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REDUCTION OF DISTORTION IN SIGNAL TRANSMISSION SYSTEMS

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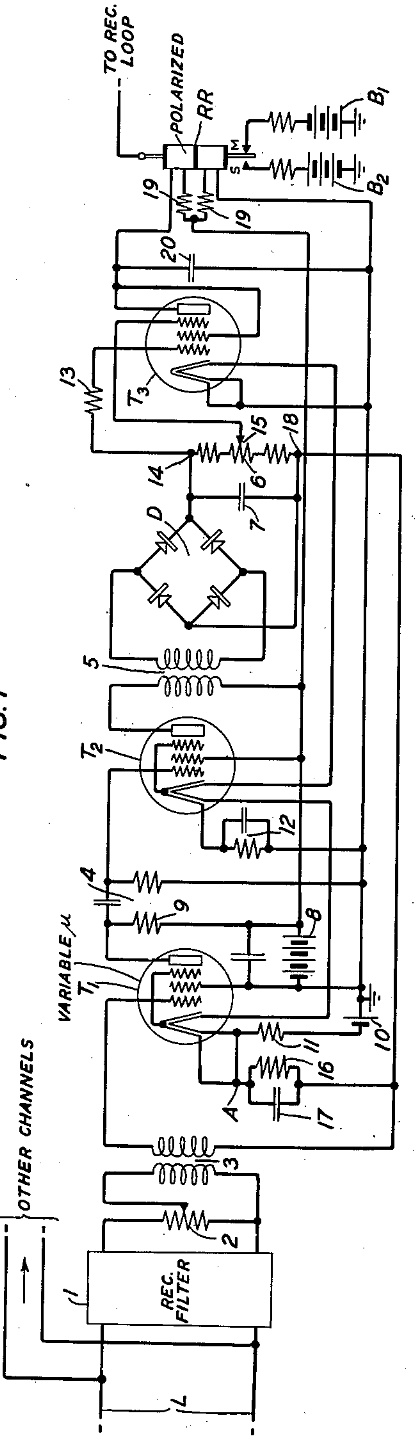

FIG. 1

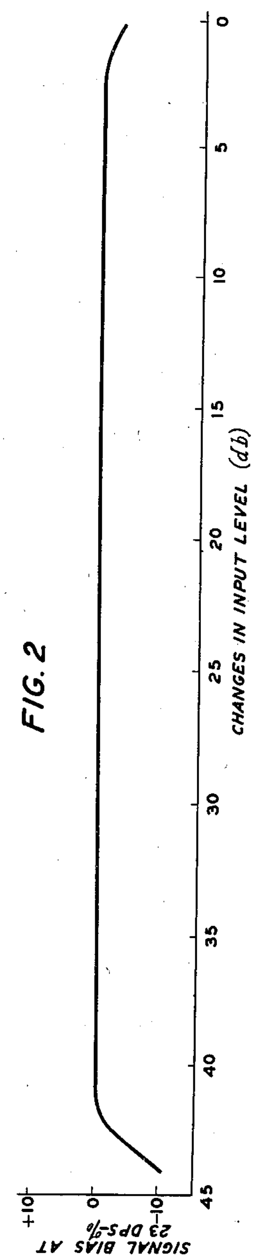

FIG. 2

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REDUCTION OF DISTORTION IN SIGNAL TRANSMISSION SYSTEMS

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The present invention relates to signal transmission systems and particularly to circuits for compensating for signal distortion in such systems.

An object of the present invention is to compensate for variations in the amplitude level of transmitted signals in a signal transmission system.

Another object is to reduce signal distortion in a telegraph transmission system, including a type of distortion known as "telegraph bias."

It has been found in telegraphy that marking and spacing signals in transmission over a system are subject to distortion such that at the receiving end of the system the durations of the marking and spacing signals are different from those they had at the transmitting end of the system, and will vary from time to time. This type of distortion, commonly called "telegraph bias", may be due to changes in repeating relay adjustments, battery voltages or received telegraph currents caused by changes in line equivalent. Heretofore, this telegraph bias has been reduced by utilizing the received signal variations to control the bias on the control grid of a vacuum tube detector in the telegraph receiving circuit, to vary the gain of that circuit so as to compensate for the received level variations and thus prevent them from affecting the operation of the receiving relay.

