April 5, 1949. H. GOLDBERG 2,466,229

AUTOMATIC GAIN CONTROL SYSTEM

Filed April 21, 1944 2 Sheets-Sheet 1

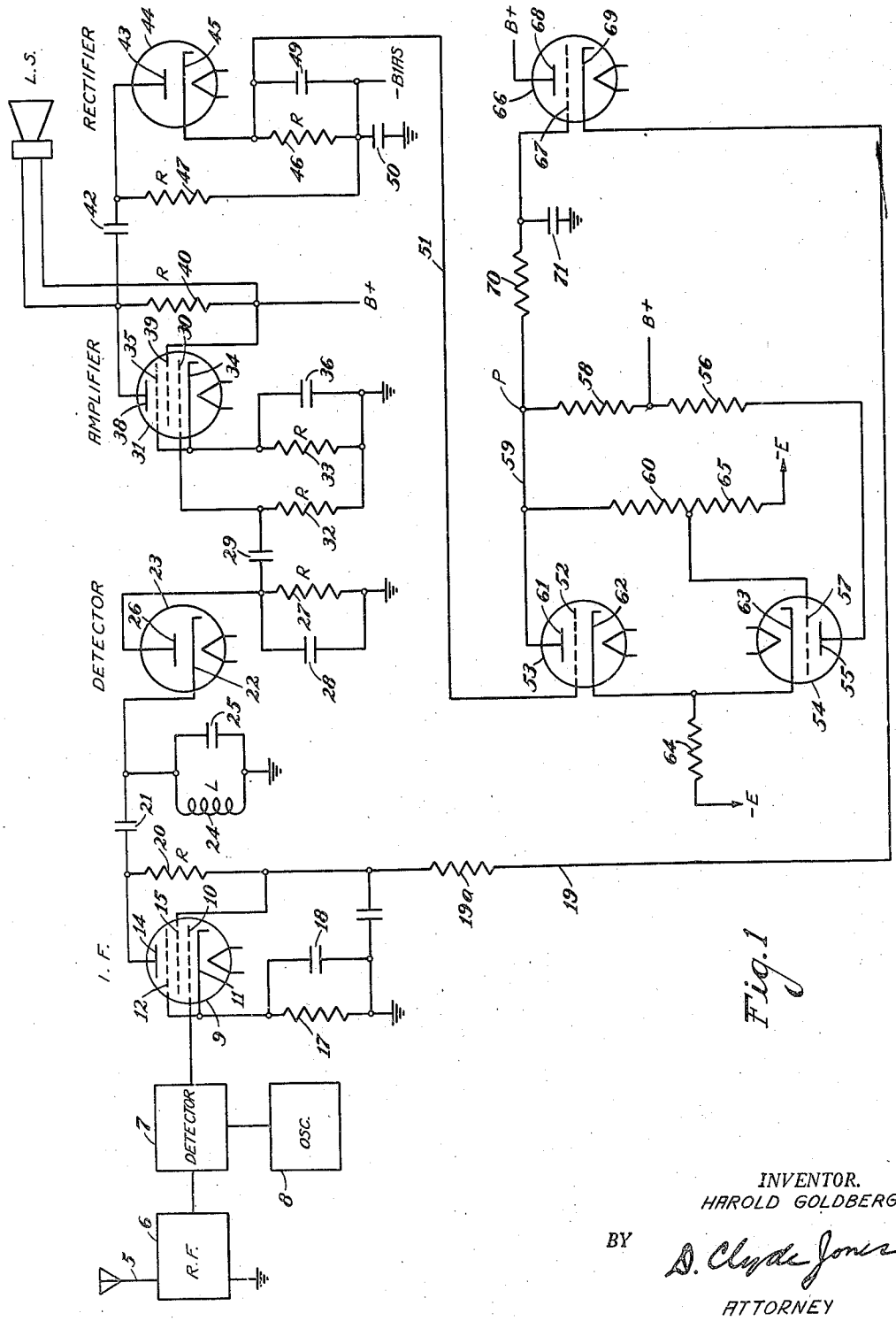


Fig. 1

INVENTOR.
HAROLD GOLDBERG

BY D. Clyde Jones

ATTORNEY

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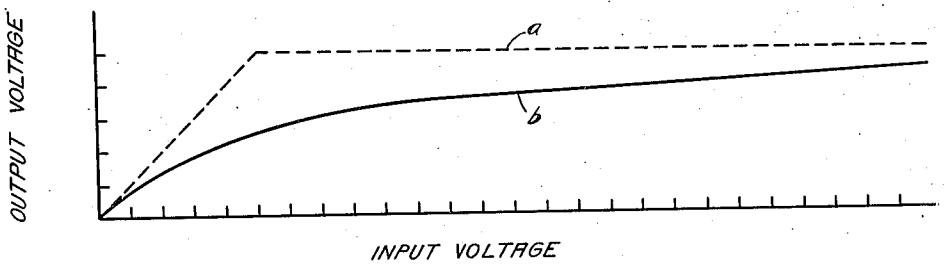


