Feb. 10, 1942. N. BISHOP 2,272,788

CARRIER OPERATED CONTROL SYSTEM FOR LIMITING AMPLIFIERS

Filed April 11, 1940 2 Sheets-Sheet 1

Fig. 1.

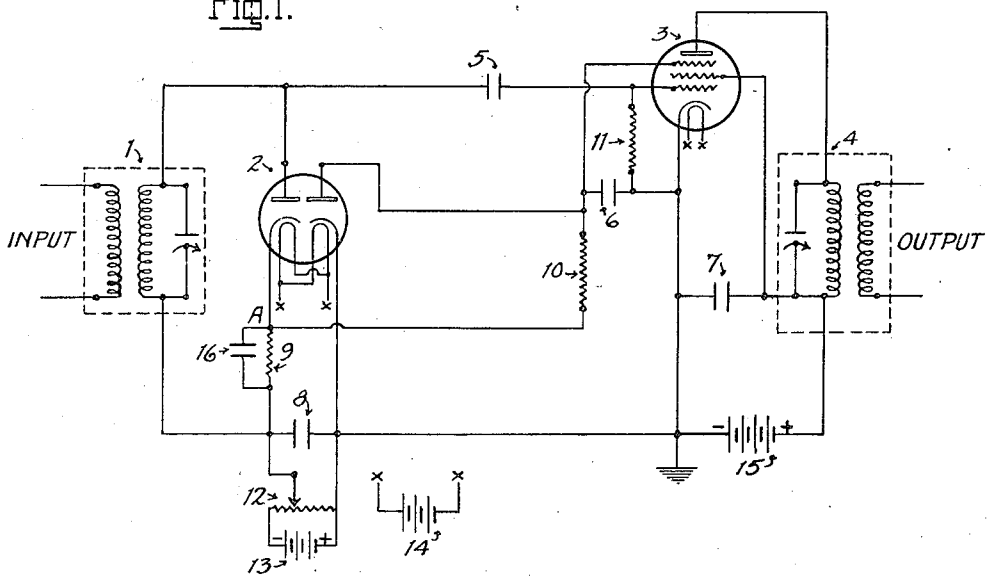


Fig. 2.

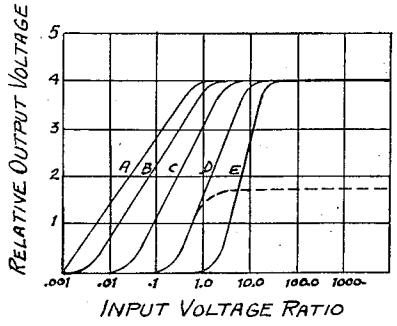


Fig. 3.

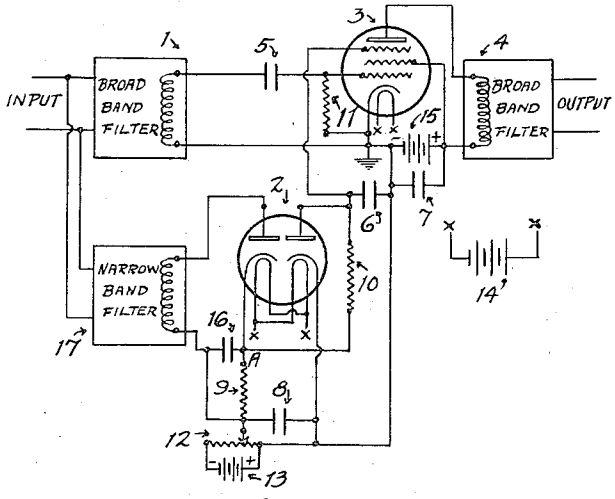
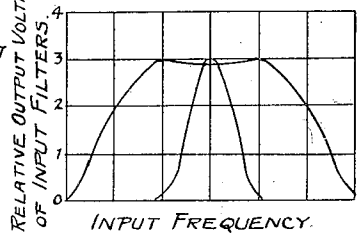


Fig. 4.



