

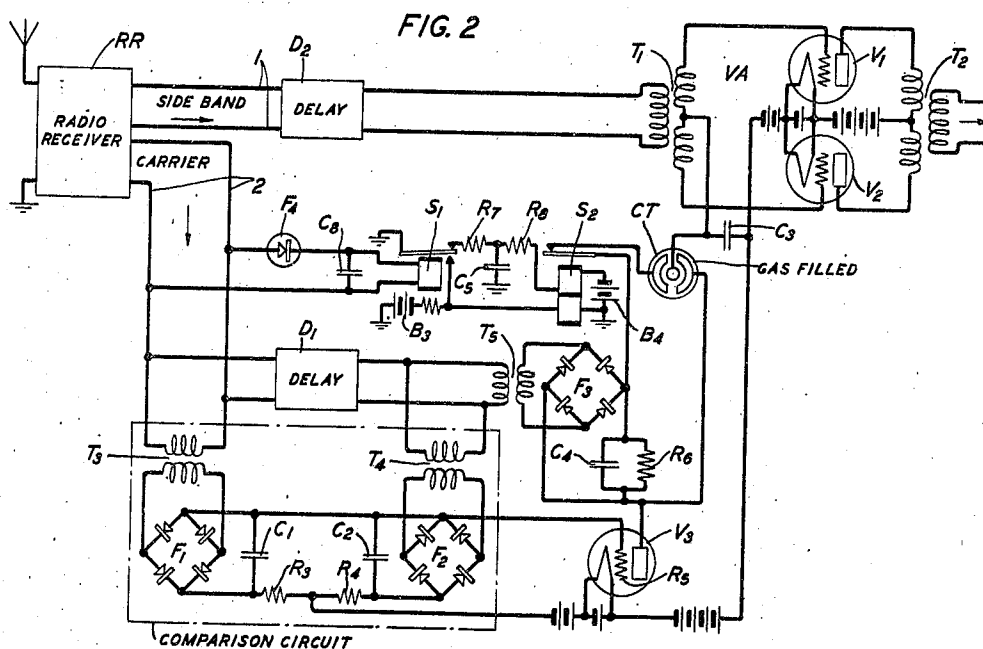
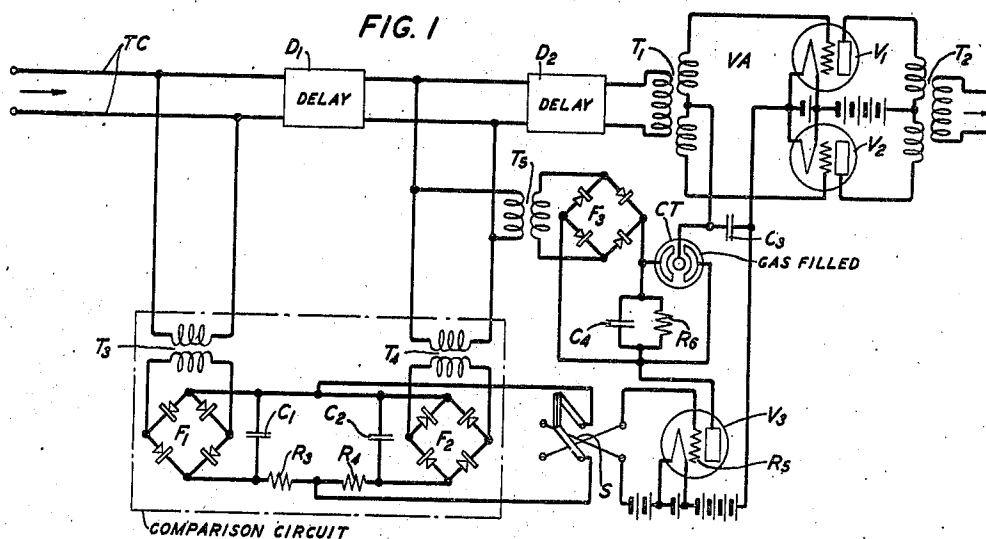
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AMPLITUDE RANGE CONTROL IN SIGNAL TRANSMISSION SYSTEMS

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AMPLITUDE RANGE CONTROL IN SIGNAL TRANSMISSION SYSTEMS

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The invention relates to the control of transmission in signal transmission systems and particularly to the control of the amplitude range of signals in such a system.

