due to sudden changes of impedance or loss therein when the echo suppressor operates. These transients may result in annoying "click" disturbances in the receiving apparatus of the system, their disturbing effects being enhanced by the long time delay in very long transmission circuits.

In the echo suppressors of the invention substantial elimination of click and other disturbances as well as fast operation, a high degree of suppression and uniform hangover in operation are attained by suitably designed circuits utilizing gas-filled tubes.

The objects and advantages of the invention will be clear from the following detailed description thereof when read in connection with the accompanying drawings Figs. 1 and 2 of which show schematically portions of a four-wire toll telephone system equipped with echo suppressors embodying different modifications of the invention.

The four-wire toll telephone circuit of Fig. 1 comprises a one-way transmission path EA for repeating telephone signals in the direction from west to east and a one-way transmission path WA for repeating telephone signals in the direction from east to west. The transmission paths EA and WA may be connected at their ends in substantially conjugate relation with each other and in energy transmitting relation with the two-way lines between which the telephone signals are to be repeated, by means of the usual hybrid coil transformers and associated balancing networks (not shown) or by any other suitable means.

As indicated in Fig. 1, the echo suppressor associated with the transmission paths EA and WA, comprises a "suppressor" portion and a "disabler" portion. The suppressor portion of the echo suppressor comprises three parts; the input circuit, the "control" circuit and the variable impedance or suppressing element.

The input circuit furnishes the required amplification and selective action. It comprises, as indicated in Fig. 1, a special high input impedance amplifier **1** having its input connected across the path WA, the suppressor amplifier **2** and a selective network or equalizer **3** coupled between the ouput of the amplifier **1** and the input of the suppressor amplifier **2**. The equalizer **3** may be any network which will give the proper input frequency-sensitivity characteristic to the suppressor to make it more selective to speech than noise. This may be accomplished, for example, by designing the equalizer so that it produces the least loss to the frequencies which predominate in speech.

The suppressor amplifier **2** comprises a three-electrode thermionic amplifying tube (for example a Western Electric Company 244—A tube) having a low negative grid bias and a large resistance **4** in the grid circuit in series with the secondary of the input transformer **5**. This is for preventing an excessive increase in the hangover of the suppressor at high input levels.

The output of the suppressor amplifier tube is coupled to the control circuit by means of transformer **6**. The control circuit comprises the "control" gas-filled tube **7** comprising a cathode

8, an anode or plate 9, a cylindrical grid 10 located between the cathode and plate, and a spiral grid 11. The spiral grid 11 is located between the cathode 8 and the cylindrical grid 10, being very close to the cathode. The spiral grid 11 corresponds to the control grid of the ordinary three-electrode thermionic tube being connected to the cathode 8 through the secondary of the input transformer 6 and the negative grid biasing battery 12. The cylindrical grid 10 is connected directly to the cathode 8. Under these conditions the cathode 8 and the cylindrical grid 10 will be at the same potential and when the impressed input voltage is sufficient to produce ionization in the tube, the positive ions will, in general, move toward both the cathode and cylindrical grid, but the cylindrical grid will collect a large fraction of the positive ions, due to its large surface area. The space between the cylindrical grid and cathode will then contain relatively few positive ions, thus tending to leave the spiral grid in control of the cathode emission and hence of the plate current.

The variable impedance element of the suppressor comprises a four-element gas-filled tube 13, similar to the gas-filled control tube 7, having a cathode 14, an anode or plate 15, a cylindrical grid 16 located between the plate and cathode, and the spiral grid 17 located between the cathode and cylindrical grid and near the cathode. The plate-cathode circuits of the control tube 7 and the variable impedance tube 13 are in series. The resistance 18 in this series circuit is provided to limit the plate current to a safe value. The high resistance 19 connected in series with the plate battery 20, choke coil 41 and resistance 18 between the cathode and plate of the control tube 7, is shunted between the plate 15 and the cathode 14 of the variable impedance tube 13 so as to normally supply through its RI drop the full plate voltage to the variable impedance tube when the control tube operates.