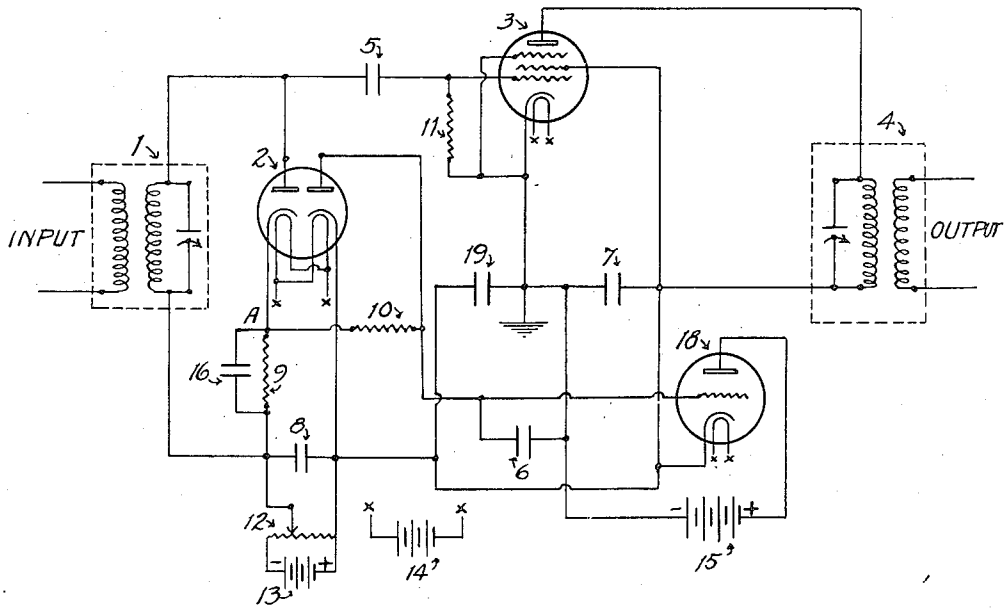
INVENTOR
NATHANIEL BISHOP.
BY
ATTORNEY

Feb. 10, 1942. N. BISHOP 2,272,788

CARRIER OPERATED CONTROL SYSTEM FOR LIMITING AMPLIFIERS

Filed April 11, 1940 2 Sheets-Sheet 2

Fig. 5.



INVENTOR
NATHANIEL BISHOP.
BY
Thurston Matthews
ATTORNEY

Patented Feb. 10, 1942

2,272,788

UNITED STATES PATENT OFFICE

2,272,788

CARRIER OPERATED CONTROL SYSTEM FOR LIMITING AMPLIFIERS

Nathaniel Bishop, Fairfield, Conn.

Application April 11, 1940, Serial No. 329,036

13 Claims. (Cl. 179—171)

The present invention relates to a carrier operated control system for limiting amplifiers, and particularly circuits for use therein which provide automatic control of the threshold of limiting of said amplifiers, and which automatically adjust the operating potentials of the limiting amplifiers so as to allow manual adjustment of the threshold of output, by means of potentials derived from the incoming carrier or signal voltage applied to the input of the amplifier. The term "threshold of limiting" as used in this specification refers to value of input applied to the limiting amplifier above which there is no increase in the output. The term "threshold of output" refers to the value of input below which there is no output from the amplifier.

The uses of limiting amplifiers are well known in the art of carrier communication, both in radio and "wire directed" or "wired wireless" systems. If such systems use amplitude modulation of the transmitted carrier, limiting amplifiers are often used in the receivers to prevent noise voltages from exceeding the peak signal voltage present in the receiver prior to final detection. If such systems use frequency (or phase) modulation of the transmitted carrier, limiting amplifiers are used to erase all possible traces of amplitude modulation from the incoming carrier in the receiver, and hence most of the noise, prior to detection. Limiting amplifiers as used in the above applications may take many forms, such as: amplifiers with manually adjustable operating potentials which will overload at some predetermined input level; amplifiers with negative feedbacks beyond a predetermined and manually adjustable value of input, as disclosed in my U. S. Patent No. 1,863,895; two amplifiers connected in parallel with the outputs connected 180° out of phase and one amplifier adjusted to have no output until a predetermined level is reached. Voltage regulation may be used in the input or output circuits of an amplifier and adjusted manually to have a delayed action so as to give the desired limiting effect. Many variations and combinations of the above schemes are known to the art. It should be noted that all limiting amplifiers heretofore known require manual adjustment, or a predetermined choice of the threshold of limiting, that is, the value of input beyond which there is no increase in output.