In a "non-linear" transducer, the output power is not proportional to the input power. Consequently, the ratio of maximum to minimum power at the output differs from that at the input. The ratio of maximum to minimum power is an expression of amplitude range. A device designed to alter this range may be called a range controller. In telephony, the term "range controller" includes many devices which have been designated with more specific names, such as volume limiters, volume control devices, range reducers, compressors, expanders, vogads (volume-operated gain-adjusting devices) etc.

An object of the invention is to improve the operation of such devices.

A more specific object is to improve the operation of a range controller in a telephone system subject to variable interference, such as line noise, static, or selective fading.

These objects are attained in accordance with the invention by circuits for making the time action of a range controller depend on the rate of variation of its input. In one embodiment applicable, for example, to a volume range expander or compressor, the time constant of the device is adjusted to provide for slow operation when the input has the nature of a strong, suddenly applied sound, such as a click of noise (short period), and fast operation when the input consists of waves of gradually changing amplitudes (long period), such as the syllabic variations in speech, so as to produce the desired operation on applied speech but not on applied noise.

Another embodiment is in an automatic gain control circuit for a radio receiver of the single side-band type, in which the time constant of the gain control circuit is made a function of the rate of change of the carrier envelope, so that the receiver output is improved when conditions change as a result of selective fading.

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

Figs. 1 and 2 show schematically the invention embodied in a range controller of general application, and, in an automatic gain control circuit for a radio receiver, respectively.

The amplitude range controller of Fig. 1 includes a vario-amplifier VA inserted in a tele-

phone circuit TC subject to variable interference such as line noise. The vario-amplifier VA includes an input transformer T₁ having its primary winding connected to the incoming portion of the telephone circuit TC; an output transformer T₂ having its secondary winding connected to the outgoing portion of the telephone circuit TC; two three-electrode amplifying tubes V₁ and V₂ having their control grid-cathode circuits connected in push-pull relation through respective halves of the secondary winding of input transformer T₁, and their anode-cathode circuits connected in push-pull relation through the respective halves of the primary winding of output transformer T₂; and a condenser C₃ connected in series with the common portion of the control grid-cathode circuit of tubes V₁ and V₂, the variable voltage across which controls the gain of the vario-amplifier VA.

The circuit arrangement modified in accordance with the invention for controlling the voltage across the gain control condenser C₃ includes the delay circuits D₁ and D₂ connected in tandem in the incoming portion of the telephone circuit TC in front of the vario-amplifier VA, the delay circuit D₂ being the usual one provided for delaying the application of the signal waves to the input of the amplifier until after the forward-acting control circuit has completed the adjustment of its gain, whereas the delay circuit D₁ has a different function in accordance with the invention, which will be described below.

The charge on gain control condenser C₃ is controlled partly by a branch control circuit, including input transformer T₃, full-wave rectifier F₃ and the gas-filled control tube CT, having its input connected across the circuit TC between the delay circuit D₁ and the delay circuit D₂; and partly through the anode-cathode impedance R_s of a three-electrode vacuum tube V₃, the value of which impedance is controlled by the voltage applied between the control grid and cathode of the latter tube from the output of a "Comparison circuit," shown within the dot-dash box so labeled.

The comparison circuit consists of two full-wave rectifiers F₁ and F₂, the inputs of which are respectively connected across the circuit TC through transformers T₃ and T₄, respectively, on the input and output sides of the delay circuit D₁. The outputs of these rectifiers are connected in opposition respectively across equivalent condensers C₁ and C₂ connected in a closed series circuit with equivalent series resistances R₃ and R₄.

