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HARMONIC CONTROL SYSTEM

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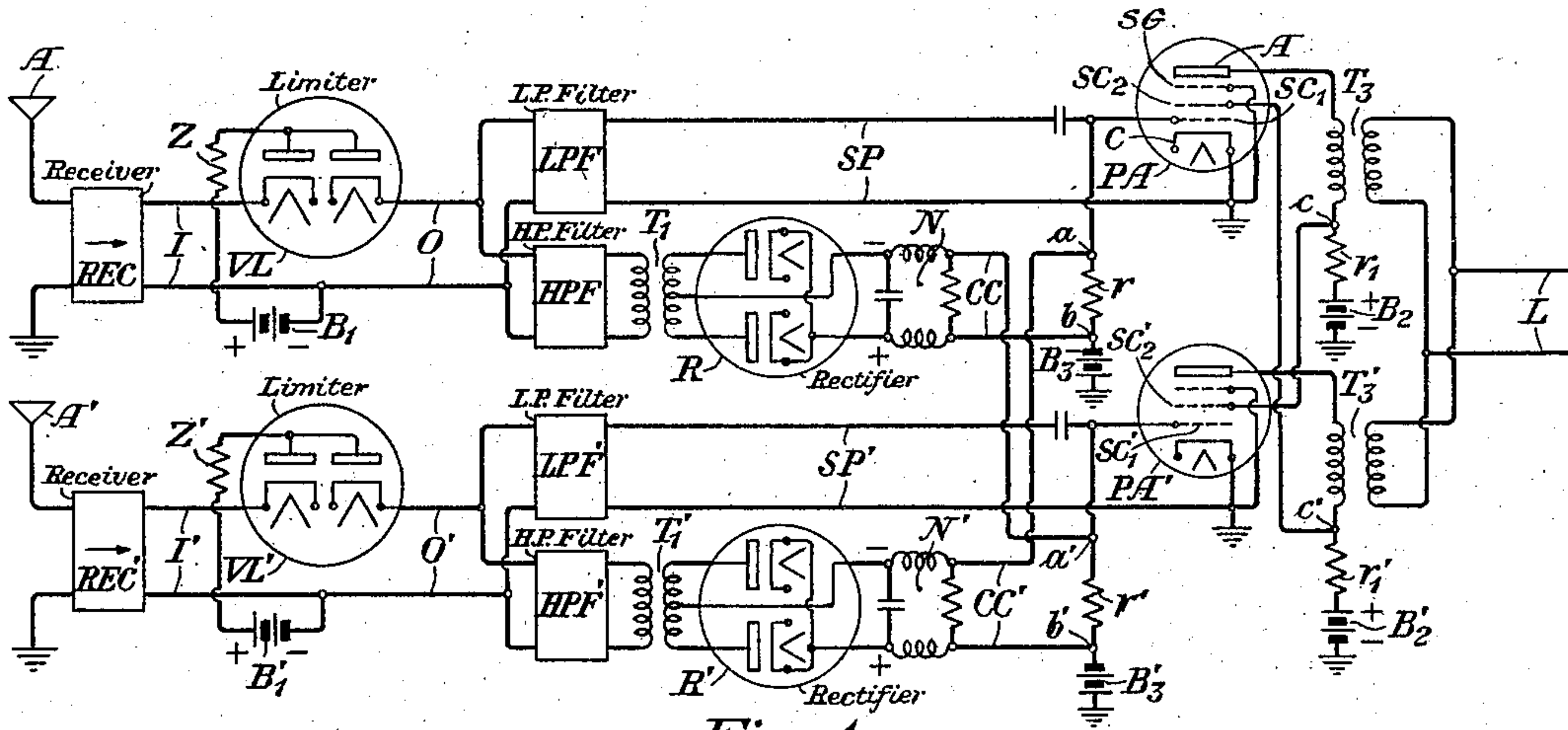


