

Feb. 1, 1944.

J. A. RANKIN

2,340,429

AMPLITUDE MODULATION LIMITER CIRCUIT

Filed July 10, 1941

2 Sheets-Sheet 1

Fig. 1.

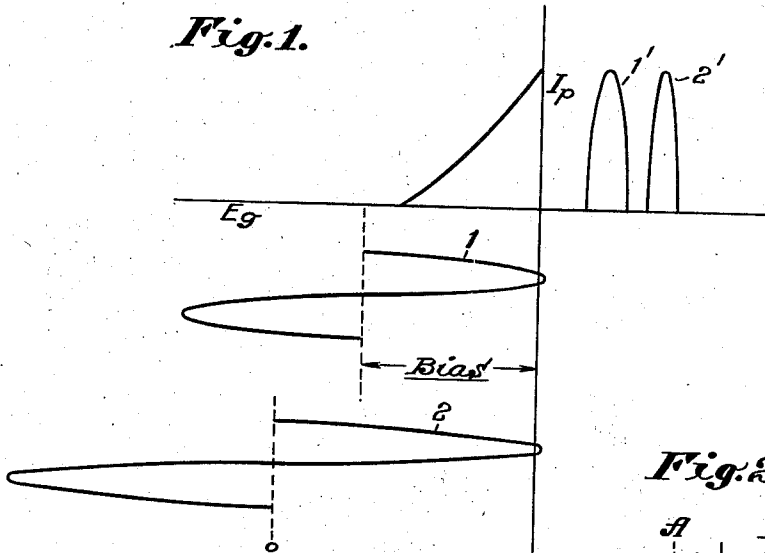


Fig. 2.

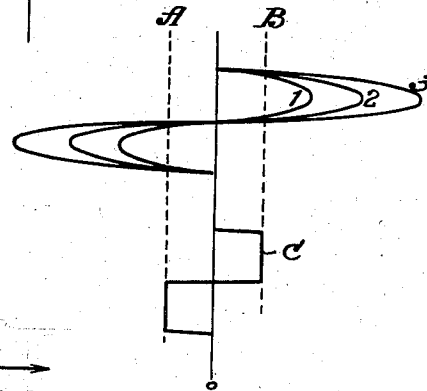


Fig. 3.

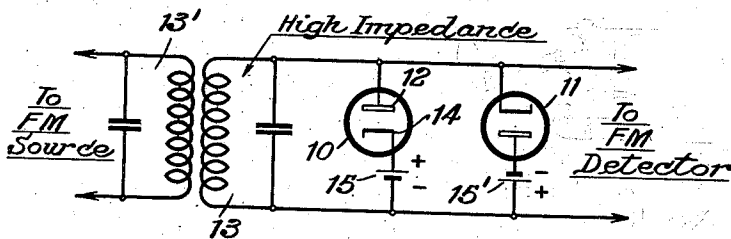
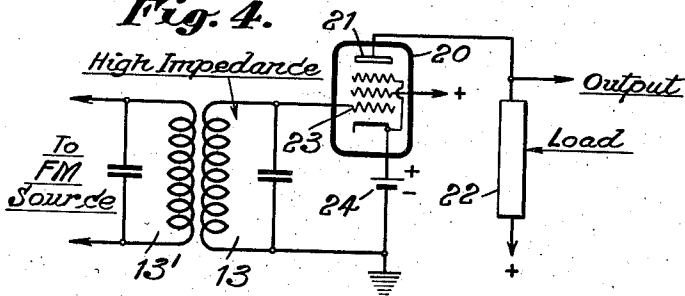


Fig. 4.



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2 Sheets-Sheet 2

Fig. 5.

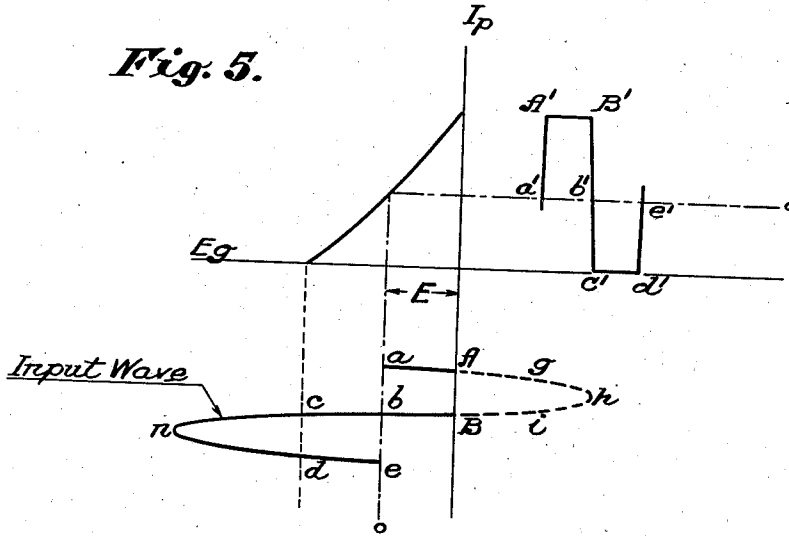


Fig. 6.