In accordance with the present invention, the above objects are attained in an improved design of voice-frequency carrier telegraph receiving circuit, the operation of which is practically independent of changes in vacuum tubes, receiving relays and battery voltages, and in which the signal distortion is negligible even at the lowest carrier frequencies.

A feature of this circuit is an easily adjustable level compensator circuit which will maintain substantially unbiased signal reception over a wide range of amplitude levels of the received current, and which is practically free of any "drift" effects, that is, a circuit in which the compensating voltage is a function of the incoming level only, and not of the signal characters being received. The circuit employs a suppressor grid of a multigrid vacuum tube controlling the operation of the receiving telegraph relay, to obtain a readily adjustable current for controlling the gain of one or more amplifying tubes in the circuit to obtain the desired compensation.

An auxiliary feature is the use of the multigrid vacuum tube to obtain a low resistance in the charging path of a condenser controlling the gain of the compensating vacuum tube, to enable it to be quickly charged during marking signals, and a high resistance in the discharge path for the condenser during the spacing period, thus reducing the amount of "drift", i. e., change in control voltage across the condenser due to the varying length of successive marking signal characters, and the resulting characteristic distortion.

These and other features of the circuits of the invention will be understood from the following detailed description thereof when read in connection with the accompanying drawing in which:

Fig. 1 shows schematically a receiving circuit for a voice-frequency carrier telegraph system embodying the invention; and

Fig. 2 is a curve illustrating the improved operation characteristic obtained in the circuit of the invention.

The receiving circuit of the invention is shown in Fig. 1 incorporated in one channel of a voice-frequency carrier telegraph system. A receiving filter or other selective network 1 is provided in the input of the circuit for selecting from the carrier modulated telegraph signal waves received over the transmission line L the particular frequencies assigned to that channel. The output of the filter 1 is connected through the gain-control potentiometer 2 and input transformer 3 to the input of an amplifier comprising two pentode amplifying vacuum tubes T_1 and T_2 coupled in tandem through the resistance-condenser coupling circuit 4, the first pentode tube T_1 preferably being of the variable-mu type.

The transformer 5 couples the output of the second tube stage T_2 of the amplifier across the input diagonal of the full-wave copper-oxide detector bridge D. An adjustable potentiometer 6 shunted by the by-pass condenser 7 is connected directly across the output diagonal of the detector D.

A third tube T_3 also of the pentode vacuum tube type has its control grid-cathode circuit connected across the potentiometer 6. The anode-cathode circuit of tube T_3 includes the windings of the polar receiving relay RR, so that the current output (approximately 10 milliamperes) of the tube, when signals are applied to its control grid-cathode circuit, will operate the relay.

Plate current is supplied from plate battery 8 to the plate of the tube T_1 through the resistance 9 of the interstage coupling circuit 4, to the plate of the tube T_2 through the primary winding of output transformer 5 and to the plate of the tube T_3 through part of the windings of the relay RR.

Suitable heating current is supplied from the filament battery 10 through the series resistance 11 to the heaters of the heater type cathodes of the tubes T_1, T_2 and T_3 in series.

The suppressor grids of the tubes T_1 and T_2 are connected directly to the cathodes of the respective tubes. The screen grid of the tube T_1 is shown connected directly to ground, which is 20 volts above cathode potential, the screen grid of the tube T_2 is connected directly to the positive terminal of plate battery 8 and the screen grid of the tube T_3 is connected directly to the plate of that tube. The screen grids of the tubes may, of course, be connected to other points of positive potential.

The parallel resistance-condenser grid biasing arrangement 12 is connected in the cathode-control grid circuit of the tube T_2. The control grid of the tube T_3 is connected to the upper terminal 14 of the potentiometer resistance 6 through the large series resistance (10 megohms) 13. The suppressor grid of the tube T_3 is connected to the variable tap 15 on the potentiometer 6.