There are two series resistance-condenser combinations connected directly between the plate 9 and the cathode 8 of the control tube 7. These two combinations have different time constants, one combination comprising the small resistance 21 and the small condenser 22 in series having a short time constant enabling grid control in the control tube, while the other combination comprising a larger resistance 23 and a larger condenser 24 in series having a longer time constant being provided to smooth out the plate current in the variable impedance tube 13, and to give the proper hangover time to the suppressor. The variable impedance path between the cylindrical grid 16 and the cathode 14 of the variable impedance tube 13 is shunted across the path EA at the points 25, 26 between the step-up transformer 27 and the step-down transformer 28. The transformers are provided for the purpose of stepping-up the impedance of the portion of the path EA therebetween and thus enabling a higher loss to be inserted by the variable impedance tube 13 in that path when the tube is operated in the manner which will be described below. The spiral grid 17 of the tube 13 is normally maintained by the grid-biasing battery 44 at a potential sufficiently below that of the cathode 14 to prevent the setting up of ionization in the tube 13 by normally transmitted speech currents in the path EA.

The input circuit of the "disabler" portion of the suppressor is connected across the path EA on the low side of the step-down transformer 28. It comprises the special high input impedance amplifier 30, similar to the amplifier 1 in the suppressor, having its input connected across the path EA, the disabler amplifier 31, similar to the suppressor amplifier 2, and the selective network or equalizer 32 coupling the output of the amplifier 30 to the input of the amplifier 31. The equalizer 32 is designed to give the disabler circuit the same input frequency-sensitivity characteristic as given to the suppressor circuit by the selective network or equalizer 3 therein.

The output of the disabler amplifier 31 is coupled by transformer 33 to the input of a three-electrode, gas-filled tube 34 (for example, a Western Electric Company 256—A tube) which will be referred to hereafter as the disabler tube. The tube 34 comprises a cathode 35, an anode or plate 36 and a grid or control electrode 37. The cylindrical grid 37 of the tube 34 is negatively biased by grid battery 38. Connected directly across the plate 36 and the cathode 35 of the disabler tube 34 is a resistance 39 in series with a condenser 40. Plate current is supplied to the plate 36 of disabler tube 34 from plate battery 20 through choke coil 41, high resistance 42 and choke coil 43. The high resistance 42 is provided to keep the current in the plate circuit of the disabler gas-filled tube 34 at a low value so as to enable control of the space current therein by the grid 37. When plate current flows in disabler tube 34, additional negative bias is supplied to the spiral grid 17 of the variable impedance tube 13 by the IR drop in resistance 42. The resistance-condenser filter 45 smoothes out fluctuations in this additional bias.

The operation of the suppressor will now be described. With no signal currents flowing in path WA, the impedance between the cylindrical grid 16 and the cathode 14 of variable impedance tube 13, connected across the path EA, is substantially infinite and the loss inserted in the path EA by that tube is zero or very low. The path EA is therefore in condition to transmit efficiently in the direction from west to east. Let it be assumed that speech waves are being transmitted over the path WA in the direction from east to west and, at the time these waves arrive at the input to the suppressor, no west to east currents have arrived in the path EA at the point at which the input of the disabler is connected. A portion of these speech waves in the path WA will be diverted into the suppressor circuit and will be selectively amplified in the input circuit thereof. The amplified speech currents in the output of the suppressor amplifier 2 are impressed upon the input of the gas-filled control tube 7 by transformer 6.

When the speech input voltage impressed upon the control tube 7 reaches a definite value ionization takes place in the tube and current will pass from its plate 9 to its cathode 8. This is followed practically instantaneously by the establishment of a flow of current between the cathode 14 and the plate 15 of the variable impedance tube 13 due to the voltage drop in the resistance 19 connected therebetween. This flow of current in the plate circuit of the variable impedance tube 13 establishes a relatively low impedance between cylindrical grid 16 and the cathode 14 of that tube which, by its shunting action across the high impedance portion of the path EA, produces high loss therein, and effectively disables the path EA.

While the speech voltages are being applied to the control tube 7, the plate current therein is very irregular going on and off at a rate depending on the input level. Before ionization starts in the tube, condensers 24 and 22 are charged to the voltage of the plate battery 20, but when a positive peak of the applied speech voltage starts ionization in the tube, the large condenser 24 will discharge through the resistance 23 in series therewith and tube 7 and the small condenser 22 will discharge through the resistance 21 and the tube to a voltage equal to the voltage drop across the tube. The small shunt condenser 22 and the small series resistance 21 are provided to make the control tube 7 unstable so as to enable high frequency oscillations therein to be quickly started by an applied input voltage when the current through the tube falls to the value at which the spiral grid of the tube regains control.