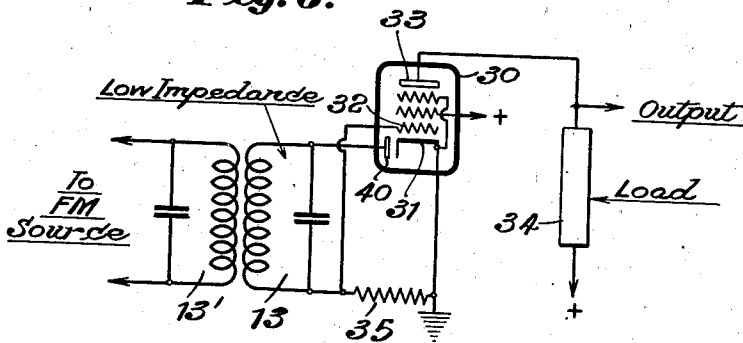
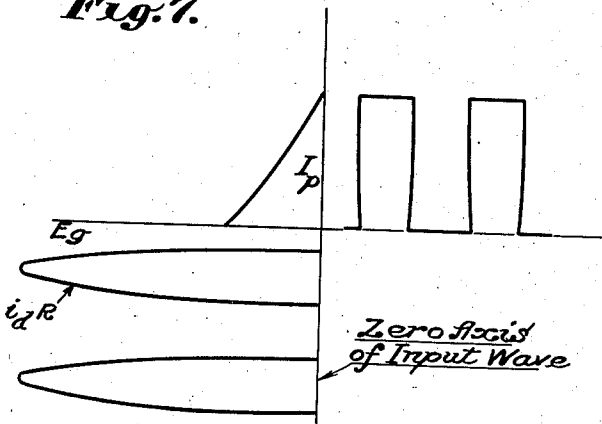


Fig. 7.



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AMPLITUDE MODULATION LIMITER
CIRCUITJohn A. Rankin, Port Washington, N. Y., assignor
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Application July 10, 1941, Serial No. 401,745

4 Claims. (Cl. 178-44)

My present invention relates to amplitude limiter networks, and more specifically to limiting circuits particularly adapted for eliminating amplitude modulation effects in angular velocity-modulated carrier waves.

As is well known to those skilled in the art, the usual form of amplitude modulation limiter circuit employed in receiving systems for angular velocity-modulated carrier waves, such as, for example, frequency modulated carrier waves (FM), depends at least in part upon the grid bias developed by the applied modulated carrier waves in the grid circuit of the limiter tube. In this type of limiter circuit there is utilized a resistance-capacity network in the grid circuit which functions to develop grid bias for the signal grid of the limiter tube, and the grid bias is directly dependent upon the amplitude of the applied modulated waves. In this form of limiter circuit there are two major disadvantages. In the first place, the bias for the grid is developed in an RC circuit that has a time constant. This means that the bias can change only as rapidly as the RC time constant permits it to change. Secondly, most limiter circuits operate on a portion of the input wave that is not symmetrical about the zero axis of that wave, and, hence, there is secured a constant output over only a small range of input signal amplitude.

It may, therefore, be stated that it is one of the main objects of my present invention to provide an amplitude modulation limiter circuit wherein the time constant network is eliminated, and operation occurs about the zero axis of the applied modulated carrier waves so that the range of input over which constant output obtains is unrestricted.

Another important object of the invention is to provide an amplitude modulation limiter circuit for frequency modulated waves wherein a pair of electronic rectifiers are employed in reversed relation and are biased in opposite senses, and both rectifiers having a common input circuit of relatively high impedance.

Another object of the invention is to provide a limiter stage having a high impedance input circuit wherein the limiter tube is of the multi-grid type, the grid circuit being free of any RC network, and operation being secured at the zero axis of the applied modulated waves.