Fig. 1

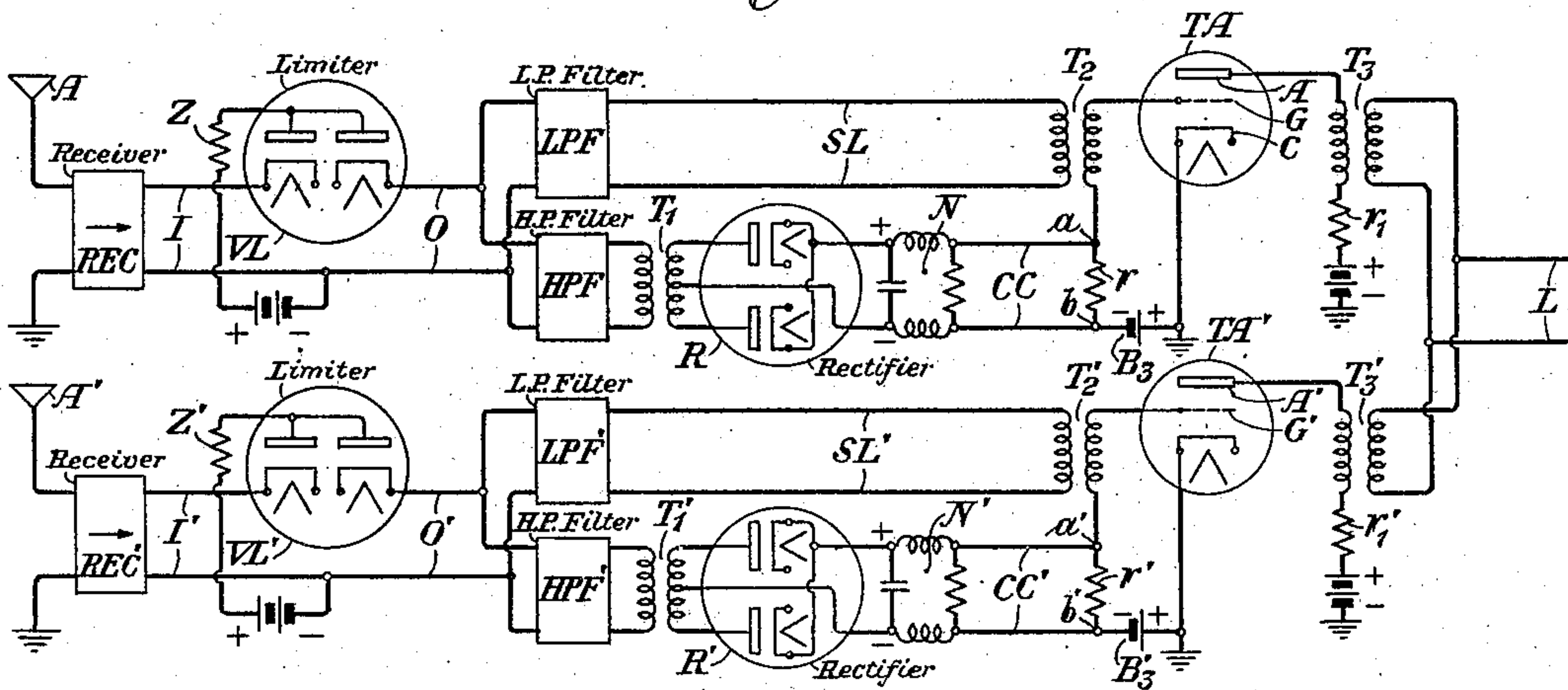


Fig. 2

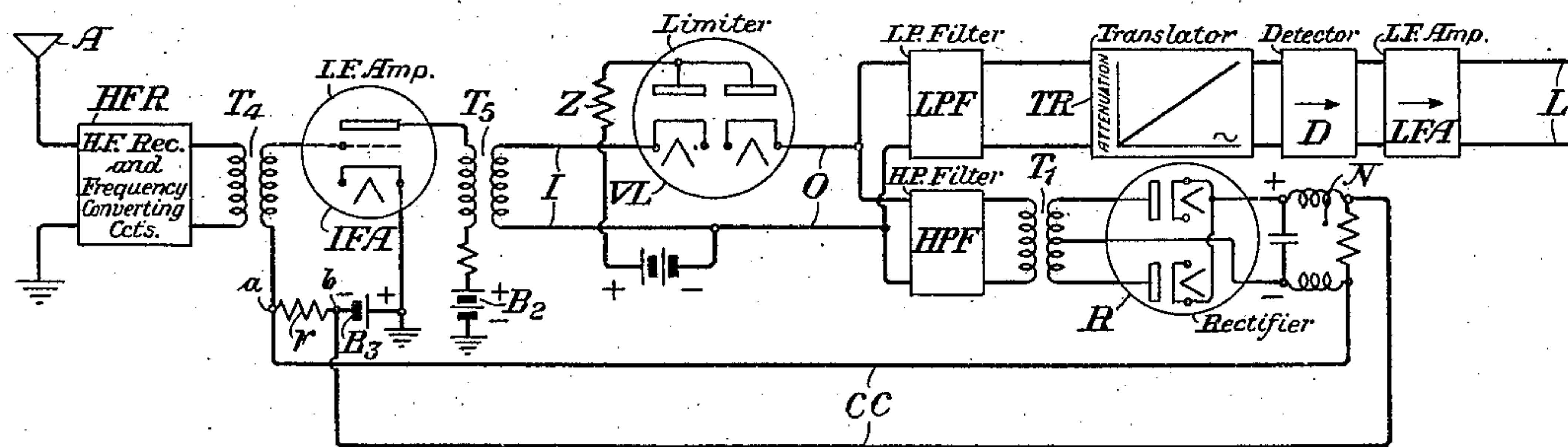


Fig. 3

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HARMONIC CONTROL SYSTEM

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12 Claims. (Cl. 178—44)

This invention relates to arrangements for automatically controlling an element or elements of a system such as a radio or wire communication system.

In the art of communication, instances frequently arise in which it is desirable to control a given transmission circuit or some other transmission circuit in accordance with transmission conditions existing in a given circuit. For example, it has been common practice to use transmission entering a path transmitting in one direction, to change the condition of a path transmitting in the opposite direction by disabling it, by rendering it capable of transmitting or by changing the volume level of the path. It has also been common practice to use the transmission entering a given transmission path to render such path capable of transmission where it is normally disabled, to disable it where it is in normal transmitting condition, or to change the volume of transmission through the circuit. In other instances, some element in a transmission path is used in response to the volume level of transmission in that path to control some other element in the path to keep the transmission constant. As another example, in diversity reception, the signals in one or more radio receivers have been used to determine which of the several available receivers should be used at a given time.