When the current from the discharging condensers decreases to such a value that the negative voltage swing of the input waves becomes sufficient to stop ionization in the tube, the spiral grid 11 in the tube 7 will regain control of the space current. As soon as ionization stops, the condensers 22 and 24 will charge up again. The next positive peak of the input speech voltage will start ionization again and the process will be repeated. Thus, the plate current in the variable impedance tube 13 is maintained by the charging current of the large shunting condenser 24. For high input levels to the control tube 7 there will be only slight ripples in this plate current, but near the operating level considerable variations will exist. However, the plate current flow in the variable impedance tube during the continuous application of speech currents to the control tube 7 will be such as to maintain a low impedance between the cylindrical grid 16 and the cathode 14 of the variable impedance tube 13 and thus a high loss in the transmission path EA.

When the application of speech voltages to the control tube 7 ceases, first the control tube 7 and then the variable impedance tube 13 will return to the normal inoperative condition causing the high loss in the path EA to be removed. By proper selection of the size of the condenser 24 and associated elements, any desired hangover in operation of the suppressor may be obtained. The amount of hangover required will depend on the location of the suppressor in the four-wire circuit. If the suppressors are connected at the mid-point of the four-wire circuit, a large amount of hangover will be required to prevent premature release whereas if the echo suppressors are located at or near the terminals of the four-wire circuit, little or no hangover is necessary.

It will be noted that there is no battery in the circuit connecting cylindrical grid 16 and the cathode 14 of the variable impedance tube 13 across the path EA and hence the current flowing in that circuit when the variable impedance tube 13 is operated is very small. It has been found that this current during operation of the suppressor is so small that "click" disturbances in the receiving circuits associated with the path EA and WA are substantially eliminated.

The "disabler" portion of the echo suppressor operates as follows: Let it be assumed that speech currents to be transmitted from east to west are initiated in the path EA, and, at the time they reach the point therein where the input of the disabler is connected, no west to east speech currents have reached the input of the suppressor associated with the path WA. The speech voltages diverted from the path EA into the disabler are selectively amplified in the input circuit thereof by special amplifier 30 and amplifier 31, and are then impressed on the input of the three-electrode gas-filled disabler tube 34 by transformer 33. When the impressed speech voltages reach a sufficiently high level, ionization will take place in the tube 34 and a small current will flow in its plate circuit. This current flows through the resistance 42 in the spiral grid circuit of the variable impedance tube 13 and the IR drop in resistance 42 adds a negative bias to the total bias of the spiral grid sufficient to hold the variable impedance tube 13 unoperated even though the control tube 7 subsequently operates since when the variable impedance tube is in the de-ionized conditions the spiral grid has a greater control over the ionization than does the cylindrical grid. Therefore, the action of the suppressor is prevented since its operation depends upon the ionization of the variable impedance tube 13.

The variable impedance tube 13 is placed in the circuit in such manner that the spiral grid 17 thereof loses control when ionization takes place in the tube and therefore any impulse which arrives from the disabler circuit after ionization has already taken place in the variable impedance tube cannot affect its operation. False disabling of the suppressor by too quick action of the disabler on initial echoes is prevented by the slowing up of the effective disabling potential on spiral grid 17 provided by the choke coil 43 and the resistance condenser filter 45, but if the disabler has built up a voltage drop across the condenser in filter 45 the normal available plate voltage is not sufficient to cause ionization in the variable impedance tube 13.

The echo supressor circuit shown in Fig. 2 differs from the echo suppressor circuit of Fig. 1 just described merely in the construction of the variable impedance element and the control circuit for controlling that element, the other parts of the circuits of Fig. 2 being identical with the corresponding parts in the circuit of Fig. 1 as indicated by the use of the same reference characters for designating them.

The variable impedance device 46 comprises two four-electrode gas-filled tubes 47 and 48, similar to the tubes 7 and 13 of the system of Fig. 1, and the bridging transformer 49. The tube 47 comprises a cathode 50, a plate or anode 51, a cylindrical grid 52 located between the cathode and anode, and a spiral grid 53 located between the cathode and the cylindrical electrode and very close to the cathode. Similarly, the gas-filled tube 48 comprises a cathode 54, a plate or anode 55, a cylindrical grid 56 located between the cathode and anode and a spiral grid 57 located between the cylindrical grid and the cathode and very close to the cathode. The plates 51, 55 of tubes 47 and 48 are connected through the equal resistances 58 and 59.