Still another object of the invention is to provide a limiter stage having a low impedance input circuit wherein the limiter tube includes a rectifier device providing signal for the control grid of a separate electronic section.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 illustrates the characteristics of limiter circuits of the prior art,

Fig. 2 illustrates the ideal characteristic for a limiter,

Fig. 3 illustrates one embodiment of the invention,

Fig. 4 illustrates a modification,

Fig. 5 shows the characteristics of the limiter circuit in Fig. 4,

Fig. 6 illustrates another modification of the invention,

Fig. 7 depicts the characteristics of the arrangement in Fig. 6.

Referring to the accompanying drawings, wherein like reference characters in the different figures designate similar elements, there is shown in Fig. 1 in a purely qualitative manner the characteristics of the prior art circuit which has been referred to above. As pointed out previously, multi-grid tube limiter circuits of the type employing an RC time constant network in the control grid circuit permit grid bias to be developed in proportion to the amplitude of the applied modulated carrier waves. The RC network is either in the low potential side of the input circuit, or a condenser is inserted in series in the grid circuit and a grid leak resistor is connected directly from the control grid to ground. In either form of prior limiter circuit the operation is substantially similar. In Fig. 1 there is shown the signal grid voltage-plate current ($E_g - I_p$) characteristic of such prior limiter circuits. The curve 1 represents an assumed applied FM wave, whereas curve 2 denotes an applied FM wave of greater amplitude. It will be seen from the diagram in Fig. 1 that the limiter output is derived from a different portion of the input waves for each different amplitude of input.

The greater the input wave amplitude, the narrower will be the pulse of plate current produced; further, the bias voltage developed by the input voltage is proportional to the amplitude of the input waves. This is clearly shown, but in a somewhat exaggerated manner, in Fig. 1. The

pulse of plate current designated 1' corresponds to that produced by the applied input wave 1, whereas the pulse of plate current 2' results from the application of the input wave of a greater amplitude. The output pulse 2' is narrower than pulse 1' due to the fact that plate current flowed for a shorter time interval. If the input wave is modulated with sharp noise pulses, the grid bias must change at a rate more rapid than the noise pulse, otherwise the noise pulse will not be limited.

Referring, now, to the curve shown in Fig. 2, there is shown the difference in limiter action which is secured when the limiter operation takes place about the zero axis of the applied input waves. It is shown that the range of input over which constant output obtains is unrestricted above a low threshold value. The dotted vertical lines A and B represent the limiting, or clipping, level. A series of curves 1, 2 and 3 are shown, and these are to be understood as applied FM waves of gradually increasing amplitude. These applied waves are illustrated as swinging above and below the zero axis *o*. If, by some means to be described at a later point, the applied waves are symmetrically clipped at points A and B, then the fundamental components of the output wave would be very nearly the same for all values of amplitude of applied modulated carrier waves from curve A upwards. If greater amplitude of applied waves were used the fundamental component would likewise be the same. The curve C denotes the clipped wave which results from the limiting action, and it will be seen that this clipped wave is symmetrical about the original axis. It will also be observed that if greater amplitude of applied waves were used, no appreciable change in the wave form of curve C would be secured. Comparison between curve C and the plate current pulses 1' and 2' of Fig. 1 shows the desirable characteristic of the former.

In Fig. 3 is shown one embodiment of the invention with which may be secured the desirable characteristic shown in Fig. 2. The limiting stage comprises a pair of rectifiers 10 and 11. They are specifically shown, and merely by way of illustration, as diodes. Preferably, they should be similar diodes, as those of a 6H6 type tube. The plate 12 of diode 10 is connected to one side of the resonant input circuit 13, while the cathode 14 is connected to the opposite side of the input circuit through a negative biasing voltage source 15. The opposite diode 11 is connected in reverse manner to input circuit 13, and the biasing source 15' biases the cathode of diode 11 negatively with respect to the anode thereof just as in the case of diode 10. The input circuit 13 is of relatively high impedance. Assuming that the limiter is used in an FM receiver adapted to receive signals in the presently assigned 42 to 50 megacycle (mc.) band, it is well known that the superheterodyne type of receiver is employed for such purposes.

In that case the circuit 13 would be arranged to follow the intermediate frequency (I. F.) amplifiers of the receiving system. Briefly, for such receivers are well known in the art, the networks preceding circuit 13 would comprise a signal collector feeding a converter stage which would be followed by one or more I. F. amplifiers. The I. F. value usually employed is of the order of 4.3 mc. Further, since the FM channel width which is assigned is of the order of 150 kilocycles (kc.), then it will be understood that the net-

work 13' and 13 would have a pass band at least 150 kc. in width. The circuit 13' could be, for example, in the plate circuit of the last I. F. amplifier.