A resistance 16 in parallel with the compensating condenser 17 is connected in the control grid-cathode circuit of the tube T_1 between the cathode thereof and the lower terminal of the secondary winding of input transformer 3, so that the negative terminal of condenser 17 is connected to the control grid of tube T_1. The lower terminal 18 of the potentiometer 6 is connected to a point between the parallel resistance-condenser network 16, 17 and the secondary winding of the transformer 3, so that the latter network is connected also in common to the control grid-cathode and the suppressor grid-cathode circuits of the tube T_3, and the negative terminal of condenser 17 is connected to the control grid and suppressor grid of tube T_3.

A fixed negative bias is supplied from the filament battery 10 to the suppressor and control grids of tube T_3 over paths which may be traced from the negative terminal of that battery through resistances 11 and 16 and the lower portion of potentiometer 6 to the tap 15 thereon, from tap 15 directly to the suppressor grid, and from tap 15 through the upper portion of potentiometer 6 and resistance 13 in series to the control grid.

The plate battery 8 supplies biasing current to the windings of the receiving relay RR through the resistances 19, and the by-pass condenser 20 is connected between the plate and the cathode across the windings of the relay.

The armature of the receiving relay RR is connected to a receiving telegraph loop. When the armature of the relay RR is on the marking contact "M" as indicated, the battery B_1 is connected to the receiving loop, and when the armature is on the spacing contact "S", the battery B_2 is connected to the receiving loop, respectively, to actuate sounder or other apparatus to indicate marking and spacing signals in accordance with well-known telegraph practice.

The receiving relay RR is initially adjusted, for example, by proper selection of the values of resistances 19 in the biasing circuit to make the amount of biasing current supplied to its windings from battery 8 such that the relay will operate to and fro in response to the plate current of the controlling tube T_3 as nearly at the mid-point on the tube characteristic as is feasible. Thus, the relay will pick up and fall away at the proper time intervals depending on the length of the applied marking and spacing signals for a given intensity of the received signals.

The circuit of the invention, as shown in Fig. 1, operates in the following manner to prevent the advance or retarding of the pick-up and fall-away times of the relay, or changes in signal bias, tending to change the marking and spacing signal durations, with changes in level of the applied signals.

The potentiometer 2 is normally set to give the proper circuit gain at the time of installation, and generally will not need further adjustment unless the normal received energy level is radically changed. Line-up of the circuit consists merely in transmitting dots (23 dots per second) through the receiving filter 1 and adjusting potentiometer 2 until the signals transmitted by the receiving relay RR are unbiased.

The incoming carrier wave modulated with the marking and spacing signals generated at the transmitting end of the system (not shown), received over the transmission line L are impressed on the receiving filters in the receiving channels at the receiving station. That portion within the frequency range of the receiving filter 1 in the receiving channel, illustrated in detail in Fig. 1, will be passed thereby and with an intensity regulated by the setting of the potentiometer 2 will be impressed by the input transformer 3 on the input of the amplifier and will be amplified by the amplifying tubes T_1 and T_2 therein in accordance with the initial gain setting of these tubes.

The amplified waves in the output of the second tube T_2 of the amplifier will be impressed by transformer 5 on the full wave copper-oxide detector bridge D and will be demodulated thereby. The resulting unidirectional current, with the carrier components largely filtered out by the condenser (0.05 microfarad) 7, will flow through the potentiometer resistance 6 producing a voltage drop therein which is applied to the control grid-cathode circuit of tube T_3 connected across said potentiometer, operating as a direct-current amplifier. The resulting amplified signal current in the plate-cathode circuit of the tube T_3 will cause the operation of the receiving relay RR to its marking "M" contact in response to a received marking signal and to the spacing contact "S", in response to a received spacing signal.

Direct-current amplification is used in the last amplifier stage in order that a large output may be obtained from the high impedance pentode tube T_3. This tube is worked at an unusually high negative control grid bias to provide a high degree of signal shaping, thereby making the signal bias more independent of receiving relay variations than would otherwise be the case.