The cathode-cylindrical grid circuits of the tubes 47 and 48 are connected in push-pull relationship. The cylindrical grid-cathode circuit of tube 47 comprises the parallel resistance-condenser combination 62 and the upper half of the primary (high) winding 63 of the step-down bridging transformer 49, and the cylindrical grid-cathode circuit for tube 48 comprises the parallel condenser-resistance combination 64 and the lower half of the primary winding 63 of transformer 49. The secondary (low) winding 65 of bridging transformer 49 is connected across the path EA at the points 66, 67 in the output of a repeater (not shown) in that path. The bridging transformer 49 is utilized to step down the output impedance of the variable impedance device 46 to such a low value as to increase the attenuation in the path EA when the suppressor is operated to a value which will be sufficient to suppress echoes when the four-wire circuit is very long. The use of a bridging transformer for stepping down the output impedance of the variable impedance device to obtain the maximum amount of attenuation in the echo path is alternative to the use of tandem transformers in the transmission path itself for stepping up the impedance of that path for that purpose as shown in the system of Fig. 1. Since the loss in the path EA during transmission of speech currents has to be kept small and substantially constant in the speech frequency range, the open-circuited impedance of the transformer 49 is made high. In order to increase the maximum loss during suppression, the resistance of the transformer windings is made low and the turns ratio high for stepping down the impedance of the tubes.

The control circuit comprises three gas-filled tubes, i. e., the operator tube 68, the "starter" tube 69 and the "stopper" tube 70. The operator gas-filled tube 68 is a three-electrode tube similar to the gas-filled disabler tube 34 in the system of Fig. 1. The cathode 71 and cylindrical grid 73 of the tube 68 are coupled to the output of the suppressor amplifier tube 2 by transformer 6. The cylindrical grid 73 is negatively polarized by the battery 74. Plate current is supplied to the plate 72 of tube 68 through the resistance 75 from plate battery 76. A condenser 77 and a resistance 78 are connected in series directly across the plate 72 and the cathode 71 of the tube 68. A resistance 79 is connected between the negative side of plate battery 76 and the cathode 71 of the tube 68. The resistances 75 and 79 are very high (substantially 100,000 ohms each) so that the current flowing in tube 68 when the ionization takes place therein is very small. The gas-filled starter tube 69 comprises four electrodes, a cathode 80 a plate 81, a cylindrical grid 82 connected between the plate and cathode, and a spiral grid 83 connected between the cylindrical grid and the cathode and very near the cathode.

The gas-filled "stopper" tube 70 is similar to the operator tube 68 comprising three electrodes, a cathode 84, a plate or anode 85 and a cylindrical grid 86.

Space current is supplied from the plate battery 87 to the plate of the starter tube 69 through the resistance 88, to the plate of the stopper tube 70 through the resistance 89, and to the plates 51, 55 of the variable impedance tubes 47 and 48 through resistance 58 and resistance 59, respectively. A condenser 90 is connected between the plate 85 of stopper tube 70 and the plate 81 of starter tube 69, in shunt with resistances 89 and 88 in series.

The cylindrical grid 82 of the starter tube 69 is negatively biased by battery 91 so as to be normally in the de-ionized condition. The cylindrical grid-cathode circuit of the starter tube includes between the cylindrical grid 82 and the cathode 80 the battery 91 and the resistance 79. The cylindrical grid 86 of the stopper tube 70 is negatively biased by the grid battery but is connected to the positive pole of the plate battery 76 through the grid-biasing battery and high resistance 75 so that it has a resultant positive bias and is normally in the ionized condition. The spiral grid 83 of the starter tube 69 is negatively biased by the battery 93 and is connected to the positive pole of battery 76 through resistance 94 so that normally the spiral grid 83 has a small positive bias.

The suppressor portion of the echo suppressor of Fig. 2 operates as follows: Let it be assumed that the transmission paths EA and WA are in their normal operative condition, and that speech waves for transmission from east to west are initiated in the transmission path WA. A portion of these speech waves will be diverted into the input circuit of the suppressor and will be selectively amplified in the input circuit thereof. The resultant amplified speech voltages are impressed through the transformer 6 on the cylindrical grid-cathode circuit of the gas-filled operator tube 68. When the positive peak of the impressed speech voltage exceeds a given value, the operator tube will ionize and current will be established in the high resistances 75 and 79 in the plate circuit of the tube.