Fig. 2

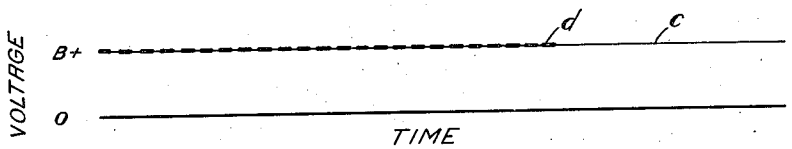


Fig. 3A

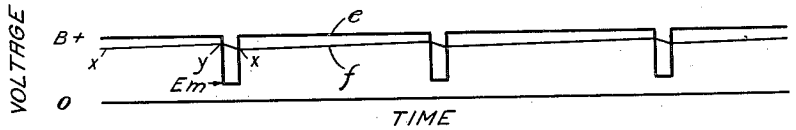


Fig. 3B

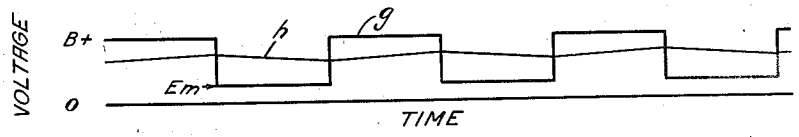


Fig. 3C

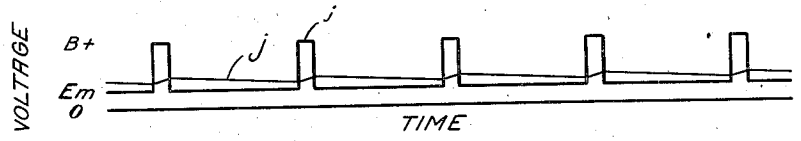


Fig. 3D

INVENTOR.
HAROLD GOLDBERG

BY D. Clyde Jones
ATTORNEY

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2,466,229

AUTOMATIC GAIN CONTROL SYSTEM

Harold Goldberg, Irondequoit, N. Y., assignor to The Stromberg-Carlson Company, Rochester, N. Y., a corporation of New York

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1 Claim. (Cl. 250—20)

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This invention relates to a method of and to apparatus for providing automatic gain control in signaling systems.

In signaling systems which are used for the transmission or reception of carrier, radio or pulse signals, it is essential that the gain of such systems be controlled in accordance with some function of the incoming signals so that the resulting amplified signals will approximate a predetermined level or limiting value.

In prior arrangements for providing automatic gain control in a signaling system, the amplification or gain effected in the system decreases asymptotically as the input voltage increases so that the desired level or limiting value of output voltage is approached at a constantly decreasing rate and consequently the gain does not attain its limiting value promptly. Also, in such prior arrangements, a relatively large input voltage is necessary to produce an amplified output voltage at approximately the limiting value.

In accordance with the main feature of the present invention, there is provided a method of automatic gain control in which the output is approximately proportional to the value of incoming signal until a predetermined value of such signal is reached, and thereafter a given output level is maintained as long as the incoming signal equals or exceeds the predetermined incoming signal value.

In accordance with another feature of the invention, an automatic gain control arrangement is provided, in which the gain of an amplifier is controlled as a function of a square wave which is variably triggered in response to changes in the strength of the incoming signal to be amplified.

Another feature of the invention relates to an automatic gain control arrangement, in which the control of the gain or amplification of an incoming signal is effected by rectifying a component of the incoming signal, and utilizing the rectified component to govern the duration of generated square waves which maintain the gain at a given level.

For a clearer understanding of the invention, reference is made to the drawings in which Fig. 1 is a diagrammatic showing of a radio receiver incorporating the present automatic gain control arrangement; Fig. 2 is a chart graphically illustrating the performance of conventional automatic gain control arrangements and also illustrating the ideal performance of a gain control arrangement; and Figs. 3A, 3B, 3C and 3D are graphs indicating different operating conditions of the invention for different signal strengths.