Heretofore, in the various types of systems above outlined, the control of some element in a transmission path by another element in the same or another transmission path has been controlled in accordance with the volume of a signal or the volume of the carrier on which such signal is superimposed. In accordance with the present invention, however, it is proposed to exercise the control not by means of the signal or a carrier upon which the signal is superimposed, but by means of the harmonic condition in the output of a limiting device through which the signal (or carrier) is transmitted.

Various types of limiting devices are known in the art which operate in response to alternating currents of varying amplitudes to limit the amplitude of a given alternating current wave to a preassigned maximum value. In a limiting device of this type, when an alternating current wave exceeds the preassigned limit, the tops of the waves are, in effect, cut off, thereby producing harmonics of the fundamental signal or carrier wave. In accordance with the present invention the volume of the harmonics appearing in the output of the limiting device is used to control an element in a transmission circuit to

produce some desired result, such as disabling the circuit, rendering it capable of transmission, changing the volume level, or selecting a desired circuit from a group of available circuits.

The invention will now be more fully understood from the following description thereof, when read in connection with the accompanying drawing, in which Figure 1 shows the invention applied to the selection of a preferable receiver in a radio system employing diversity reception; Fig. 2 shows the invention applied to a diversity reception system operating on a slightly different basis, and Fig. 3 shows the invention employed to control the gain of a preceding stage in a frequency modulation radio receiver to insure proper limiting of the signal at all times.