Before ionization starts in the operator tube 68, the condenser 77 is charged to the voltage of the plate battery 76, but when the tube ionizes due to the applied positive peak speech voltage, the condenser 77 must discharge through the resistance 78 and the tube to a voltage equal to the voltage drop across the tube. The resistance 78 is small so that the initial current flowing therein and hence in the tube will be high and will diminish in a regular exponential manner. During the discharge of the condenser 77, the very low value of current flowing through the high resistances 75 and 79 will also be passing through the tube 68 quite independent of the discharge current therethrough from the condenser 77, since the voltage drop across the tube is independent of current. During the time of the condenser discharge the total currents of the tube will be high and, therefore, a higher negative grid current (current from cathode to grid within the tube 68) will berequired to stop ionization. The current in resistances 75 and 79 remains constant until the current from the discharge condenser 77 decreases to such a value that the negative voltage swing of the input current becomes sufficient to stop ionization as indicated by the first abrupt change in the current after the tube first ionizes. As soon as the ionization stops the condenser 77 is charged up again by current from the battery 76. This charging tends to maintain the current in the resistances 75 and 79. The condenser voltage builds up to a certain value determined by the positive peak in the output voltage which is sufficient to start ionization again. This process is continued over and over during the time speech waves are impressed upon the input circuit of the suppressor. With increasing levels of the impressed speech waves the condenser voltage at which the operator tube 68 goes out, that is, is rendered inoperative, becomes higher with the result that this process of starting and stopping of the ionization becomes much more rapid as the input level is increased. The total effect is to give a fairly steady unidirectional current in the resistances 75 and 79. This steady current is used as a source of grid-biasing voltage for the following starter and stopper tubes.

When the input voltage to the operator tube 68 is removed and ionization stops, current will continue to flow in the resistances 75, 78 and 79 during the period required for the condenser 77 to be charged up to the voltage of the plate battery 76. By proper selection of the value of the condenser 77 and the series resistance 78, therefore, the suppressor may be given any desired hangover in operation.

When the operator tube 68 ionizes, the grid potentials of the stopper and starter tubes are reversed in polarity due to the IR drops in the resistances 75 and 79. Because of the positive bias supplied to the grid of the starter tube 70, that tube will immediately ionize. Though the resultant negative bias on the grid of the stopper tube 70 is not sufficient to stop ionization therein (which depends upon the plate current), the action of the condenser 90 connected between the plate 85 of the stopper tube 70 and the plate 81 of the starter tube 69 will practically instantaneously stop ionization in the stopper tube.

Normally the condenser 90 is charged to a voltage of a value which is equal to the difference between the normal voltage above ground of the plate 81 of the starter tube and the lower normal voltage above ground of the plate 85 of the stopper tube. When the starter tube 69 ionizes, the potential of the terminal of the condenser 90 connected to its plate 81 is suddenly brought to a potential equal to the voltage drop of the starter tube above ground. The other terminal of the condenser 90 which is connected to the plate of the stopper tube 70 must undergo an instantaneous change of the same magnitude on account of the high transient impedance of the external circuit compared with that of the condenser This makes the plate potential of the stopper tube 70 sufficiently negative with respect to the potential of its cathode to bring about de-ionization in that tube which condition is maintained by the negative input bias. The condenser 90 will then charge up to a voltage equal to the difference between the value of the plate battery 87 and the voltage drop of the starter tube 69, in the reverse direction. When the operator tube 68 is returned to normal, that is, to the inoperative condition, the polarities of the potentials applied to the grids of the starter and stopper tubes will be again reversed and the stopper tube 70 will be ionized, whereupon the action of the condenser 90 as before will stop ionization of the starter tube 69 and the entire circuit will return to normal.

In this circuit either the starter tube 69 or the stopper tube 70 will be continuously ionized during the time in which speech voltages are being impressed upon the operator tube 68. It should also be noted that this method of stopping the ionization will be effective theoretically for all values of plate current.

The IR drop in the resistance 88 when the starter tube 69 ionizes, becomes the plate voltage of the variable impedance tubes 47 and 48. The spiral grid 53 of variable impedance tube 47 and the spiral grid 57 of variable impedance tube 48 also become positive with respect to the cathodes of these tubes when this IR drop across resistance 88 is supplied with the result that current flows in the tubes 47 and 48. The value of this current is limited only by the value of the resistances 58 and 59 connected in series between the plates of the variable impedance tubes. When current flows in the variable impedance tubes 47 and 48, a low impedance path is established between the cathode and cylindrical grid of each tube. The primary winding 63 of the bridging transformer 49 is thus effectively short-circuited through the low impedance paths within tubes 47 and 48. As stated before, the secondary (low impedance) winding 65 of transformer 49 is connected directly across the transmission path EA at the points 66 and 67. The impedance across path EA, therefore, as the result of operation of the variable impedance tubes 47 and 48, is reduced to such an extremely low value that the path EA is effectively short-circuited. Thus, any echoes or reflected currents which may reach the bridging point in that path while the variable impedance tubes 47 and 48 are maintained operated in response to the speech waves from the path WA are substantially suppressed.