The gain of the receiving circuit is automatically adjusted to compensate for changes in the received carrier level by the portion of the rectified output voltage of the copper-oxide detector D applied from the tap 15 of potentiometer 6 to the suppressor grid of the tube T_3. The resulting grid current flow when the grids of tube T_3 become positive, charges the compensator condenser 17 shunted by resistance 16. Due to the effect of the large resistance (10 megohms) in the control grid circuit of the tube T_3, the amount of control grid current flowing through resistance 16 is comparatively small, and the voltage drop in the resistance 16, therefore, will be mainly due to the flow of suppressor grid current of tube T_3 therein.

It will be noted that the suppressor grid current of tube T_3 flows through the lower portion of potentiometer 6, the resistances 16 and 11 and the 24-volt filament battery and ground. The current in this path is in such direction as to make the lower end of resistance 16 negative, and this negative potential becomes the control grid potential of the variable-mu tube T_1.

The charge applied to condenser 17 being proportional to the voltage drop produced in the potentiometer 6 by the detected signal variations in the output of the detector D, will be a function of the incoming carrier level. The condenser-resistance arrangement 17, 16 being common to the control grid-cathode circuits of the tubes T_1 and T_3, a negative potential varying in accordance with the signal variations will, therefore, be applied to the grids of these tubes and will cause a proportional adjustment of gain therein.

The negative terminal of the condenser 17 being connected to the control grid of the tube T_1, the gain of that amplifier tube will be varied in a direction and to an amount such as to tend to maintain the output voltage of the following detector D constant for an extended range of input variations. A further compensating action is obtained in the last amplifier tube T_3, the control grid of which is also connected to the negative end of the compensating condenser 17.

To minimize the effects on the bias of signals of changes in the receiving relay RR, it is desirable to supply a large operating current and a steeply rising signal wave front to this relay. A steeply rising signal wave front is obtained from the considerably rounded carrier signal by biasing the control grid of the tube T_3 supplying the relay operating current, well beyond cut-off so that a small percentage change in the signal voltage applied to the grid causes a large change in the plate current of the tube. The tube T_3 selected for this purpose was one which requires a rather low value of negative grid bias to reduce the plate current to zero. This made it possible to use the filament battery to supply a grid biasing potential large compared to the cut-off potential thus making it unnecessary to use an auxiliary grid potential supply circuit.

A relatively large relay operating current is obtained from such a small tube by rectifying the carrier in the full-wave copper-oxide detector, suppressing the carrier frequency components of demodulation and impressing the direct-current signal voltage on the grid of the tube T_3. In this way, the full value of plate current of the tube T_3, as determined by the static characteristic of the tube, is obtained. This is an improvement over the voice-frequency carrier telegraph receiving circuits of the prior art in which the carrier is supplied directly to the relay-controlling tube grid, so that plate current flows during only a small part of each carrier cycle. Hence, the current which can be obtained from the tube in the latter case to actuate the relay is considerably less than that which would be indicated by the static characteristic of the tube.

The manner in which the circuit of the invention minimizes "drift", i. e., change in the control voltage across the compensating condenser 17 due to the varying length of marking signal characters being received, resulting in characteristic distortion, without requiring a compensator relay to prevent discharge of the condenser during a spacing signal as in prior art circuits, may be explained as follows:

The problem may be stated as follows: In a level compensating device in which a voltage proportional to incoming level is established across the resistance shunted condenser and used to control the gain of the receiving circuit, it is desired that the voltage remain practically constant for a given line equivalent, regardless of the character of the signals being received. That is, a voltage produced across the condenser when a steady unmodulated current is being received should change very slightly, if any, when the incoming current is modulated with telegraph signals.