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Although the invention is applicable to a wide variety of amplifiers, there is illustrated, by way of example in Fig. 1, a radio receiver provided with an antenna 5 on which incoming signals are intercepted. This antenna is coupled to a radio frequency amplifier 6, tuned by suitable means (not shown), to select signals of a desired frequency, and to amplify them. The selected signals, thus amplified are introduced into a detector-oscillator unit 7, 8 wherein they are translated into intermediate frequency signals. These last-named signals are further amplified in an intermediate frequency amplifier which may comprise several stages although only a single stage is herein illustrated. This stage includes a pentode tube 9 comprising a grid 10, to which the intermediate frequency signals are applied, and also comprising cathode 11, suppressor grid 12, plate 14 and screen 15. The cathode 11 and suppressor grid 12 are connected in multiple to ground through the resistor 17 which is by-passed by the capacitor 18. The plate supply voltage, derived over the automatic gain control conductor 19 (to be described), is applied to the screen 15 and through resistor 20 to anode 14.

The output of the amplifier is coupled through the capacitor 21 to the cathode 22 of the diode detector 23, the input to the diode being tuned by the inductor 24 and capacitor 25 connected in multiple to ground. The anode 26 of the detector is connected to ground through the resistor 27, which is by-passed by the capacitor 28. The anode of the detector is coupled by the capacitor 29 to the control grid 30 of an amplifier tube 31, which is preferably of the pentode type, although other types of thermionic tubes can be employed as amplifiers. The input circuit of this amplifier includes the control grid 30, resistors 32, 33 and the cathode 34, the cathode being also connected to the suppressor grid 35. The lever end of cathode resistor 33 is connected to ground, this resistor being by-passed by the capacitor 36. A source of positive potential B+ is connected directly to the screen 39 and through resistor 40 to the anode 38 of this amplifier. There is connected across the terminals of the resistor 40 a utilization circuit which may include a loudspeaker LS.

In accordance with the novel method and apparatus of the present invention, the radio receiver proper, above described, is provided with an automatic gain control circuit, in which there is utilized a square wave generator triggered by a component of the incoming signal. This component may be provided by rectifying a varying current corresponding to the incoming signal, in

order to derive therefrom a voltage which will trigger the square wave generator. This generator with related means provides a low average control voltage under one limiting condition, and a predetermined average voltage of relatively large value under the alternate limiting condition, with correspondingly varying average voltages between these limits. These voltages control the amount of gain effected in an amplifier stage of the radio receiver, for example, in the intermediate frequency amplifier 9 thereof. The effect of this arrangement is that the output is proportional to the strength of the incoming signal up to a certain critical value but the output is maintained at a certain level when the strength of the incoming signal reaches or exceeds the mentioned critical value, as indicated in graph "*a*" of Fig. 2. The present arrangement thus distinguishes from prior automatic gain control circuits wherein the full control effect is achieved only gradually, such as in accordance with an asymptotic function, as illustrated by graph *b* of Fig. 2.

In this automatic gain control arrangement, the output of the amplifier 31 is coupled by the capacitor 42 to the anode 43 of a rectifier 44. The cathode 45 of this rectifier is connected through the resistors 46 and 47 to the rectifier anode 43, the resistor 46 being by-passed by the capacitor 49. The lower terminal of the resistor 46 is directly connected to a source of negative "Bias" and is also connected to ground through the capacitor 50.

The cathode 45 is connected by the conductor 51 to the grid 52 of the electron tube 53, which is connected in a circuit network with the electron tube 54 to function as a square wave generator. The rectifier 44 is so arranged that its output is positive and increases with an increase in strength of the incoming signal. It should be mentioned that if the receiver is used for pulse reception, the output of the rectifier should read peak or average values and should not reproduce the individual input pulses. This may be accomplished by using suitably high values of resistor 46 and capacitor 49, such that the time constant of this circuit (product of the values of resistor 46 and capacitor 49) is great in comparison with the period of repetition of the pulse. In addition, the portion of the system involving the negative "Bias," the rectifier 44 and the grid 52 of electron tube 53, must be connected for direct current so that the voltage applied to the mentioned grid 52, shall be the algebraic sum of the mentioned negative "Bias" voltage and the rectifier voltage.