When the speech waves from the path WA cease, the operator tube 68, the starter tube 69 and the stopper tube 70 return to their normal conditions with the result that the flow of space current in the variable impedance tubes 47 and 48 is stopped and the normal high impedance shunt across the path EA provided by the bridging transformer 49 is re-established making that path again operative to transmit efficiently.

The negative voltages applied normally to the spiral grids 53 and 57 of tubes 47 and 48, respectively, due to the grid-biasing batteries 60 and 61, respectively, are made high enough to prevent the setting up of ionization between the cathode and cylindrical grid of either tube by the normally transmitted speech in the path EA. The condensers in the parallel-condenser-resistance combinations 62 and 64 in the output circuits of the variable impedance tubes are made of such values as to neutralize the leakance inductance of the bridging transformer 49 and bring the point of maximum loss across the path EA to the frequency where the greatest power in speech lies, which is at about 1000 cycles. The resistances in the combinations 62 and 64 supply a direct current path between the grids and their respective cathodes. These resistances may be made of such high value that they will not affect the tuning because of the extremely low direct current flowing in the output circuits of the variable impedance tubes 47 and 48.

The operation of the disabler circuit will now be described. It will be assumed that speech waves are being transmitted over the path EA in the direction from west to east and at the time at which these waves arrive at the point in the path EA where the disabler is connected, no east to west speech waves have arrived at the point in the path WA where the input of the suppressor is connected.

The speech waves diverted into the disabler circuit are selectively amplified in the input circuit thereof and after a sufficiently high level has been reached, the speech voltages impressed upon the input of the disabler tube 34 will cause ionization in that tube resulting in a small current flow in the plate circuit thereof. Before the tube 34 ionizes, the spiral grid 83 of the starter tube 69 has a normal positive bias equal to the difference between the positive voltage of the battery 76 and the negative bias provided by the biasing battery 93. After ionization starts in the disabler tube 34, the current flowing in the resistance 94 in the output circuit of that tube causes a negative bias equal to the voltage drop in that resistance to be added to the total bias of the spiral grid of the starter tube. By proper selection of the value of the resistance 94, this negative bias may be made such as will hold the starter tube 69 unoperated even though the operator tube **68** subsequently operates, since the spiral grid **83** of the tube **69** has a greater control over the ionization therein than does the cylindrical grid **82**. Therefore, after the disabler tube **34** has been once operated in response to speech waves received from the path EA, action of the suppressor portion of the circuit is prevented since the operation of the last tubes therein, variable impedance tubes **47** and **48**, depends upon the ionization of the starter tube. However, if the starter tube **69** is operated in response to speech waves from the path WA prior to operation of the disabler tube **34** in response to speech waves from the path EA, the operation of the suppressor will not be interrupted since the negative bias applied through resistance **94** to the spiral grid **83** of the starter tube will not be sufficient to stop the high ionization current in that tube.

It is usually desirable to have the suppressor and the disabler remain operated for about $\frac{1}{10}$ second after the inputs thereto have been removed, to allow for the suppression of weak endings of syllables in speech and echoes. The desired hangover time in the operation of the suppressor portion of the circuit is obtained by giving the proper value to the condenser **77** and series resistance **78** in the output of the operator tube **68**. As was explained above, the condenser **77** charges up through the resistances **75**, **79** and **78** when ionization in the operator tube **68** stops. Similarly, when the input speech voltage is removed from the operator tube **68**, the current therein stops and the condenser **77** is charged up by current from the plate battery **76** and keeps the suppressor operated until the IR drops in the resistances **75** and **79** are sufficiently reduced to allow the stopper tube **70** to ionize and cause the starter tube **69** to be de-ionized whereupon the suppressor operation stops.

The disabler circuit can likewise be made to have any desired hangover time by suitably selecting the value of the condenser **40** and the series resistance **39** shunting the plate and cathode in the disabled tube **34**.

There are certain variations in the hangover time of the suppressor both at fixed and also at different levels. As might be expected from the previous explanation of the action of the condenser **77**, the hangover at a constant input depends upon the charge of the condenser **77** at the moment the input to the operator tube **68** is removed. By making the normal negative bias on the cylindrical grid **73** of the operator tube **68** high, the variations in the condenser voltage can be kept within narrow limits if the input level exceeds the minimum operating level by about one decibel.

After the voltage on the operator tube has reached a given value, the establishment of the loss in the echo path is practically instantaneous.