In a diversity receiving system it is desirable to select the receiving circuit which at any particular time has the strongest signals and is, therefore, most likely to give the best signal-to-noise ratio. Such a system is shown in Fig. 1, and the harmonics appearing in the output of a limiting device or devices are used to determine which radio receiver will be used at a given time. While any known type of limiting device may be employed, the limiting device shown in Fig. 1 is a vacuum tube arrangement employing two indirectly heated cathodes and two anodes connected in a circuit in such a way as to prevent a received current wave from exceeding a preassigned limit.

In the system of Fig. 1, two alternative receiving circuits are disclosed, either of which may be used to transmit the received signals to an outgoing line or circuit L. One of the receiver circuits includes an antenna A, a radio receiver of any known type such as REC, a limiting device VL of the type just referred to, and a pentode amplifier PA which may be used to control the volume level or the effectiveness of transmission through the particular channel. The other receiver circuit similarly includes antenna A', receiver REC', limiter VL', and pentode amplifier PA'.

The limiter VL, as already stated, has two indirectly heated cathodes and two anodes so that two separate transmission paths pass through the limiter. The two anodes are connected together and a source of direct current B is bridged from the junction point of the two anodes through a resistance Z across the transmission path to a conductor which is connected through terminal apparatus to the two cathodes. A limiter of this general type is disclosed and described

in U. S. patent to Schelsinger, No. 2,309,258, issued January 26, 1943.

In the operation of a limiter of this type the current in the output circuit resulting from the voltage induced by the oscillations applied to the circuit, cannot exceed in either direction the direct current supplied by the battery B to one of the anodes. Therefore, all higher amplitudes applied to the circuit are reduced to the maximum predetermined by the battery supply. It will be seen that the battery supply circuit is, in effect, bridged across the junction of an input circuit I and an output circuit O, each of which has a one-way vacuum tube path included therein, the vacuum tubes being conductive in opposite directions. With such a connection a wave applied to the input circuit I produces a variable wave in the output circuit O whose maximum amplitude will not be greater than the voltage between the output cathode and the output anode produced by the battery B. The current flowing from the input cathode to the output anode acts, in effect, as a shunt upon the path from the output cathode to the output anode of the device VL.

For example, when the signal wave received by the receiver REC is in such a direction as to increase the normal current flow between the input cathode and the input anode of the device VL, the current in the output O is decreased by the lowered impedance of the input path but, of course, cannot decrease below zero value. When the input wave is in such a direction as to oppose the normal current flowing from the input cathode to the input anode due to the battery B, the shunting effect of the input circuit I is reduced by the increased impedance between the input electrodes of this tube, and the current in the output circuit O increases, but not beyond a maximum imposed by the potential of the battery B. This is because the applied input wave opposes the normal current flow from cathode to anode in the input circuit, and when it attains the same value as said normal current or exceeds that value, no current flows from cathode to anode in the input path I, and the maximum wave appearing in the output circuit O cannot attain a greater value than that produced by the voltage of the battery B. Consequently, the alternating current waves in the output circuit are limited or have their tops cut off so that they do not exceed a pre-assigned value.

As already stated, this results in producing harmonics in the output circuit O whose energy is determined by the degree of limiting of the received signal waves. The energy of the harmonics may then be used to control elements in the receiving circuits of a diversity reception system in such a way as to determine which of the receivers at a given moment will be effective to transmit to the outgoing line L. In order to obtain this result the output circuit O of the limiter is connected through a low-pass filter LPF and over a signal path SP to a pentode amplifier PA whose output transformer T₃ is connected to the line L. The circuit just described selects and transmits only signals of the desired signal frequency. The output circuit O is connected to an alternative path through a high-pass filter HPF which passes the harmonics produced by the limiter VL through a transformer T₁ to a

This rectifier may be of any known type, but, as shown, is a tube having two transmission paths between two indirectly heated cathodes and two corresponding anodes. The paths through the

tube are connected in the usual push-pull circuit arrangement so that one-half of an A. C. wave passes through one of the paths while the half of the A. C. wave of opposite sign goes through the other path of the rectifier. Thus both halves of the A. C. waves are rectified. In the output circuit of the rectifier R is a network N of known type, which serves to smooth out the rectified current so that in the circuit CC a rectified direct current appears whose value at any given time is proportional to the harmonics appearing in the output circuit O. The D. C. voltage appearing across the terminals of the network N will apply a negative potential to the conductor of the circuit CC connected to the cathodes of the rectifier R, while the conductor connected to the anodes of the rectifier will have a positive voltage applied thereto.