A mid-point between the two condensers C₁ and

C_2 and a mid-point between the two resistances R_3 and R_4 are connected to the control grid and cathode of the tube V_3 by the double-pole, double-throw switch S , the poling depending on whether the switch is operated to the left or right. The value of the anode-cathode impedance R_5 of tube V_3 by these connections is made dependent on the amount the charge on condenser C_2 exceeds the charge on condenser C_1 in the comparison circuit. The anode-cathode impedance R_5 of the tube V_3 is connected in series with condenser C_4 and parallel resistance R_6 and the cathode-to-anode impedances of the gas-filled control tube CT across the gain control condenser C_3 , and the output of the full-wave rectifier F_3 is connected across condenser C_4 and parallel resistance R_6 .

The circuit arrangement of Fig. 1 operates as follows:

Let it be assumed, first, that a short-period click of noise is applied to the input of the telephone circuit TC . A part of the noise voltage in the input of delay circuit D_1 will be passed through transformer T_3 to the comparison circuit, and will be rectified by full-wave rectifier F_1 to produce a proportional charge on the condenser C_1 . Assuming that the double-pole, double-throw switch S is operated to the left, this charge applied between the control grid and cathode of the tube V_3 will tend to decrease the anode-cathode impedance R_5 of that tube, thus tending to decrease the time constant of the gain control circuit of the vario-amplifier VA . However, a short time later when the voltage due to the noise click appears at the output of delay circuit D_1 , other portions will pass through the input transformer T_4 in the comparison circuit, and input transformer T_5 in the main gain control branch, which have their primary windings connected in parallel across the circuit TC at a point between delay circuits D_1 and D_2 , thus actuating both full-wave rectifiers F_2 and F_3 .

The charge applied by rectifier F_2 on the condenser C_2 in the comparison circuit will be in opposition to that previously placed by the noise click on the condenser C_1 of that circuit, the charge on C_1 by this time having been diminished due to the noise click having passed through delay circuit D_1 . Consequently, the voltage due to the difference between the charges on condensers C_2 and C_1 will apply through switch S a negative bias to the control grid of the tube V_3 , thus increasing the value of the anode-cathode impedance R_5 of that tube and thereby increasing the time constant of the vario-amplifier gain control circuit.

The output voltage of full-wave rectifier F_3 is applied across resistance R_6 in parallel with condenser C_4 to the control discharge gap of gas-filled control tube CT . The main discharge gap of tube CT acts practically as an open circuit with no voltage applied by F_3 . When F_3 delivers a sufficient voltage across R_6 , the control gap of tube CT breaks down which causes the main gap of control tube CT to become conductive, so that part of the applied voltage from F_3 is placed in series with C_3 and R_5 and will place a charging voltage across C_3 . By this time, the noise click will have passed through the delay circuit D_2 and, because the time constant of the main control branch of vario-amplifier VA has been set to a high value in the manner just described, the gain change will be too slow to respond

to the click voltage until after the noise click has been dissipated in input transformer T_1 .

Now, let it be assumed that a longer period wave, such as a speech wave, is impressed on the input of the circuit TC . In the same way as above described for the applied noise click, a portion of the speech voltages in the input of delay circuit D_1 will be first applied through transformer T_3 to the comparison circuit and will be rectified in rectifier F_1 to apply a charge on condenser C_1 . After passing through the delay circuit D_1 in the circuit TC , other portions will be applied through transformer T_5 to rectifier F_3 in the main gain control branch, and through transformer T_4 to rectifier F_2 in the comparison circuit. The output of rectifier F_2 will produce a charge on condenser C_2 in the comparison circuit.

Because of the longer period of a speech wave, during the building up of the wave, the difference between the charges produced on the condensers C_1 and C_2 of the comparison circuit will be smaller than in the case of the short-period noise click, and the difference voltage, therefore, will apply only a slight negative bias to the control grid of the tube V_3 so that its anode-cathode impedance R_5 will be smaller than before. This will cause the time constant of the gain control circuit of the vario-amplifier VA to be made smaller and, by the time the speech waves in the circuit TC reach the output of delay circuit D_2 , the gain of vario-amplifier VA will have increased due to the charge produced on condenser C_3 from the gas-filled control tube CT . Thus, it will be seen that the speech waves are more effective in increasing the gain of the vario-amplifier VA than the suddenly applied clicks. At the end of each speech sound, the charge on condenser C_2 of the comparison circuit will predominate and therefore the impedance R_5 of tube V_3 will be large, but owing to the lag in operation due to the varied time constant, the distortion will be less than at the beginning of the sound.