The time of operation of the disabler will be only slightly longer than that of the suppressor. The retardation coil **43** in the output of the disabler tube **34** and the associated shunting condenser **95** and resistance **96** act to slow up the initial current in the plate circuit of the disabler tube and hence make the operation of the disabler slightly longer. The purpose of this slowing up of the disabler operation is to insure the operation of the suppressor before that of the disabler if the same voltage is applied simultaneously to both of them so as to prevent the initial echoes of incoming speech from falsely operating the disabler. The time of operation of the disabler obviously need not be very fast.

It will be noted that there is no battery in the cylindrical grid-cathode mesh of the variable impedance tube **47** or of the variable impedance tube **48** and hence the current which will flow through the primary winding of the bridging transformer **49** when the suppressor is operated is very small. With such a circuit, the click is reduced to a minimum since the initial currents through the condensers in the combinations **62** and **64** are small. However, with some tubes it may be advantageous to insert a small battery in the cylindrical-grid-cathode meshes of the variable impedance tube to reduce the click or shift the characteristic.

For simplification, only one of the pair of echo suppressors which are usually associated with the four-wire transmission circuit has been illustrated in the systems of Figs. 1 and 2. It is to be understood that another echo suppressor identical with that illustrated would be provided to suppress echoes when the transmission is from west to east. The input of the suppressor portion of the latter echo suppressor would be connected to the path EA and the disabler portion thereof to the path WA.

The circuits of the invention as illustrated and described employ a particular type of gas-filled electric discharge device comprising four electrodes as the variable impedance device for controlling the transmission characteristics of the signal transmission paths. However, it is to be understood that in accordance with the invention any other types of gas-filled electric discharge devices normally having a high impedance between the two of its electrodes which are connected directly in shunt or effectively in shunt of the transmission path to be controlled, and which is changed to a low impedance in response to establishment of direct current flow between certain of its electrodes may be utilized in place of the devices illustrated and described.

In the circuit of Fig. 2, the variable impedance device **46** has been shown as comprising two four-element gas-filled tubes connected in push-pull relation as it was found that somewhat better results from the standpoint of elimination of "click" disturbances was obtained by the use of the push-pull tubes. However, if the variable impedance device **46** comprises a single four-electrode tube connected in a manner similar to that of either push-pull tube illustrated, the single tube will produce a substantial reduction in click disturbances inasmuch as no plate battery would be used in the cylindrical-grid-cathode mesh thereof.

In the circuits illustrated and described, each of the various tubes have been shown as utilizing a heater type cathode. For simplification, the details of the cathode circuits have not been illustrated. Of course, any other type of cathode may be used in place of those shown. Other modifications which may be made in the circuits of the invention without departing from the spirit and scope thereof as defined in the appended claims will occur to persons skilled in the art.

What is claimed is:

1. In combination, a transmission circuit, a source of alternating current signals, a normally unoperated gas-filled electric discharge device having a cathode, an anode, a grid electrode located between said cathode and said anode, and circuits therefor, the normal high grid-cathode

impedance of said device being coupled effectively in shunt with said transmission circuit, means responsive to the alternating current signals received from said source to apply a voltage between said cathode and said anode to cause a flow of direct current between said cathode and said anode, of sufficient amplitude to reduce the impedance of the path between said cathode and said grid electrode and thus said shunt impedance to a low value and means for maintaining said flow of direct current for a time interval at least equal to the duration of said signals.

2. The combination of claim 1 and in which the said means for causing said flow of direct current comprises a second electric discharge device having an input and an output circuit, said output circuit and the cathode-anode circuit of the first electric discharge device being connected in series, means for impressing said received alternating current signals on said input circuit so as to cause operation of said second device to initially establish a flow of direct current of the required amplitude in the series circuit, and said means for maintaining said flow of direct current between the cathode and anode of said first device comprises means associated with said second discharge device for maintaining said current flow in the cathode-anode circuit of said second device, at least as long as said alternating current signals are impressed on said input circuit.

3. The combination of claim 1 and in which the said means for applying a voltage between said cathode and anode comprises a second gas-filled electric discharge device having a cathode, an anode, a control grid therebetween, a second grid electrode located between said control electrode and said anode and connected directly to the cathode, and circuits therefor, a resistance connected directly between the cathode and anode of the first device, the cathode-anode circuits of the two discharge devices being connected in series, a source of plate current in said series circuit, means for impressing said alternating current signals on the cathode-control grid circuit of said second device so as to cause operation of said second device to initially produce a flow of direct current through said resistance, and said means for maintaining said flow of direct current between the cathode and anode of the first device comprises a condenser in series with a small resistance shunted directly between the anode and cathode of said second device, said condenser being normally charged from said plate current source and discharging through said small resistance and said second device when said second device is operated.

