Aug. 13, 1946. E. R. PFAFF 2,405,845

COMBINED LIMITER AND SQUELCH CIRCUIT

Filed Feb. 20, 1942

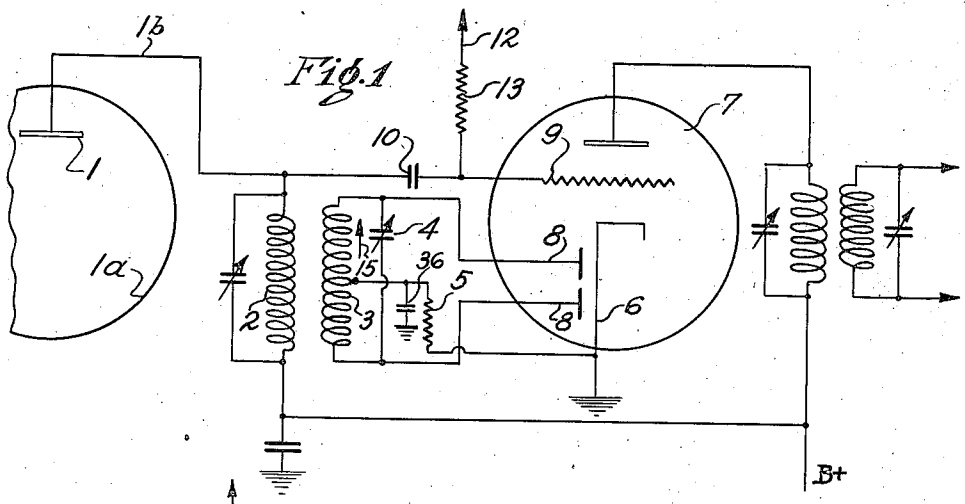


Fig. 1

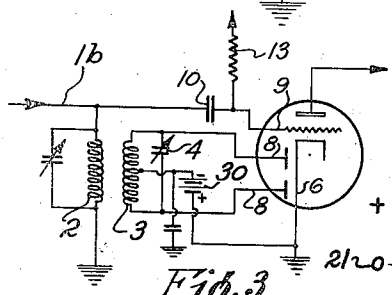


Fig. 3

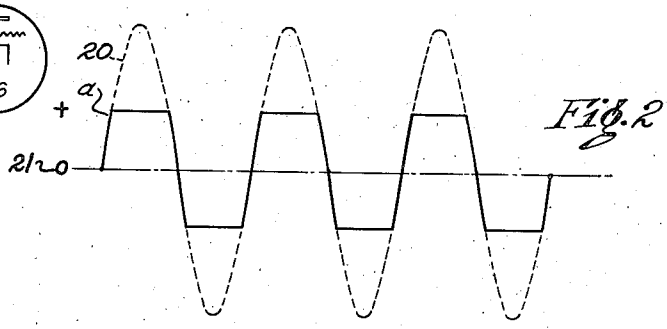


Fig. 2

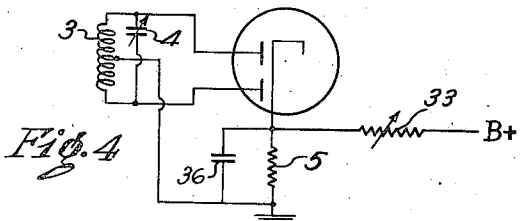


Fig. 4

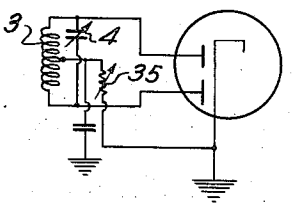


Fig. 5

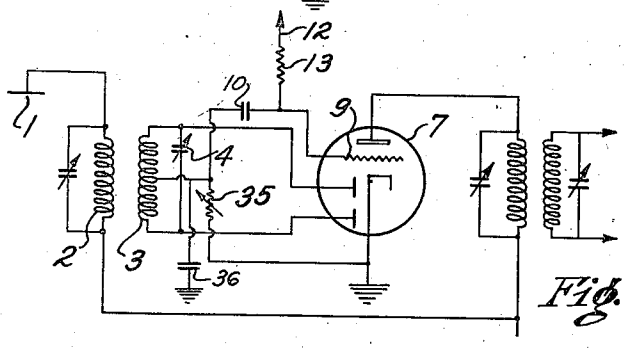


Fig. 6

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COMBINED LIMITER AND SQUELCH CIRCUIT

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6 Claims. (Cl. 178—44)

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This invention relates to improvements in radio receiving circuits and more particularly to an improved amplitude limiter and so-called "squelch" circuit particularly useful in receivers for frequency modulated signals.

As is well known to those versed in the art, frequency modulation receivers include among their various components one component of the circuit that is known as the limiter circuit, which circuit acts to remove amplitude modulations from the signal. In some instances the limiting action was accomplished by causing the signal to utilize the complete characteristic curve of a vacuum tube device. That is, a vacuum tube cuts off signals at saturation for one-half of a cycle and by negative grid bias cuts off signals on the other half of the cycle.