The amplifier PA in the signal path SP involves a pentode type tube having an indirectly heated cathode C, an anode A, a controlling screen or grid SC₁, a second controlling screen or screen grid SC₂, and a suppressor grid SG. The conductors of the path SP are connected to the cathode C and the screen SC₁, respectively. The anode A is energized by D. C. potential from a battery B₂ through a resistance r₁ and is connected through a transformer T₃ to the output circuit L. The suppressor grid SG is connected to the cathode C and serves to pick up electrons driven out of the anode A as secondary emission, thus preventing such electrons from affecting the operation of the tube. The normal gain of the pentode amplifier PA is determined by a so-called C potential supplied by the battery B₃ through a resistance r to the controlling grid or screen SC₁.

Another receiving circuit, similar to that already described, is connected to the antenna A' and, as previously stated, includes a radio receiver REC', a vacuum tube limiter VL', filters LPF' and HPF', a pentode amplifier PA', and a rectifier R', all of these elements being similar to the corresponding elements associated with the antenna A, and also being similarly connected. The output of the pentode amplifier PA' is connected through a transformer T'₃ to the outgoing circuit L.

The rectified potential applied on the output side of the rectifiers R and R' is connected to control the pentode amplifiers PA and PA', as follows: The positive side of the rectifier R is connected to a junction point b between the C-battery B₃ and the resistance r. The negative side of the rectifier R is connected to the upper terminal a' of the resistance r' in the C-battery control circuit of the pentode amplifier PA'. Similarly, the positive side of the rectifier R' is connected to the lower terminal b' of the resistance r' in the C-battery supply of the pentode amplifier PA'. The negative side of the rectifier R is connected to the upper or a terminal of the resistance r in the C-battery supply lead for the pentode amplifier PA.

Further control is effected by connecting the screen grid SC₂ of amplifier PA to the point c' in the battery supply path of the plate or anode of the pentode amplifier PA'. Similarly, the screen grid SC'₂ of the pentode amplifier PA' is connected to the terminal c in the battery supply path of the pentode amplifier PA.

The arrangement above described operates substantially as follows: The two pentode amplifiers PA and PA' in the two receivers are adjusted with proper control bias supplied from the batteries B₃

and B_3' , respectively, through the resistances r and r' , respectively, to the control grids SC_1 and SC_1' , so that both amplifiers will have substantially equal amplification without any added voltage from the rectifiers R or R' , as the case may be. If the limiter VL is limiting the signals received from the antenna A , then a voltage will be generated in the output of the rectifier R . Due to the negative connection from the output of the rectifier to the point a' of the biasing control path to the control grid SC_1' of the amplifier PA' , this rectified voltage, which is proportional to the harmonics appearing in the output O of the limiter VL , will increase the negative potential on the control grid SC_1' of the pentode amplifier PA' , thus reducing the gain of said amplifier.

The reduction in the gain of amplifier PA' results in decreasing the plate current in said pentode amplifier. Consequently, the positive potential in the plate circuit will be increased at the point c' . This increase in positive voltage in the plate circuit of the pentode amplifier PA' will react back on the screen grid SC_2 of the pentode amplifier PA to increase the positive potential on said screen, thereby increasing the gain of the pentode amplifier PA . Furthermore, this reduces the positive potential at the point c of the output circuit of the pentode amplifier PA so that it in turn reacts back on the screen SC_2' of the pentode amplifier PA' to decrease the positive potential applied to said screen SC_2' . This further reduces the gain through the pentode amplifier PA' . The result is that the transmission in the receiving circuit connected to the antenna A' is reduced to the point where it is relatively ineffective, while the amplifier connected in the circuit to the antenna A has its gain increased. Thus the harmonics produced by the limiter VL effectively increase the output of the signal path SP and reduce or render ineffective the output from the path SP' .