Since the FM detector following the limiter stage functions to produce the modulation voltage which was applied to the carrier at the transmitter, it is essential that the FM detector have no amplitude modulation effects on the carrier at the detector input circuit. Hence, the output of the limiter stage in Fig. 3 is to be understood as feeding a FM detector circuit of any well known form, and since the limiting characteristic is that shown in Fig. 2, it will be seen that the applied waves at the FM detector input circuit will be free of any amplitude modulation effects. Therefore, the output of the detector will depend solely upon the frequency deviation of the carrier, or center, frequency of the applied FM waves.

The circuit shown in Fig. 3 functions to produce the clipped wave form C of Fig. 2 for the following reasons. As the applied input waves increase from zero in a positive direction, no current flows in either diode until the peak amplitude of the applied waves exceeds *E* volts, *E* representing the bias voltage applied from either of the sources 15 and 15'. For values of applied waves exceeding *E* volts, the diode 10 that draws current acts as a short circuit, that is to say a low impedance, compared to the relatively high impedance of the input circuit 13. Hence, all of the voltage is dissipated in the input circuit 13. On the negative half of the cycle the other diode 11 acts in the same manner so that the output wave has the shape C shown in Fig. 2. It will be seen, therefore, that the arrangement of Fig. 3 functions to provide the ideal symmetrical limiting characteristic by virtue of the application of the FM waves to a high impedance input circuit which has operatively associated therewith a pair of devices of uni-directional conductivity, the devices being inversely connected with respect to the high impedance input circuit, and the devices being similarly biased with the result that for applied waves which exceed a predetermined amplitude the devices function alternately as low impedance shunts across the high impedance input circuit.

In Fig. 4 there is shown a modification of the arrangement of Fig. 3 wherein the limiter tube is a multi-grid tube 20 whose plate 21 is connected through the load element 22 to the positive terminal of the direct current energizing source. The limiting output voltage developed across load 22 is applied to the utilization output circuit, which may be the FM detector input circuit. The cathode of the limiter tube 20 is connected to the signal grid 23 through a negative biasing source 24. The grid 23 and negative terminal biasing source 24 are connected to opposite sides of the high impedance input circuit 13. The limiter tube 20 may be of the pentode type.

The operating characteristics of the circuit of Fig. 4 are shown in Fig. 5. Considering the operation of this form of invention, it will be understood that the grid 23 functions to replace one of the diodes in the circuit shown in Fig. 3, and the second diode is omitted. As the applied FM waves swing positive the grid 23 starts drawing current. When the amplitude of the applied waves exceeds *E* volts, the voltage in excess of *E* volts is dissipated in the high impedance input circuit 13 as explained previously. Hence, the

biasing source 24 applies a normal negative bias of E volts to the grid 23. On the negative half of the cycle the waves are clipped by plate current cut-off. Considering Fig. 5, it will be seen that the applied waves are shown with respect to the zero axis of the E_g-I_p characteristic. The zero axis o is symmetrical relative to that curve. The resulting output curve is illustrated in the upper right hand portion of Fig. 5. It will be noted that the clipped wave is symmetrical relative to the horizontal zero axis.

If one starts at point a, the value of the signal input is zero at this point. The plate current that flows is determined by the bias E. As the input wave increases in the positive direction to point A, so does the plate current as shown. As the input continues to increase in a positive direction, the grid starts conducting (at A) and hence shorts out the input circuit, and the plate current does not increase further. The dotted wave shape g, h and i indicates what would happen if the input circuit were of low impedance. With a high impedance input circuit the input wave voltage between A and B is dissipated in the input circuit.

From point B the value of the input wave decreases to b which is zero, and then increases in a negative direction to point c. The plate current has followed this change as indicated. However, at point c the plate current has decreased to zero value so that it can decrease no more. The input wave goes on increasing negatively, until it reaches its maximum negative point n, at which point it decreases in amplitude to point d where plate current again starts to flow. Between A and B the grid is drawing current, and provides limiting, and between c and d the limiting is done by plate current cut-off.