These circuits are not as effective as could be desired because the tube characteristic curve is unsymmetrical. Furthermore these types of limiters are also undesirable because it is necessary to get grid saturation on one side of the curve and plate saturation on the other side, which is merely overloading the tube. Thus it is necessary to have a signal of a certain amplitude which is strong enough to operate the device, with the result that under conditions of "weak signals" there is no limiting action and static is brought in; this is particularly noticeable when tuning between stations. On weak signals or no signal there is obviously no limiting action.

By my present invention I have provided a limiter which does not rely on the saturation or grid bias cut-off of a tube to obtain limiter action. The circuit of my invention operates to eliminate noise or static during both weak and no signal periods and also provides a new improved type of limiting action without overloading the tube and which action is effective to provide a symmetrical output.

It is, therefore, an object of my invention to provide a new type of limiter circuit for frequency modulation reception.

Another object of my invention is to provide a limiter circuit wherein the limiting action is a function of the signal strength and wherein the amount of the signal removed from the wave is proportional to the signal being received.

Another object of the invention is to provide a limiter action which is not effected by overloading a tube.

Another object of the invention is to provide a limiter circuit for frequency modulation receivers that has a symmetrical characteristic for both halves of the signal wave.

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Another object of the invention is to provide a combined limiting and squelch circuit.

Another object of the invention is the provision of a limiter which operates on weak as well as strong signals.

Another object of my invention is to provide a limiter circuit wherein the limiting action can be adjusted manually to provide any desired cut-off or wherein the limiting action can be adjusted manually to automatically provide for any desired proportion of cut-off.

Still other objects of the invention and the invention itself will become more apparent from the following description of an embodiment thereof, which description is illustrated by the accompanying drawing and forms a part of this specification.

Fig. 1 is a circuit diagram of a portion of a receiver circuit showing my invention;

Fig. 2 is a view showing a signal wave before and after limiting action occurs;

Figs. 3 to 6 inclusive show circuit modifications of my invention.

Referring to the drawing, 1 represents the anode of any one of the preceding stages of a frequency modulated receiver. This may be a mixer stage, but for purposes of this application is considered as being one of the intermediate frequency stages. The output from the tube is fed to the tuned primary 2 of a transformer which is inductively coupled to a center tapped secondary 3. The plate 1, besides being connected to the primary 2 of the transformer, is also coupled through the coupling condenser 10 to the grid of the amplifier section of the tube 7. Although the coupling is shown as being to an amplifier, it might be to a second limiter. The secondary 3 of the intermediate frequency transformer is tuned by the adjustable capacity 4; and the center tap of the secondary is coupled through a resistor 5 to the cathode 6 of the vacuum tube 7 which may be a 6B8 and which is a double diode pentode. The ends of the secondary 3 are connected to the anodes 8 of this tube.

The output from the tube 7 may go to another transformer which may be the input to a discriminator circuit or another intermediate frequency circuit. Grid bias for the tube 7 is had by way of the line 12 through the resistor 13. The center tap to the secondary 3 may also be by-passed to ground by the condenser 36.

Although the tube 7 is shown as a double diode pentode, it will be obvious that separate tubes providing the function of an amplifier and a double diode could be used and in some instances

may be desired because of the higher gain that it is possible to obtain, this being due to the fact that in single purpose tubes a greater selection of tubes is available.

In order to better understand the invention, reference is had first to Fig. 3 for discussion of the operation. Fig. 3 also illustrates a condition where the variable bias furnished by the resistor 5 in Fig. 1 is substituted by a biasing battery 30. In other respects the two circuits are the same.

Signals are received and amplified in the radio frequency and mixer stages, not shown, and the output from the tube 1—A which may be an intermediate frequency stage, is connected by the conductor 1b to the input circuit of the transformer 2—3. The output connector 1b is also connected to the input of the amplifier section of the tube by the coupling condenser 10, the coupling being to the grid 9 of the tube, bias voltage being furnished through the resistor 13. The output of the tube 7 may be connected to a discriminator or other amplifier circuit, not shown.

The signals are transferred inductively from the primary 2 to the secondary 3. It will be noted that the bias battery 30 which connects the center tap of the transformer 3 maintains the two anodes 8 at a predetermined negative potential. It will be seen that as long as this potential is not exceeded by the signal induced in the secondary 3, no current will flow in the diode circuit. However, as soon as the voltage in the diode circuit exceeds the bias on the anodes as furnished by the battery, rectifying action takes place in the anode cathode circuit and current flows in the secondary. It is believed that this current flow constitutes a constructive short which because of the close coupling between the primary and secondary, also results in a short for the primary, diverting the signal from the amplifier section of the tube.

In this respect the results realized by the limiter of Fig. 3 are similar in nature to those realized by prior limiters which operate on the heel and shoulder of the characteristic curve, although the manner of obtaining the results, as has been explained, is quite different. In the device of Fig. 3 the limiting action will occur, while with the stronger signal the greater portion of the signal will be cut off.

This battery may be supplanted by a voltage from the regular power supply, and in this case the resistor 5 is placed in the cathode circuit, but the cathode ground is moved to enable a positive voltage to be applied to the cathode (see Fig. 4). This voltage is obtained from the B supply and may be fixed or manually variable by the resistor 33.