It will be seen from the above discussion of prior art that frequent reference is made to "manual adjustment." Certain highly desirable advantages in operation would be obtained by the elimination of the necessity of manual adjustment of limiting amplifiers, as regards the threshold of limiting, and it is, accordingly, an object of my invention to provide means for automatically adjusting the characteristics of a limiting amplifier, insofar as its threshold of limiting is concerned, in accordance with the level of the applied carrier. A further object is to provide a circuit for accomplishing this result, but which will at the same time prevent a very strong carrier from increasing the threshold of limiting beyond a predetermined and desired level.

A further object of my invention is to provide a means for automatically adjusting the operating voltage or voltages of a limiting amplifier so as to allow the manual adjustment of the threshold of output in a limiting amplifier, and thereby providing a circuit which may be adjusted to be silent, i. e., no output, in the absence of an incoming signal.

With the above and other objects in view, embodiments of the invention are shown in the accompanying drawings, and these embodiments will be hereinafter more fully described with reference thereto, and the invention will be finally pointed out in the claims.

In the drawings:

Fig. 1 shows a schematic circuit of a carrier controlled automatic threshold limiting amplifier, according to the invention, as applied to the intermediate frequency channel of a radio receiver designed for the reception of frequency modulated signals.

Fig. 2 is a graph showing a series of curves illustrating the characteristics of such an automatic threshold limiting amplifier for various settings of the initial adjustment provided.

Fig. 3 shows the special application of such a carrier controlled automatic threshold limiting amplifier to a system requiring the transmission of a broad band of frequencies.

Fig. 4 is a graph illustrating the necessity of a circuit such as that shown in Fig. 3 for this type of application.

Fig. 5 is a schematic circuit of a limiting amplifier system in which the threshold of limiting is controlled by a control of the plate and screen voltage of a pentode limiting amplifier tube by means of a series connected triode vacuum tube regulator whose control grid bias is controlled by voltages derived from the incoming signal.

Referring to Fig. 1, the circuit of a carrier controlled automatic threshold limiting amplifier,

according to the exemplary embodiment of the invention illustrated therein, comprises a tuned input transformer 1 designed to pass the desired range of frequencies, a double diode rectifier tube 2 having separate anodes, cathodes, and an indirect heater, or two separate diode rectifier tubes, a pentode amplifier tube 3 consisting of heater, cathode, control grid, screen grid, suppressor grid and anode preferably of the sharp cut-off type, a tuned output transformer 4 passing the desired range of frequencies, a grid blocking capacitor 5 for the amplifier tube 3, a suppressor grid by-pass capacitor 6, a plate and screen supply by-pass capacitor 7, a threshold bias supply by-pass capacitor 8, a diode rectifier load resistor 9, a suppressor grid filter resistor 10, an amplifier input grid resistor 11, an adjustable threshold bias voltage divider 12, a source of negative D. C. threshold bias 13, a source of heater voltage 14 for tubes 2 and 3 (A. C. or D. C.), a source of plate and screen potential 15 for tube 3, and a diode rectifier load by-pass capacitor 16.

The operation of this circuit is as follows:

The input voltage to this amplifier which may be a frequency modulated carrier, plus noise, is introduced onto the limiting amplifier control grid through the grid blocking capacitor 5 and by-pass capacitor 8. Assume for the moment that the slider of the bias voltage divider 12 is set to the right so as to give zero initial threshold voltage. The suppressor grid of tube 3 is then at cathode potential. As the level of input voltage is increased a rectified voltage will appear across resistor 9 and the point A will become positive with respect to the cathode of tube 3. This voltage will have practically no effect on the potential of the suppressor grid of tube 3 with respect to ground because of the connection of the extra diode rectifier plate shown at 2 to the suppressor grid, because the potential appearing at point A due to the rectified signal reaches the suppressor grid through resistor 10, and as soon as A becomes positive with respect to the cathode of tube 3 current will flow from the right hand plate of tube 2 to its cathode and hence to ground. Resistor 10 is made sufficiently high so that the current flowing through resistor 10 causes a large IR drop, thereby preventing the suppressor grid of tube 3 from assuming an appreciable positive potential.