The electron tubes 53 and 54, comprising the square wave generator, are so connected that the electron tube 53 is non-conducting, i. e. the bias at grid 52 is sufficiently negative to render tube 53 normally non-conductive and the electron tube 54 is completely conducting as long as the voltage on the grid 52 of tube 53 is less than some critical voltage, herein designated E_c. If the voltage on the grid 52 is greater in the positive direction than the critical voltage E_c, electron tube 53 becomes fully conducting and electron tube 54 is non-conducting. The electron tube 54 will be normally conducting, as mentioned, since its anode 55 is supplied with anode potential from the source B+, through resistor 56 to this anode. The grid 57 of electron tube 54 at this time is also supplied with a positive operating potential from the positive source B+, resistor 58, conductor 59, voltage dividing

resistors 60 and 65, to the mentioned grid. Conductor 59 also supplies positive potential to the anode 61 of the electron tube 53 which, however, is normally kept non-conducting because of the normally negative bias supplied to its grid through resistor 46 and conductor 51. The cathodes 62 and 63 of the electron tubes 53 and 54 are connected in multiple through the resistor 64 to the negative source —E. When the voltage on the grid 52 is less than the critical voltage, the point P is at the voltage of the source B+, relative to ground. When the voltage on the grid 52 is greater than the critical voltage, the point P is at a voltage E_m which is less than the source B+ and is determined by the source —E and the circuit constants of the square wave generator. These constants may be adjusted, for instance, so that E_m is the cut-off voltage for the cathode follower tube 66, to be referred to. This is a desirable condition since it means that the automatic gain control circuit, herein illustrated, can reduce the anode and screen supply voltages of the intermediate frequency amplifier 9, to zero value.

The mentioned point P on the output of the square wave generator is connected to a low pass filter or integrating network connected to the grid 67 of a cathode follower tube 66. This integrating network includes a resistor 70 connected in series between the point P and grid 67, and also includes the capacitor 71, connected in multiple therewith to ground. The cathode follower tube has its anode 68 connected to a positive source B+ and the cathode 69 of this tube is connected over the conductor 19 to the intermediate frequency amplifier 9 and thereby supplies the anode and screen supply voltages of this amplifier.

The operation of the automatic gain control circuit will best be understood by reference to the graphs shown in Figs. 3A, 3B, 3C and 3D. Let it first be assumed that there is no input signal and that the negative "Bias" is adjusted to some value which is less than the previously mentioned critical value E_c. At this time the voltage on the grid 52 is less than the critical value and the point P on the square wave generator is at the voltage B+ of the supply. Under such conditions, the capacitor 71 charges toward the limiting value B+ and thereby raises the potential on the grid 67 of the cathode follower 66 toward the voltage of the B+ supply, represented by the solid line graph *c* (Fig. 3A). The cathode follower in turn supplies a corresponding voltage indicated by the broken line *d* (superimposed on graph *c*) through the conductor 19 and resistor 19*a*, to the anode 14 and the screen 15 of the intermediate frequency amplifier. If no signal occurs in a time equal to several time intervals of the resistor-capacitor unit 70, 71, the intermediate frequency amplifier will be operated to effect maximum gain.

If now a signal is introduced into the receiver, a more positive voltage will be produced at the output of the rectifier 44 because of the greater drop across resistor 46 and the voltage applied to the grid 52 of the square wave generator will increase in the positive direction toward the critical voltage value E_c. As long as the signal is sufficiently weak so that the voltage on the grid 52 does not exceed the critical voltage, then the square wave generator, the intergrating network 70 and 71, as well as the cathode follower 66 and the intermediate frequency amplifier will continue in the same state as that just described

when there is no signal input. This condition is likewise indicated in the chart (Fig. 3A) wherein the voltage after filtering or integrating at the grid of the cathode follower is indicated by the mentioned broken line graph *d* which is essentially the same as the voltage of the B+ supply.

When, however, the input signal is strong enough to raise the voltage at the grid **52** above the critical voltage, the voltage at point P decreases to some value E_m. The capacitor **71** then begins to discharge toward the value E_m. The positive voltage on the grid **67** will therefore decrease and this follower will thereby supply reduced voltage over the conductor **19**, to the intermediate frequency amplifier. As a result of this, the gain of the amplifier is reduced so that the voltage output of the rectifier **44** drops and this continues until the voltage on the grid **52** is less than the critical voltage. As soon as this happens, the voltage on point P again rises to the value of the voltage on the B+ supply. Capacitor **71** then stops discharging and starts to recharge toward the value of B+. This will raise the voltage on the grid **67** of the follower which again increases the voltage supply to the screen **15** and anode **14** of the amplifier, thereby increasing the gain. With this increased gain, the output of the rectifier **44** will be such that the critical voltage on the grid **52** is exceeded and the cycle is again reversed. The cycle of operations of the square wave generator under the conditions just assumed is illustrated by the square wave voltage graph *e* in Fig. 3B, which indicates the voltage at point P. The average voltage developed by the integrating network **70** and **71**, from this square wave voltage, is shown by the graph *f* in Fig. 3B. It will be noted from this graph that this average voltage slightly rises from the initial value *x* to a value *y* while the vacuum tube **54** is conducting, and then drops off slightly to the initial value *x* during the period that the electron tube **53** is conducting. This slight variation in the average voltage, while it does cause some hunting about the critical value, is negligible.