The explanation will be simplified by referring first to the action in an analogous simple circuit in which a battery of voltage E is connected across a condenser C shunted by a resistance R_C, through a resistance R_S and a switch S in series. With the switch S closed, a voltage e_C is established across the condenser C. When the switch is opened, the voltage e_C will diminish as the condenser discharges through the parallel resistance R_C. If the switch S is alternately opened and closed for varying lengths of time, as during the transmission of telegraph signals, the condenser discharge occurring during even the longest spacing signal required by the telegraph code can be made small by making the value of the shunting resistance R_C large. Upon the closure of switch S, the voltage e_C will practically reach a steady state value before the beginning of the next spacing signal, if the series resistance R_S is sufficiently small. Therefore, by suitably choosing the constants in this simple circuit, the voltage across the condenser can be maintained at a fairly constant value regardless of the character of the signals being sent by the switch S. Furthermore, if the charging voltage E could be increased and the series resistance decreased momentarily when recharging the condenser after a spacing signal, the condenser voltage could be maintained at an even more nearly constant value.

The application of this basic idea to the carrier telegraph receiving circuit of the invention will now be specifically described with reference to Fig. 1.

The rectified signal voltage output of the copper-oxide detector D is impressed across potentiometer 6 on the control grid-cathode circuit of the pentode tube T_3. A portion of this voltage is applied to the suppressor grid of tube T_3 from tap 15 of potentiometer 6. This gives rise to a flow of grid current from the suppressor and control grids to the cathode. The control grid current is prevented from becoming very large by the large resistance 13 in series with the control grid. The suppressor and control grid currents flow through compensator resistance 16 shunted by condenser 17, causing the terminal of that resistance connected to the grid of tube T_3 to become negative. The compensator voltage across the parallel condenser 17 and hence the gain of the receiving circuit can be adjusted to the desired value by moving the adjustable tap or slider 15 of potentiometer 6 as required to increase or decrease the potential applied to the suppressor grid of tube T_3.

The compensator condenser voltage is a function of the potential between the suppressor grid and cathode of the tube T_3. This potential is the algebraic sum of the positive potential between the slider 15 and terminal 18 of the potentiometer 6, due to the signal, and the negative potential due to the sum of the fixed biasing voltage E_C applied to the control grid of tube T_3 and the compensator potential e_C across condenser 17. These opposing voltages are relatively large and nearly equal so that their difference is small. That is, the compensator voltage e_C is a function of a resultant of two large opposing voltages. A small change in one of the large voltages will produce a large change in the difference voltage in a direction such as to tend to restore the condition existing before the change.

During the reception of a spacing element of a telegraph signal, the suppressor grid to cathode resistance of tube T_3 being low, the only path for the discharge of condenser 17 is through the parallel resistance 16 which is high in value compared to the resistance in series with the condenser 17 during the charging period. Because of this, the condenser 17 will discharge slightly thus reducing by a small amount the negative bias on the grid of the variable-mu tube T_1 and hence slightly raising the gain of the amplifier. This will result in a small increase in the positive voltage between the slider 15 and the terminal 18 of the potentiometer 6 when the next marking signal is received. As a result of this small change in the positive and negative potentials, the difference between them will increase by a very large percentage. This gives rise to a very much greater flow of suppressor grid current momentarily. The increase in grid current will be more than proportional to the increase of suppressor grid-cathode voltage because of the non-linear characteristic of the suppressor grid-cathode resistance of tube T_3, which decreases rapidly with increase in voltage. Hence, the condenser charge lost during a spacing signal will be restored very quickly during the following marking signal interval because of the low resistance in the charging path of the condenser 17 due to the operated condition of the tube T_3 during that interval. In other words, there is only a small amount of "drift" in the control voltage across the compensating condenser 17 due to the varying length of succeeding marking signal characters, and the characteristic distortion due to this is so small as not to affect appreciably the operating periods of the receiving relay RR.

The small variation in the signal voltage in the output of the copper-oxide detector due to input level change, not compensated for in the first stage of the amplifier, will be corrected for by the secondary compensating action in tube T_3. This is obtained by applying the voltage of condenser 17 not only to the grid of tube T_1 but also to the grid of tube T_3, and by properly proportioning the values of the fixed grid biasing voltage and compensator voltage.

By selecting the initial grid biasing voltages, such that the change in the compensator voltage, due to the change in signal input level, will be just the correct proportion of the initial grid biasing voltage, the signal current in the output of tube T_3 may be made to pass through the value required to operate the receiving relay RR at the proper time intervals to produce undistorted signals.