Referring to the arrangement shown in Fig. 6, the input circuit 13 is of a low impedance in contradistinction to the input circuits of the first two embodiments. Those skilled in the art are fully aware of the manner of choosing the constants of circuit 13 of Fig. 6 so as to impart a low impedance thereto relative to the impedances of circuits 13 of each of Figs. 3 and 4. The limiter tube 30 has two independent electronic sections, one of these includes a cathode 31, a control grid 32 and a plate 33. The plate is connected through load element 30 to the positive terminal of the direct current source. The cathode is connected to ground, and a resistor 35 is connected between the low potential side of input circuit 13 and the grounded cathode. The diode section of the tube comprises a portion of cathode 31 and an auxiliary diode anode 40, the anode 40 being connected to the high potential side of input circuit 13. The control grid 32 is directly connected to the anode end of resistor 35. During the negative half of the input cycle no current flows through diode 40-31.

In Fig. 7 there is shown the characteristic of the limiter stage of Fig. 6. Considering the operation of the arrangement of Fig. 6, the diode 40-31 draws current only through the positive half of the applied FM waves. This produces a voltage drop across resistor 35 that has the form of half sine waves which are applied to the grid 32. The device 40-31 is not a detector, but is merely a uni-lateral control device which has a series load impedance 35. Across the latter appears half-wave pulses of voltage of the carrier frequency. The horizontal wave forms designated i_R designate the voltage pulses applied to grid 32 and developed across resistor 35. If the

applied FM waves increase in amplitude the fundamental component in the output is not materially changed.

The output wave shown in Fig. 7 is not symmetrical about the original zero axis of the wave, but the original zero axis is one extremity of the output wave. The output wave, nevertheless, is taken from the center portion of the input wave, and the fundamental component in the output wave will not change materially as the amplitude of the input wave is increased after the threshold value of input amplitude has been reached. The diode 40-31 draws current during the positive half of the input cycles. The current flows through load 35, and hence a half sine wave voltage appears across 35 and is applied to grid 32.

Preferably, in the circuits of both Figs. 4 and 6 the screen voltage should be fed from a constant voltage source, or from a stiff supply. In this way the cut-off of the tube will not change with input signal amplitude. A triode section could be used instead of the pentode section in the tube of Fig. 6.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In a limiter stage for frequency modulated carrier waves, an electron discharge tube including at least a diode section and an independent electronic section having at least a cathode, a control grid and plate, a load element connected to said plate, said load element being connected solely in the space current path of said independent electronic section and developing thereacross frequency modulated carrier voltage substantially free of amplitude variation, a wave input circuit of substantially low impedance connected between the diode electrodes and including a resistor across which is developed voltage of solely carrier frequency for said grid during positive half cycles of the waves at said input circuit, and means connecting said grid to a point on said resistor which assumes an increasing negative potential with increasing amplitude of applied waves.

2. In a limiter stage for frequency modulated carrier waves, an electron discharge tube including at least a diode section and an electronic section having at least a cathode, a control grid, positive screen and plate, a load element connected to said plate, said load element being arranged in the space current path of the electronic section and developing thereacross limited frequency modulated carrier wave voltage, a wave input circuit of substantially low impedance connected between the diode electrodes and including a resistor across which is developed carrier frequency voltage in the form of half sine waves for said grid, means to apply frequency modulated carrier waves to the input circuit, and means connecting said grid to a point on said resistor which assumes an increasing negative potential with increasing amplitude of applied waves.

3. In an amplitude limiter stage for frequency modulated carrier waves, an electron discharge tube including at least a diode section and an independent electronic section having at least

a cathode, a control grid and plate, a load element arranged in the space current path of the electronic section and connected to said plate, a wave input circuit of substantially low impedance connected between the diode electrodes, a resistor in series with the input circuit across which is developed voltage of solely carrier frequency for said grid during positive half cycles of the waves at said input circuit, said resistor being connected solely in the space current path of said diode section, and means connecting said grid to a point on said resistor which assumes an increasing negative potential with increasing amplitude of applied modulated carrier waves.

4. In a limiter stage for frequency modulated carrier waves, an electron discharge tube including at least a diode section and an electronic section having at least a cathode, a control grid,

screen and plate, a load element connected to said plate, said load element being arranged solely in the space current path of said electronic section and developing thereacross amplitude-limited modulated carrier wave voltage, a wave input circuit of substantially low impedance connected between the diode electrodes and including a series resistor across which is developed carrier frequency voltage in the form of half sine waves for said grid, means for maintaining the screen at an invariable positive potential, means to apply frequency modulated carrier waves to the input circuit, and means connecting said grid to a point on said resistor which assumes an increasing negative potential with increasing amplitude of applied waves.

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