If the range controller of Fig. 1 is used as a volume range expander, the circuit constants would be selected so that the vario-amplifier VA would normally have a low gain, and speech when it is applied to the input of the circuit would be more effective in increasing this gain than would short-period noise, as is apparent from the above description of operation.

If the double-pole, double-throw switch S in the circuit of Fig. 1 is thrown to the right, and the batteries and other circuit constants are selected to provide the proper bias and other characteristics in the vario-amplifier VA , the device of Fig. 1 may be arranged so that the variation in the ratio of the time constant to the period of the envelope tends to be smaller as the envelope frequency varies, thus giving a more uniform operation than a device in which the time constant is fixed and the envelope period varies. Such an arrangement might have application in a compressor at the sending end of a telephone circuit. To obtain the compressor action with the circuit of Fig. 1 it will be necessary to reverse the leads connecting the terminals of C_3 to the grids and cathodes of the vario-amplifier tubes V_1 and V_2 so that the control voltage from V_3 will effect an increase in gain of VA when control tube CT operates from increasing input.

The operation of the circuit arrangement of Fig. 1 so modified would be as follows: Assuming that the envelope period of the speech wave applied to the input of the circuit TC is short, at the instant the wave reaches the input of the vario-amplifier VA, the charge produced on the condenser C₂ will exceed that on the condenser C₁ of the comparison circuit, and the value of the anode-cathode resistance R_s of tube V₃ will consequently be low. This will permit the gas-filled control tube CT to operate with a small time constant.

If, on the other hand, the syllabic period of the applied speech wave is long, there would be a smaller difference produced in the charges on the condensers C₂ and C₁ in the comparison circuit so that the impedance R_s would be correspondingly greater. Thus, the time constant obtained in the control for the vario-amplifier VA at the instant of the arrival of any portion of the applied wave in the output of delay circuit D₂ would bear a proper relation to the period of the wave, that is, a long time constant with a long period.

Fig. 2 shows a modification of the invention applied to a carrier-operated automatic volume control for a single side-band radio receiver in which the time constant is made a function of the rate of change of the carrier envelope so that the output is improved when conditions change as a result of selective fading. The elements of the arrangement of Fig. 2 corresponding to those of Fig. 1 are identified with the same identification characters.

As shown in Fig. 2, the radio receiver RR has a side-band output circuit 1 corresponding to the telephone circuit TC in the system of Fig. 1, and a carrier output circuit 2 which is employed as a forward-acting circuit for controlling the gain of a vario-amplifier VA, corresponding to the amplifier so identified in the system of Fig. 1, connected in the side-band output circuit 1 by the input and output transformers T₁ and T₂ and preceded by a delay circuit D₂ corresponding to the delay circuit similarly identified in the circuit TC in the arrangement of Fig. 1. The first delay circuit D₁ in the system of Fig. 2, however, corresponding to the delay circuit so identified in the system of Fig. 1, is connected in the carrier output circuit 2 instead of in the main signal circuit as in Fig. 1. A "Comparison circuit" shown within the dot-dash box so identified, identical with that of Fig. 1, has the input of its rectifier F₁ connected by transformer T₃ across circuit 2 in the input of D₁, and the input of its rectifier F₂ connected by transformer T₄ across the output of D₁ as in the system of Fig. 1.

Also in Fig. 2, as in the system of Fig. 1, gain control condenser C₃ in the common portion of the control grid-cathode circuits of the tubes V₁ and V₂ of the vario-amplifier VA obtains its charge partly from a branch control circuit including an input transformer T₅, full-wave rectifier F₃, and a gas-filled control tube CT, but having its input connected across the carrier output circuit 2 in the output of delay circuit D₁, instead of to a corresponding point in the main signal circuit as in Fig. 1. In the system of Fig. 2, like in Fig. 1, the gain control condenser C₃ obtains part of its charge through the anode-cathode impedance R_s of a three-electrode vacuum tube V₃, connected in series with condenser C₄ and parallel resistance R₆, connected across the output of full-wave rectifier F₃, and the main cathode-anode discharge gap of gas-filled control

tube CT across condenser C₃; and the value of the anode-cathode resistance R_s of tube V₃ is controlled by the difference in the voltages of condensers C₁ and C₂ of the comparison circuit, applied between the control grid and cathode of the tube V₃.