If, on the other hand, the signals received from the antenna A' are large enough so that the effect of the limiter VL' is to produce harmonics in its output path O' , the rectified potential across the terminals of the rectifier R' will in a similar manner decrease the amplification of the pentode amplifier PA and increase the amplification of the pentode amplifier PA' . Therefore, the receiver connected to the antenna A' will be effective to transmit to the outgoing line L .

If it should happen that the signals received on both antennae A and A' were exactly equal, then at that time both receivers will contribute equally to the outgoing circuit L . However, since the balance in such a case is unstable, a slight preponderance of the one received signal over the other will result in the larger of the two signals taking control until the gain of the pentode amplifier, through which the stronger signal normally passes, is increased to the point where it has the effect of substantially disabling the other pentode amplifier.

In general, the receiver which takes control will only be strong enough to produce harmonics in the output of its limiter when the received signal is considerably greater than the noise normally appearing in the path. The noise is usually made up of tube noise and resistance noise generated within the receiver itself and is, therefore, fairly constant. Consequently, when the signal in one path is strong enough to produce limiting and take control, the signal-to-noise ratio in

that path will be good. Of course, if the signals received in both paths are so poor that no limiting takes place in either the limiter VL or the limiter VL' , the output from both paths will be effectively transmitted to the line L . Under these circumstances the signal received by the line L will, of course, be poor, but this is because neither receiver is receiving a signal of sufficient volume to be effective. With a system involving only two receivers such a condition may occasionally arise, but fortunately will seldom occur.

A modified arrangement is shown in Fig. 2. In this figure all of the elements are substantially the same as in Fig. 1 and are connected in a similar manner, except that instead of pentode amplifiers PA and PA' being employed, triode amplifiers TA and TA' of the type in which the cathode is indirectly heated are employed. Also the connections from the output of the rectifiers R and R' are reversed with respect to the connections in Fig. 1. For example, the positive side of the rectifier R is connected to the upper terminal a of the resistance r in the C-battery supply circuit from battery B_3 to the grid G of the triode amplifier TA . The negative side of the rectifier R is similarly connected to the terminal b of said resistance r . So also, the positive connection from the rectifier R' is made to the upper terminal a' of the resistance r' in the biasing circuit of the triode amplifier TA' , while the negative side of the rectifier R' is connected to the terminal b' of said resistance r' .

The operation of the arrangement of Fig. 2 is somewhat as follows: Normally both triode amplifiers TA and TA' are adjusted to the cut-off point by the bias voltages supplied from the batteries B_3 and B_3' through the resistances r and r' , respectively. In other words, both amplifiers are normally adjusted to non-amplifying condition. When the signals connected to the antenna A are strong enough to be limited by the limiter VL so that harmonics are produced in the output circuit thereof, the harmonics are rectified by the rectifier R to produce a voltage which is applied across the terminals of the resistance r in such a direction as to render the triode amplifier TA effective to amplify the received signal. In other words, the rectified voltage in the path associated with the antenna A is applied in such a way as to reduce the normal biasing voltage upon the grid G of the amplifier, thus permitting the amplifier to amplify signals. The amplifier TA' in the other path, however, will still remain in its normally disabled condition.

Similar action takes place in the lower receiver connected to the antenna A' when the signal received in said branch is of sufficient amplitude to produce a limiting effect by means of the limiter VL' . The resultant rectified harmonics act to cause the triode amplifier TA' to amplify while the other triode amplifier TA remains in its normally disabled condition.

If the signals are strong enough in both receiving branches, both will contribute substantially equally in the combined output circuit L . However, if the signal in one receiver decreases below a threshold value, the biasing current on the grid of the corresponding triode amplifier will be increased to the point where that amplifier becomes disabled. Thus the corresponding receiving path is cut off completely, leaving only the alternate receiving path to pass signals to the output circuit L .

Fig. 3 shows how the harmonics from a limiting device may be applied to control the gain of a

preceding stage in a frequency modulation radio receiver to insure proper limiting at all times.