Under these conditions therefore a characteristic of the limiting amplifier may be illustrated as curve A in Fig. 2. This curve shows that as the input voltage is increased the output of the amplifier increases up to the threshold of limiting, at which point the amplifier is overloaded. This point of overload is determined by a preliminary choice of plate and screen voltage applied to tube 3 by the source 15. So far it will be seen that the characteristics of this limiting amplifier are no different than the usual type of limiting amplifier well known to the art.

If now, however, an initial negative potential is applied to the suppressor grid of tube 3 by moving the slider of the bias voltage divider 12 to the left an entirely different type of action results. For the sake of illustration it is assumed that this initial bias is adjusted to a value which gives no output from the amplifier until the input voltage has been raised to an appreciable amount. The characteristic of the amplifier may now be described by curve D of Fig. 2. In this case no plate current will flow in tube 3 unless the suppressor grid voltage is made less negative with respect to the cathode of tube 3. This is accomplished by bucking out the initial threshold bias, as supplied by the source 13 and voltage divider 12, by the voltage across the diode load resistor 9 and capacitor 16 produced by rectification of the incoming signal by means of the left hand plate and cathode of the rectifier tube 2. As the input voltage increases the arithmetical sum of this voltage and the initial threshold bias will be such as to allow plate current to flow.

As the signal is still further increased the voltage across resistor 9 will exceed the initial threshold bias, and the suppressor grid would go positive were it not for the regulating action of resistor 10 and the right hand section of diode 2, which will draw current and hence limit the voltage at the suppressor grid to a positive value just above zero.

Curve D on Fig. 2 illustrates the way the output voltage varies if the input voltage is raised slowly. It will be noted from this curve that if the input signal is sufficient to drive the amplifier beyond the threshold of limiting, as illustrated by the upper knee of the curve, full limiting effect will be obtained, but at the same time the output of the amplifier will be zero when the input drops below the value indicated as .1 input voltage ratio on the curve.

Assume for the moment that the input signal is sufficient to make plate current flow in the output of the amplifier, and hence give an output voltage, but is insufficient to bring the suppressor grid voltage up to zero or slightly above. Under these conditions the limiting amplifier will operate on the carrier in a way indicated by the dotted curve. The fact that the suppressor grid voltage is still negative with respect to the cathode of tube 3 means that the threshold of limiting is actually moved down on curve D as far as rapid changes in the amplitude of the incoming carrier are concerned, due to the time constant of the suppressor grid filter resistor 10 and capacitor 6. Hence noise or any other type of amplitude modulation on the incoming carrier will be limited along an output line as indicated by the dotted curve.

Curves B, C and E show other modes of operation for other settings of the suppressor grid threshold bias control.

The advantages of this type of operation as compared to the more usual types of limiting amplifiers are obvious. In the first place when such a device is used on a frequency modulation receiver, which is to be used in broadcast reception, the receiver may be initially adjusted by means of the suppressor grid threshold bias control to be silent except when the desired signals of sufficient strength to give good quality are tuned in. At the same time if a weaker signal is tuned in, the receiver will automatically adjust itself to give the best limiter operation on such a signal, and hence provide the best possible signal to noise ratio. It will be noted that the upper limit of the threshold of limiting is definitely established by the fact that the suppressor grid of tube 3 is not allowed to go far enough positive on strong signals to increase the volume of a strong signal or a moderately strong signal, thereby retaining the automatic volume control features of the usual limiting amplifier.

Fig. 3 illustrates a more complex arrangement for the application of the principles described in Figs. 1 and 2 to a limiting amplifier used in a system which must pass a wide range of frequencies. Under such conditions it is desirable

to have the output threshold action take place at some desired portion of this wide band of frequencies. This may be accomplished as illustrated in Fig. 3 by inserting a narrow band filter 17 between the input of the amplifier and the control rectifier. The elements indicated in Fig. 3 are essentially the same as those illustrated in Fig. 1, with the exception of the filters.

Fig. 4 illustrates how a sharp filter on the input of the control rectifier may be adjusted to fall in the middle of the band pass of a much wider filter used in the signal channel. Under this condition of operation the threshold of output may be made to occur within a small percentage of the exact center of the band pass of the signal channel. Thus by proper design the receiver could be made to be silent except when it was exactly tuned.