In addition, the circuit of Fig. 2 includes an electromagnetic threshold (marginal) relay S₁ having its winding connected across the carrier output circuit 2 at a point in front of delay circuit D₁ through the series half-wave rectifier F₄ and shunt condenser C₅. The relay S₁ is operated in response to normal carrier, but releases in response to the falling off of the carrier output of the radio receiver RR during a selective fading period to control relay S₂ and associated timing circuits, to disable the charging circuit for the gain control condenser C₃ of vario-amplifier VA, and to hold its disabled for a definite time interval as required to prevent gain adjustment of the vario-amplifier VA during the time when the carrier is being restored to its normal value, in a manner which will be described below.

When the carrier in the carrier output circuit 2 of radio receiver RR is normal, it applies through full-wave rectifier F₃ connected across the output of delay circuit D₁, a negative charge on gain control condenser C₃ which will adjust the gain of the vario-amplifier VA so that it is correct for its input. As the carrier amplitude decreases, the charge produced on gain control condenser C₃ is reduced, causing the gain of the vario-amplifier VA to be proportionately increased.

Assuming that the carrier begins to fade, the carrier output of delay circuit D₁ will tend to become stronger than the carrier input to delay circuit D₁ thus building up an excess charge on the condenser C₂ in the comparison circuit through transformer T₄ and rectifier F₂, the effect of which is to make the anode-cathode impedance R_s of tube V₃ small. This will cause the time constant of the amplifier VA to be small so that the control circuit acting through rectifier F₃ produces gain changes rapidly following the carrier envelope. However, as the carrier drops below the threshold value for which the relay S₁ is designed to release, no further change takes place in the time constant of the control circuits for the vario-amplifier VA or in the amplifier gain because relay S₁ releases, causing relay S₂ to be operated by current from the battery B₃ supplied to the operating winding of the latter relay. Now, as the amplitude of the carrier increases at the end of the fade, the threshold relay S₁ will reoperate. However, the release of the relay S₂ is delayed for a period determined by the values of the resistance elements R₇ and R₈ and the condenser element C₅ while the latter condenser is being charged up by current from the battery B₄ through a holding winding on relay S₂. Thus, the change which would otherwise occur due to the carrier being restored to its normal value is not allowed to effect the time constant of the control circuit for the vario-amplifier VA.

Assuming now that the amplitude of the carrier in carrier output circuit 2 remains steady or drops off very slowly, it will be desirable to have a longer time constant on the gain control for the vario-amplifier VA. This effect is obtained by the comparison circuit because for that condition the difference between the charge produced on condenser C₂ and condenser C₁ is quite small, resulting in a large value for the anode-cathode impedance R_s of the tube V₃ and thus

providing a very slow variation in the gain of the vario-amplifier.

Other arrangements of the apparatus and circuits shown in Figs. 1 and 2 which will provide the desired variation of the time constants of the control for the variable gain amplifier to provide improved operation in the presence of noise or selective fading, which are within the spirit and scope of the invention, will occur to persons skilled in the art. For example, it is apparent that the gas-filled control tube CT and the vacuum tube V₃ may be replaced by other known types of variable impedances, and that a backward-acting gain control circuit may be used with the range controller instead of a forward-acting circuit such as illustrated and described.

What is claimed is:

1. In combination with a range controller in a signal transmission circuit, including a variable gain amplifier in said circuit and a control circuit for automatically adjusting the gain of said amplifier to make the signal amplitude range in its output a desired function of the signal amplitude range in its input, means to improve the operation of said range controller in the presence in said circuit of interfering noise energy of relatively short period compared to that of the signal waves, or selective signal fading conditions, comprising means responsive to the waves applied to said control circuit to adjust its time constant so as to produce a slow variation in the gain of said amplifier for the applied waves of short period and a fast variation in its gain for applied waves of relatively long period.