As is well known, in frequency modulation the carrier is modulated by changing its frequency rather than its amplitude in response to the controlling signal. Consequently, the carrier is sent out from the transmitting station at a constant amplitude but at a varying frequency. Due to variable conditions in the transmission path to the receiver the amplitude of the carrier, as it is received, may vary from time to time. It is therefore customary to arrange a limiter in a frequency modulation receiving circuit to keep the received amplitude from exceeding a predetermined maximum value, and to eliminate amplitude modulation from the frequency modulated signals which may have been introduced by noise or by attenuation changes in the transmission path. A receiving arrangement of this type is shown in Fig. 3, and is similar to that disclosed and described in the U. S. patent to C. S. Demarest, No. 2,047,312, issued July 14, 1936, the energy limiting device being shown at L in said Demarest patent. The receiving arrangement shown in Fig. 3 differs from that disclosed in the Demarest patent in two important particulars: (1) the received frequency is stepped down to an intermediate frequency before being detected, and (2) the intermediate frequency is applied to a volume limiter (VL in Fig. 3) to produce harmonics which are rectified to control the gain of an amplifier. Such harmonics may be used to maintain the received carrier at a substantially constant level in its intermediate frequency stage, regardless of variations in the transmitting path from transmitting station to receiving station.

Referring to the apparatus of Fig. 3 in more detail, the receiving antenna A has associated therewith a high frequency receiving arrangement HFR. This functions to receive the high frequency, amplify it if desired, and then convert it by stepping it down to an intermediate frequency. At the intermediate frequency the received energy is passed through the transformer T_1 to the input circuit of the intermediate frequency amplifier IFA. This amplifier may be of the triode type having an indirectly heated cathode C, an anode A, and a controlling grid G. The output or plate circuit of the amplifier IFA is connected through a transformer T_2 to the input I of a volume limiter VL which may be similar to the volume limiters previously described in connection with Figs. 1 and 2. However, it will be understood that any known type of volume limiter may be utilized in the circuits of Figs. 1, 2 and 3.

The output circuit O of the volume limiter is connected through a low-pass filter LPF to the other elements of the frequency modulation receiving circuit which will be described later. The output O of the limiter VL is also connected through a high-pass filter HPF to a receiver R similar to the rectifier R of Figs. 1 and 2 already described. The positive and negative terminals of the rectifier R are connected over the circuit CC to the terminals b and a of resistance r in the C-battery supply circuit for the grid G of the intermediate frequency amplifier IFA, as shown. Harmonics, if any, appearing in the output circuit of the limiter VL will thus be passed through the high-pass filter HPF and rectified by the rectifier R to control the gain of the amplifier IFA, as will be described later.

The other elements of the receiver connected to the output of the low-pass filter LPF comprise

a translator or discriminator circuit TR of known type functioning as described in the Demarest patent already referred to. A detector D of known type and, if desired, a low frequency amplifier LFA are employed, the output of the latter being connected to the line L. The translator TR is a device so designed that when a constant amplitude wave of variable frequency is applied thereto its response will vary with frequency in such a way as to produce an output wave changing in amplitude in accordance with the shifting frequency of the applied wave. Thus the frequency modulated wave is in its intermediate frequency stage converted by the translator TR into an intermediate frequency wave varying in amplitude in accordance with the modulating signal applied to the distant transmitter. This modulated signal is then detected by the detector D, amplified by the amplifier LFA and applied to the outgoing line L.

The gain of the intermediate frequency amplifier IFA is controlled by a normal C voltage applied from the battery B_3 through the resistance r. When no limiting effect results from the operation of the limiter VL no harmonics will appear in the output circuit O and the amplification of the amplifier IFA will have the maximum value determined by the biasing voltage due to the battery B_3 . However, if the amplitude of the signal received by the antenna A exceeds a limiting value, the received wave in its intermediate frequency stage is applied by the amplifier IFA to the limiter VL which cuts down the amplitude of the received wave to a predetermined maximum. This limiter also produces harmonics in the output circuit O which are passed through the filter HPF to the rectifier R. The harmonic waves are now rectified by the rectifier R and applied across the terminals of the resistance r through the circuit CC in such a manner as to increase the negative bias normally applied to the grid G. This reduces the amplification of the intermediate frequency amplifier and thus tends to keep the signal applied to the translator TR within a predetermined amplitude.