The square wave voltage (graph *g*) caused by the square wave generator and the average or integrated voltage graph *h*) resulting therefrom, in response to an input signal considerably above the critical voltage, are indicated in Fig. 3C. Corresponding results, in response to a very high input signal, are indicated by the graphs *i* and *j* of Fig. 3D.

From the four figures just referred to, it will be observed that the average voltage applied to the amplifier decreases from a relatively large value in the case illustrated in Fig. 3A to a relatively low value, illustrated in the graphs of Fig. 3D. This average voltage depends upon the relative durations of the relatively positive and negative portions of the square waves, i. e., whether the signal strength is greater or less than a predetermined level or value. Viewed in another way, the control voltage depends upon the relative durations of two voltages corresponding to different conditions of signal strength. These two voltages are substantially constant in value, but one is positive with respect to the other. This average voltage is approximately constant for any given signal strength but its value depends on the relative time intervals during which the electron tubes **53** and **54** of the square wave generator are conducting. These time intervals are governed by the variation in signal strength above a predetermined critical value. Thus, with no signal present, the maximum amplification is effected in the intermediate frequency amplifier; while in response to incoming signals of increasing strength the gain of the amplifier is reduced until it approaches zero. In fact, under proper values of circuit constants, the gain can be reduced to zero in the case of extraordinarily strong signals. Since the output of the receiver is proportional to the output of the rectifier **44**, the receiver with its automatic gain control circuit has the characteristics illustrated by the graph *a* in Fig. 2, corresponding to the theoretically ideal action of an automatic gain control. The limiting amplitude of the output or amplified signal corresponding to the mentioned critical voltage, may be adjusted at will by varying the negative "Bias." It will be understood that the time constants of the integrating network, comprising the resistor **70** and the capacitor **71**, as well as the time constants of the rectifier **44** must be adjusted for satisfactory operation in each particular case or application.

Although the rectangular waves illustrated in Figs. 3B, 3C and 3D are shown as having a regular periodicity, it will be appreciated that during periods of varying input voltage this will not be the case. Rather, the relative durations of the times during which electron tubes **53** and **54** are conducting may fluctuate rapidly, resulting in corresponding variations in the output of the integrating circuit **70**, **71** to keep the output of the intermediate frequency amplifier **9** substantially constant.

While the present automatic gain control method and apparatus has been illustrated as a part of a radio receiver, the invention is not to be restricted to that purpose since it is applicable to a wide variety of applications limited only by the following claim.

What I claim is:

In combination with a signal receiver of the type having a source of input signals, first circuit means for amplifying signal-modulated currents, detecting means coupled to said first circuit means, and second circuit means for amplifying audio signal currents derived from said amplified modulated currents by said detecting means, an automatic gain control means comprising resistive and capacitive elements connected in series across a source of potential for providing a first voltage of a predetermined and substantially constant amplitude other than zero for all input signal strengths less than a predetermined level; rectifying means directly coupled to said second circuit means; electron discharge means having a control electrode which is normally biased beyond cutoff, said control electrode being conductively connected to said rectifying means in such a way that the output of said rectifying means modifies the bias on said control electrode in accordance with variations of input signal strength, the normal bias being such that said discharge means is rendered conductive for all input signal strengths exceeding said predetermined level; a connection between said discharge means and said resistive element for producing a substantial potential drop across a portion of said resistive element whenever said discharge means is rendered conductive to provide a second voltage of a different predetermined and substantially constant amplitude other than zero for all input signal strengths exceeding said predetermined level; means utilizing said voltages to derive a control voltage whose value is determined by the relative durations of said voltages;

and means for applying said control voltage to said first circuit means for modifying the amplification of said signals.

HAROLD GOLDBERG.

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Certificate of Correction

Patent No. 2,466,229. April 5, 1949.

HAROLD GOLDBERG

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 40, for the word "lever" read *lower*;

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of September, A. D. 1949.

[SEAL]

JOE E. DANIELS,
Assistant Commissioner of Patents.