2. The combination of claim 2, in which said amplifier includes an electron discharge device having a control grid circuit including a condenser, said gain-adjusting control circuit comprises means for selecting from the transmission circuit and rectifying a component part of the signal waves, and means to utilize the rectified waves to charge said condenser in accordance with their amplitude and thus produce a proportional variation in the amplifier gain, and said means for adjusting the time constant of said gain-adjusting control circuit includes a variable impedance connected in a closed circuit with said condenser, a delay circuit in the path of the waves applied to said gain-adjusting control circuit, means to compare the amplitude level of the waves in the output of said delay circuit with that of the waves in the input thereof, and means for varying the value of said variable impedance in a direction and amount dependent on the amplitude difference of the compared waves.

3. The combination of claim 2, in which said amplifier includes an electron discharge device having a control grid circuit including a condenser, said control gain-adjusting circuit is connected to the signal transmission circuit and includes means for rectifying the applied waves, and a variable impedance connected across said condenser, the value of which is varied in accordance with the amplitude of the rectified waves to control the charge on said condenser, and said means for adjusting the time constant of said gain-adjusting control circuit comprises a second variable impedance connected in series with the first variable impedance across said condenser, a delay circuit connected in said transmission circuit in front of the point of connection of said control circuit thereto, means for continuously comparing the amplitude levels of the waves in the input and output of said delay

circuit, and means responsive to the amount and direction of the differences in the levels of the compared waves to produce a proportional change in the value of said second variable impedance element to vary the charge on said condenser.

4. The combination of claim 2, in which said amplifier includes an electron discharge device having a control grid circuit including a condenser, said control gain-adjusting circuit is connected to the signal transmission circuit and includes means for rectifying the applied waves, and a variable impedance connected across said condenser, the value of which is varied in accordance with the amplitude of the rectified waves to control the charge on said condenser, and said means for adjusting the time constant of said control circuit comprises a second variable impedance connected in series with the first variable impedance across said condenser, a delay circuit in said transmission circuit in front of the point of connection of said control circuit thereto, means for respectively rectifying the voltage waves in the input and output of said delay circuit, two condensers connected in opposition and respectively charged in accordance with the amplitude level of the respective rectified voltage waves, and means responsive to the differences in the charges on the two condensers to change the value of said second variable impedance proportionately.

5. The combination of claim 2, in which said range controller is a carrier-operated automatic gain control for a radio-receiver, said amplifier being connected in the signal side-band output circuit of said receiver, and including an electron discharge device having a control grid circuit including a condenser, said control circuit being selective to the carrier component of the waves in the output of the radio receiver and comprises means for rectifying said carrier component, and a variable impedance connected across said condenser the value of which is varied in accordance with the amplitude of the rectified wave to control the charge on said condenser, so as to vary the gain of said discharge device, and said means to adjust the time constant of said control circuit comprises a second variable impedance element connected in series with the first variable impedance element across said condenser so as to vary the charge on the latter in accordance with its value, a delay circuit in said control circuit in front of the rectifying means, means for continuously comparing the amplitude levels of the waves in the input and output of said delay circuit, means responsive to difference in the amplitude levels of the compared waves to proportionately adjust the value of said second variable impedance to make the time constant of said control circuit a function of the carrier envelope, and means responsive to the carrier output of said receiver to prevent the gain of said electron discharge device from being varied during a period of selective fading and the subsequent period during which the carrier is being restored to its normal amplitude value.

6. In combination with an automatic gain control for a radio receiver comprising a variable gain electron discharge device having a control grid circuit including a gain control condenser, connected in the side-band output of said receiver and a control circuit responsive to the carrier output of said receiver to vary the charge on said condenser in accordance with the carrier amplitude variations, means to improve the op-

eration of said automatic gain control in the presence of selective signal fading conditions comprising a variable impedance in the charging circuit of said condenser in said control circuit, means to adjust the value of said variable impedance to make the time constant of said control circuit a function of the rate of change of

the carrier envelope, and means to prevent the grain of said electron discharge device from being varied during a period of selective fading and the subsequent period during which the carrier 5 is being restored to its normal amplitude value.

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