Since the control thus exercised is derived from the circuit at a point following the limiter VL, the gain control voltage of the intermediate frequency amplifier IFA will depend on the strength of the signal being limited. Consequently, the receiver gain should always be adjusted to a point high enough to properly operate the limiter at constant signal amplitude. If the signal exceeds this amount its effect will be to generate more harmonics and therefore reduce the gain of the intermediate frequency amplifier IFA. If, however, the received signal is insufficient to produce this optimum result the gain of the amplifier IFA will tend to increase to the point where the gain reduction caused by the harmonics in the output circuit will become effective.

It will, of course, be obvious that the principle of utilizing the harmonics appearing in the output circuit of the limiter to control a transmission element in a transmission circuit may be applied to various other types of circuits where gain control or other transmission control effects are desired.

It will also be obvious that while this invention has been disclosed in certain specific arrangements which are deemed desirable, the general principles herein set forth may be embodied in many other organizations, widely different from those illustrated, without departing from the

spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a signaling system, a transmission element associated with said system, a volume limiter in said system, and means controlled solely by harmonics produced by the limiting action of said volume limiter to control the effectiveness of said transmission element.

2. In a signaling system, a signaling path, a transmission element connected in said transmission path, a volume limiter in said path, and means controlled by harmonics produced by the limiting action of said volume limiter to control the effectiveness of said transmission element.

3. In a signaling system, a plurality of transmission paths, a transmission element in one of said paths, a volume limiter in another of said paths, and means controlled by harmonics produced by the limiting action of said volume limiter to control the effectiveness of said transmission element.

4. In a signaling system, an amplifier associated with said system, a volume limiter in said system, and means controlled solely by harmonics produced by the limiting action of said volume limiter to control the gain of said amplifier.

5. In a signaling system, a signaling path, an amplifier connected in said transmission path, a volume limiter in said path, and means controlled by harmonics produced by the limiting action of said volume limiter to control the gain of said amplifier.

6. In a signaling system, a plurality of transmission paths, an amplifier in one of said paths, a volume limiter in another of said paths, and means controlled solely by harmonics produced by the limiting action of said volume limiter to control the gain of said amplifier.

7. In a signaling system, a transmission element associated with said system, a volume limiter in said system, said volume limiter producing harmonics when an applied signal wave exceeds a predetermined amplitude, means to select and rectify the harmonics so produced, and means

responding to the rectified current to control said transmission element.

8. In a signaling system, a signaling path, a transmission element connected in said transmission path, a volume limiter in said path, said volume limiter producing harmonics when an applied signal wave exceeds a predetermined amplitude, means to select and rectify the harmonics so produced, and means responding to the rectified current to control said transmission element.

9. In a signaling system, a plurality of transmission paths, a transmission element in one of said paths, a volume limiter in another of said paths, said volume limiter producing harmonics when an applied signal wave exceeds a predetermined amplitude, means to select and rectify the harmonics so produced, and means responding solely to the rectified harmonics to control said transmission element.

10. In a signaling system, an amplifier associated with said system, a volume limiter in said system, said volume limiter producing harmonics when an applied signal wave exceeds a predetermined amplitude, means to select and rectify the harmonics so produced, and means responding to the rectified current to control the gain of said amplifier.

11. In a signaling system, a signaling path, an amplifier connected in said transmission path, a volume limiter in said path, said volume limiter producing harmonics when an applied signal wave exceeds a predetermined amplitude, means to select and rectify the harmonics so produced, and means responding to the rectified current to control the gain of said amplifier.

12. In a signaling system, a plurality of transmission paths, an amplifier in one of said paths, a volume limiter in another of said paths, said volume limiter producing harmonics when an applied signal wave exceeds a predetermined amplitude, means to select and rectify the harmonics so produced, and means responding solely to the rectified harmonics to control the gain of said amplifier.

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