To illustrate the improvements obtained in the circuit of the invention, reference may be had to Fig. 2 in which changes in input level of the circuit expressed in decibels (db.) are plotted as abscissae and the percentage of telegraph signal bias (at 23 dots per second) is plotted as ordinates. As shown, the percentage of signal bias remains substantially constant over a wide range of input levels extending from zero to 45 decibels.

Although the invention has been described as incorporated in a carrier telegraph receiving circuit, it is apparent that it is capable of use in connection with other types of telegraph signaling circuits. Also, the gain control circuit employing the suppressor grid current of a pentode tube is adapted for use in other types of signaling systems, for example, in connection with wire or radio telephone systems.

Various other modifications of the circuits illustrated and described within the spirit and scope of the invention will occur to persons skilled in the art. For example, it is apparent that the potentiometer 2 used for obtaining initial adjustment of the circuit may be connected across the secondary winding of the input transformer 3 instead of across the primary winding as shown.

What is claimed is:

1. A circuit for compensating for the variations in amplitude level of transmitted signals in a signal transmission circuit, comprising an electron discharge device connected in said circuit, having a cathode, an anode, and a control grid and a second grid spaced consecutively between said cathode and said anode, means positively biasing said anode with respect to said cathode, circuits respectively connecting said control grid and said second grid to said cathode, means to impress said signals on the control grid-cathode circuit, means to apply to said second grid a direct-current voltage varying in accordance with the level of said signals, and means to utilize the variations in the current produced in the second grid cathode circuit when said second grid is driven positive by the applied voltage to control the gain of said transmission circuit in such manner as to produce the desired compensation for signal level variations.

2. The level compensating circuit of claim 1, in which the last-mentioned means comprises a network consisting of capacity and resistance in parallel, connected in common to said control grid-cathode circuit and said second grid-cathode circuit so that the varying voltage produced across said network by the current flowing in said second grid-cathode circuit controls the bias on said control grid and thus the gain of said device, and means to reduce the flow of control grid current through said resistance when said control grid is driven positive by the impressed signals to a small amount compared to the flow of current therethrough from said second grid.

3. In combination with a signal transmission circuit, means for compensating for variations in the amplitude level of transmitted signals, comprising a variable-mu amplifying electron discharge device having a control electrode, connected in said circuit, a second electron discharge device having electrodes including a cathode, an anode, a control grid and a suppressor grid spaced between said control grid and said anode, circuits respectively connecting said control grid and said suppressor grid to said cathode, said anode being positively biased with respect to said cathode, means applying a fixed negative bias respectively to said control grid and said suppressor grid, a network comprising capacity and resistance in parallel connected in series in the supressor grid-cathode circuit of said second device, means to impress said signals on the control grid-cathode circuit of said second device, means to apply to said suppressor grid a direct current voltage varying in accordance with the level variations of said signals, and means to apply the voltage produced across said network in response to the varying current flowing in said suppressor grid-cathode circuit when said suppressor grid is driven positive, to said control electrode of said variable-mu amplifying device to proportionately control the gain of the latter device.

4. A carrier telegraph receiving circuit comprising means for amplifying received telegraph waves, means for detecting the telegraph signals therefrom, a telegraph relay controlled by the

detected singals, and means for reducing distortion in said circuit including telegraph bias with changes in the amplitude level of the received waves, comprising an electron discharge device connected between said detecting means and said relay, including a cathode, an anode, a control grid and a suppressor grid, circuits respectively connecting each of the grids to said cathode, means positively biasing said anode with respect to said cathode, means respectively negatively biasing said control grid and said suppressor grid with respect to said cathode, the bias on said control grid being relatively large, a network comprising a parallel condenser and resistance in said suppressor grid-cathode circuit, means for impressing the detected signals on the control grid-cathode circuit of said device, means to apply a direct-current voltage varying in accordance with the level variations of the detected signals on said suppressor grid, and means for utilizing the varying voltage produced across said network by the current in said suppressor grid-cathode circuit when said suppressor grid is driven positive with respect to the cathode by the applied direct-current voltage, to control the gain of said amplifying means in such manner as to compensate for level variations in the detached signals controlling the operation of said relay.