4. The combination of claim 1 and in which the said means for applying a voltage between said cathode and said anode comprises a second gas-filled electric discharge device having a cathode, an anode, a control grid therebetween, a second grid electrode located between said control electrode and said anode and connected directly to the cathode, and circuits therefor, a resistance connected directly between the cathode and anode of the first device, the cathode-anode circuits of the two discharge devices being connected in series, a source of plate current in said series circuit, means for impressing said alternating current signals on the cathode-control grid circuit of said second device so as to cause operation of said second device to initially produce a flow of direct current through said resistance, and said means for maintaining said flow of direct current between the cathode and anode of the first device comprises two parallel combinations shunted directly between the cathode and anode of said second device, one combination comprising a large condenser in series with a resistance and the other combination comprising a smaller condenser in series with a smaller resistance, the condensers being normally charged from said plate current source and being discharged through the series resistances and said second device when said second device is operated.

5. In combination, a transmission circuit, a source of alternating current signals, a normally unoperated gas-filled electric discharge device having a cathode, an anode, a control grid therebetween and a second grid electrode located between the control grid and the anode, the normal high impedance between said cathode and said second grid electrode being coupled effectively in shunt with said circuit, means for normally maintaining said control grid at a given negative potential with respect to said cathode, means responsive to alternating current signals received from said source to apply a voltage between said cathode and said anode to cause a flow of direct current therebetween sufficient to reduce the impedance of the space path between said cathode and second grid electrode and thus the impedance shunting said transmission circuit to a low value, and means connected to said transmission circuit and responsive to transmission of alternating current signals therein to prevent the establishment of a flow of direct current between said cathode and said anode in response to alternating current signals subsequently received from said source.

6. The combination of claim 5 and in which the value of the negative potential at which said control grid is normally maintained is sufficient to prevent ionization in the gas path between said cathode and said second grid electrode in response to alternating current signals transmitted over said transmission circuit.

7. The combination of claim 5 and in which the last mentioned means comprises means for applying sufficient negative bias to the control electrode of said device to prevent the establishment of ionization therein by subsequently received alternating current signals from said source.

8. In common, a transmission circuit, a source of alternating current signals, a normally unoperated gas-filled electric discharge device having a cathode, an anode, a control grid located therebetween and a second grid electrode located between said control grid and said cathode, the normal high impedance between said second grid electrode and said cathode being coupled effectively in shunt with said transmission circuit, means responsive to alternating current signals received from said source to apply a voltage between said cathode and said anode to cause a flow of direct current therebetween in sufficient amount to reduce the impedance between said second grid electrode and said cathode and thus the shunt impedance across said circuit to a low value, means responsive to transmission of alternating current signals in said transmission circuit for applying a negative biasing voltage to said control grid of such value as to prevent the establishment of a flow of direct current between said cathode and anode in response to alternating current signals subsequently received from

said source, but of insufficient value to cause de-ionization in said device if flow of direct current between said cathode and anode has already been established in response to alternating current signals previously received from said source.

9. The combination of claim 1 and in which the said means for causing and maintaining a flow of direct current between said cathode and said anode comprises a second and a third gas-filled electric discharge device each having a cathode, an anode, a grid electrode and circuits therefor, the cathode-grid circuits of said second and third devices and the cathode-anode circuits thereof, respectively being connected in push-pull relationship, the cathode-anode circuit of said second device and of the first gas-filled device being connected in series so that ionization in said second device establishes a flow of direct current between the anode and cathode of said first device, a condenser connected directly between the anodes of said second and third devices, said second device being normally de-ionized and said third device being normally in the ionized condition, a fourth electric discharge device supplied with alternating current signals from said source and operatively responsive to the positive peaks of the signal impulses to apply a positive bias to the grid electrode of said second device to cause ionization therein and simultaneously to apply a negative bias to the grid electrode of said third device to cause de-ionization therein and responsive to cessation in the applied signal impulse to return said second and third devices to their normal conditions, and means associated with said fourth electric discharge device for causing this operation to be repeated in response to each succeeding impulse of the applied signals so as to maintain said direct current flow between the cathode and anode of said first device at least as long as said signals are substantially continuously applied to said fourth electric discharge device.

BJORN G. BJORNSON.
QUENTIN E. GREENWOOD.