It should not be construed that the limitation of the invention to the illustrated examples means that its application is limited. The principle of the invention contemplates the control of the threshold of limiting of a limiting amplifier and allows manual adjustment of the threshold of output by means of a voltage derived from the incoming carrier. Thus for example, a similar operation may be obtained by deriving the actual plate and screen voltage of the limiting amplifier from the output of a rectifier supplied by the incoming carrier. Another possible method is the control of operating potentials of a limiting amplifier by a control tube whose primary source of power is a fixed source in the receiver but whose output voltage is controlled by voltages deriving from the incoming carrier.

In Fig. 5 I have illustrated a limiting amplifier system with automatic control of the threshold of limiting and which allows manual adjustment of the threshold of output by means of control of the plate and screen potential applied to the limiting amplifier tube 3. Instead of deriving this potential directly by rectification of the incoming signal, control is provided by varying the internal resistance of triode amplifying tube 18 by applying the output of the control rectifier and the threshold bias between the control grid of this tube and its cathode which is isolated from ground as far as direct current is concerned by capacitor 19. By adjusting the threshold bias 12 to a sufficiently high negative potential, tube 18 will be cut off and no plate current will flow. The incoming signal will produce a positive voltage across resistor 9 which as in Fig. 4 bucks out the threshold bias and plate current will flow, and consequently plate and screen potential will be applied to tube 3. The right hand section of rectifier 2 again prevents the control grid voltage of triode 18 from going more than slightly positive. Hence the initial plate and screen supply 15 should be chosen to given the desired threshold of limiting under these conditions.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. In a limiting amplifier system comprising a pentode limiting amplifier, means for controlling the threshold of limiting and for allowing the manual adjustment of the threshold of output by control of the suppressor grid potential with voltages derived from an adjustable source of negative potential in series with a potential of opposite polarity derived from the incoming signal by means of a rectifier and load resistor connected across the secondary of the input transformer, and means for preventing the sum of these two voltages from exceeding a slight positive value, comprising a high resistance connected between the suppressor grid and said load resistor and a rectifier connected between the suppressor grid side of said suppressor grid filter resistor and the cathode whereby when the suppressor grid tends to go positive current will flow through the rectifier tube producing a large voltage drop across the filter resistor.

2. An electron discharge tube amplifying device arranged to amplify and limit a carrier current which is frequency modulated over a band of frequencies, said device having input and output circuits comprising band pass filters adapted to pass said band of frequencies, and means for controlling the transconductance of said discharge tube so as to limit the currents in the output circuit thereof to a desired maximum value, said means comprising a control rectifier and a narrow band filter connecting said control rectifier to said input circuit, said narrow band filter being arranged to pass only a narrow portion of said band of frequencies.

3. In a limiting amplifier system, means for controlling the threshold of limiting by means of voltages derived from the applied input voltage, so as to automatically adjust the operating characteristics of said limiting amplifier and to allow the manual adjustment of the threshold of output further characterized in that the limiting amplifier system comprises a pentode limiting amplifier, and means for obtaining automatic control of the threshold of limiting and for allowing manual adjustment of the threshold of output comprising a triode series regulator connected in series with both the plate and screen of the limiting amplifier, the internal resistance of which is controlled by voltages derived from the incoming signal.

4. In a limiting amplifier system, means for deriving direct current potentials for controlling the threshold of limiting and for allowing the manual adjustment of the threshold of output in said limiting amplifier system, comprising a rectifier and rectifier load coupled to the input circuit of said limiting amplifier further characterized in that the limiting amplifier system comprises a pentode limiting radio frequency amplifier, and means for obtaining automatic control of the threshold of limiting and for allowing manual adjustment of the threshold of output of said pentode amplifier comprising a triode series regulator connected in series with both the plate and screen of the limiting amplifier, the internal resistance of which is controlled by voltages derived from the incoming signal by means of said control rectifier.