5. A carrier telegraph receiving circuit comprising means to amplify received carrier modulated telegraph signals, means to detect from the amplified wave the low-frequency signal components while suppressing the carrier componets, an electron discharge device having electrodes including a cathode, an anode, and a control grid and a suppressor grid spaced consecutively between said cathode and said anode, and circuits therefor, a telegraph relay connected in the anode-cathode circuit of said device so that its operation is controlled by the anode current therein, said control grid and said suppressor grid being respectively negatively biased with respect to said cathode, with the control grid bias substantially larger, means to impress the low-frequency signal components of the detected waves on the control grid-cathode circuit of said device, means to utilize a portion of the energy of the low-frequency signal components in the detected waves to apply a direct-current voltage to said suppressor grid varying in accordance with the amplitude level of said detected waves, a network comprising capacity and resistance in parallel connected in the suppressor grid-cathode circuit of said device, and means to utilize the varying voltage produced across said network by the current flowing in said suppressor grid-cathode circuit when said suppressor grid is driven positive by the applied voltage to control the gain of said receiving circuit to compensate for level variations in the received signals and thus to reduce the effects of these level variations in the operation of said relay.

6. The telegraph receiving circuit of claim 5, in which said amplifying means comprises a variable-mu electron discharge device having a control grid circuit, said network being connected in said control grid circuit so that the voltage across said network controls the gain of said variable-mu tube.

7. The telegraph receiving circuit of claim 5 in which the detecting means comprises a full-wave copper-oxide rectifier, the means for impressing the low-frequency signal components of the detected waves on the control grid-cathode circuit of the first electron discharge device comprises a potentiometer resistance shunted by a by-pass condenser, common to said control grid-cathode circuit and the output of said full-wave rectifier, and the means for applying said direct-current voltage to said suppressor grid comprises a connection from that grid to a tap on said potentiometer resistance.

8. The telegraph receiving circuit of claim 5, in which said amplifying means comprises a variable-mu electron discharge device including a control grid circuit, said network is also connected in common to the control grid circuit of said variable-mu tube and the control grid-cathode circuit of the first discharge device, so that the voltage produced across said network controls the gain of both devices, and the control grid-cathode circuit of said first device includes a resistance of sufficient value to prevent flow of sufficient control grid current in that circuit when the control grid of said other device is driven positive to produce any appreciable voltage across said network due to that current.

9. A telegraph receiving circuit comprising a vacuum tube amplifier, a detector for detecting telegraph signals from the received waves, a telegraph relay responsive to the detected signals, a network in series with the input of said amplifier, comprising a capacitor and a discharge resistor in parallel, means responsive to the detected signals to charge said capacitor to a potential which is proportional to the amplitude level of the detector output to vary the gain of said amplifier so as to compensate for distortion in the signals controlling said relay caused by variations in the amplitude level of said received waves, and means to reduce variations in the voltage produced across said network due to the varying length of successive telegraph marking signals comprising an electron discharge device connected between said detector and said network providing a low resistance in the charging path for said capacitor to enable it to be quickly charged during marking signals, and a large resistance in the discharge path for said capacitor during spacing signal periods.

10. The telegraph receiving circuit of claim 9, in which said electron discharge device is also connected between said detector and said relay and operates as a direct-current amplifier for the detected signals to provide a large relay operating current.

11. The telegraph receiving circuit of claim 9, in which said electron discharge device comprises a single amplifying vacuum tube having a heated cathode, an anode positively biased with respect to said cathode, a control grid and a second grid electrode spaced between said cathode and anode, both negatively biased with respect to said cathode, and circuits respectively connecting said cathode to said control grid and said second grid electrode, the output of said detector being connected to the control grid-cathode circuit of said tube across a potentiometer resistance, the second grid electrode-cathode circuit of said tube including a portion of said potentiometer resistance and said network in series.

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