5. In a limiting amplifier system, means for deriving direct current potentials for controlling the threshold of limiting and for allowing the manual adjustment of the threshold of output in said limiting amplifier system, comprising a rectifier and rectifier load coupled to the input circuit of said limiting amplifier further characterized in that the limiting amplifier system comprises a pentode limiting radio frequency amplifier, and means for obtaining automatic control of the threshold of limiting and for allowing manual adjustment of the threshold of output of said pentode amplifier comprising a triode series regulator connected in series with both the plate and screen of the limiting ampli-

fier, the internal resistance of which is controlled by voltages derived from the incoming signal by means of a control rectifier, and means for limiting the maximum control potential applied to said regulator tube control element.

6. A limiter for amplifying a wide band of radio frequency signal currents comprising, in combination, an electron discharge tube having an input circuit and an output circuit, means for applying the signal currents to said input circuit, adjustable control means arranged to prevent the passage in said output circuit of amplified signal currents for signal currents in said input circuit below a predetermined level, and control means for limiting the amplified radio frequency signal currents in the output circuit to a predetermined maximum value, said control means comprising a rectifier and a load impedance connected to said input circuit.

7. A limiter amplifier as set forth in claim 6 in which the discharge tube is provided with a control grid, and a direct current regulating circuit is connected to said control grid and one end of said load impedance, said circuit including a voltage regulator for limiting the voltage applied to the control grid to a predetermined maximum value corresponding to the maximum value of the amplified radio frequency signal currents.

8. A limiter amplifier as set forth in claim 6 in which the discharge tube is provided with a control grid, and the adjustable control means comprises an initial adjustable threshold bias and means for applying the sum of the rectified voltage developed in said load impedance and the initial threshold bias voltage to said control grid.

9. A limiter for amplifying to a desired maximum value radio frequency signal currents, comprising, in combination, an electron discharge tube having an input circuit and an output circuit, means for applying a band of frequency modulated carrier signal currents to said input circuit, automatic voltage control means connected to said input circuit for automatically controlling the threshold of limiting of the amplifier in accordance with the strength of the incoming carrier signal currents and a manual voltage control means for adjusting the threshold of output to prevent the passage of amplified signal currents in said output circuit in response to incoming signals below a predetermined level, the voltage generated by said automatic voltage control means for weak incoming carrier signal currents being less than that of said manual voltage control means.

10. A receiver for frequency modulated carrier waves, comprising a limiter having an input circuit and arranged to amplify a received wave, means for impressing a received wave comprising a wide band of radio frequencies on said input circuit, means including a source of potential for rendering said limiter substantially incapable of passing current, means responsive to the presence of a carrier wave of a given minimum intensity to neutralize the effect of said first mentioned means, and means for restricting the degree of such neutralization to a desired value so as to prevent interference with the normal function of the limiter.

11. A limiter for amplifying a band of radio frequency signal currents comprising, in combination, an electron discharge tube having an input circuit and an output circuit, means for applying the signal currents of different radio frequencies to said input circuit and a voltage control circuit connected to said input circuit and comprising a pair of diodes and a source of bias voltage, said voltage control circuit being arranged to automatically control the transconductance of the amplifying tube in such a manner that for incoming signal currents below a predetermined level substantially no amplified signal currents flow in the output circuit and as the incoming signal currents are increased above a predetermined level, the amplified radio frequency currents in the output circuit are limited to a predetermined maximum value.

12. In a receiver for receiving a frequency modulated carrier current, a limiter arranged to amplify and limit the received carrier current comprising a band of radio frequencies, said limiter including an electron discharge tube having a cathode, a signal grid, an anode and a control grid disposed between the signal grid and anode, an input circuit connecting said signal grid and cathode, an output circuit connected to said anode, means for applying a received carrier current to said input circuit, means for applying a bias voltage to said control grid of such value as to prevent the passage in said output circuit of amplified carrier currents for carrier currents in said input circuit below a predetermined level and control means arranged to regulate the potential of said control grid in such a manner as to limit the amplified carrier currents in the output circuit to a predetermined maximum value, said control means comprising a rectifier and a load impedance connected to said input circuit.

13. A limiter as set forth in claim 12 in which the control means for regulating the potential of the control grid comprises a filter circuit having one end connected to the control grid and its other end to a point on said load impedance, the time constant of said filter circuit being sufficiently large as to prevent a rapid change in the potential of the control grid in response to an abrupt change in the amplitude of a received carrier.

NATHANIEL BISHOP.