This allows the operator to vary the cut-off point and the limiting action with different signals, if desired. These circuits of Figs. 3 and 4 do not have the feature of squelch although it does limit the magnitude of static between stations.

The operation of the circuit of Fig. 1 is believed to be as follows: Signals are received and amplified in the radio frequency and mixer stages, not illustrated, and the output from the tube (1a), which may be an intermediate frequency stage, is fed to the transformer 2—3 and also fed to the grid 9 of the amplifier section of the tube 7 where they may be amplified and passed on to a discriminator or other amplifier circuit, not shown.

The operation of the double diode section of the tube 7 as a limiter and squelch unit is effected as follows: The signals are transferred inductively from the primary to the secondary. On the positive half of the cycle the current flow is in the direction of the arrow 15 which causes the upper plate 8 of the double diode to become positive. When this plate is positive, current flow is from the plate to the cathode 6 and by way of the resistor 5 to the center tap of the transformer. On the negative cycle, the current flow is in through the other half of the transformer secondary downward through the lower diode plate, back through the resistor 5 to the center tap.

The above described current flow through the resistor 5 causes a voltage to be built up across the resistor 5, with the higher potential at the cathode end and a negative potential at the anode end. This negative potential is thus applied to the anodes 8 of the tube, which being negative with respect to the cathode, hinders current flow. The value of the resistor 5 determines the output voltage of the limiter. That is, the higher the value of resistor 5, the greater the potential drop across the same. When the instantaneous radio frequency voltage in the circuit exceeds the rectified voltage across the resistor 5 and the negative potential on the anodes 8, the anodes are then driven more positive and a surge of current flows. This effectively short-circuits the transformer secondary for this excess impulse voltage. This shorting of the secondary is due to close coupling within the secondary itself. Furthermore, since the secondary is closely coupled to the primary, a short for the secondary operates as an effective short for the primary. In this manner the amplitude modulated peaks are limited to a certain predetermined value determined by the steady signal strength and the value of resistor 5. As soon as the impulse signal input becomes so great that on the positive half of the cycle the plate is driven more positive then rectification starts and the tube shorts the circuit for the peak of the cycle; thus the amplification of the amplifier section is also controlled, the balance being obtained due to the steady radio frequency signal causing a steady current.

When no radio frequency signal is present there is no voltage drop across the resistor 5 and therefore for sudden high amplitude noise impulses the diodes rectify the undesired impulse, and since diodes are then carrying current, they in effect short the secondary of the transformer and the primary and no signal gets through to the amplifier; thus the circuit operates as a squelch circuit between stations. This is believed to be due to the time constant of the circuit. That is, the impulse is over before the bias, caused by the voltage drop across the resistor 5, has a chance to change.

Fig. 2 is a composite view of a signal before and after limiting. In this case the signal represented by the wave form 20 varies positive and negative about the center point 21. Assuming that a fixed negative bias of 1 volt for the anodes is to be substituted for the resistor 5, of Fig. 1 by a battery 30, as in Fig. 3, then so long as the signal does not exceed 1 volt there is no rectification in the diode section since they are 1 volt negative. Thus the signal on the positive half of the wave starting from "0" raises to point "a," Fig. 2, and is normal. As soon as the signal potential exceeds 1 volt, then we have the plate being driven positive, rectification starts and continues so long as the plate is positive acting as a short circuit for the transformer and preventing the signal from getting through to the grid 9 of the amplifier. The entire upper portion of the wave exceeding 1 volt

is thus lopped off and our signal takes the form shown in the solid lines in Fig. 2.

In the case of Fig. 1 the value of the resistor 5 determines the voltage drop and hence determines the bias on the diode section; this voltage bias will vary according to signal strength, being a larger bias for a strong signal and smaller for weak signals. This voltage bias varies at a rate which is relatively slow compared to the amplitude modulation that we wish to cut off. The time constant of the circuit determines this rate. It will be seen, therefore, that the value of the resistor determines that proportion of the signal being removed. That is, one-third may be removed, or one-sixth or any desired amount, depending upon the value of the resistor 5. Furthermore, when the signal is of varying strength, the proportion removed is the same. That is, when a signal having a value of two volts is being received, and the cut-off may occur at 1 volt, then with a signal of 1 volt the cut-off would occur at one-half volt, assuming that the resistor was selected with a view to removing half of the signal.

It will thus be seen that with signals of varying strength, the output will vary in strength, although the limiting action will still be proportioned to the signal. This might be considered to be a disadvantage except for the fact that frequency modulation reception at the present time is limited to high frequencies, and the transmitting distance is usually so small that no fading ordinarily occurs. It will be understood, however, that the automatic volume control could be used ahead of this circuit to keep the signal applied to the limiter circuit relatively constant if desired.

Fig. 5 is a modification of Fig. 1 where the bias resistor 5 is replaced by a variable resistance 35 which enables the operator to vary the limiting action and the output.

Fig. 6 is another modification of Fig. 1 which operates in the same manner as Fig. 1, the only difference being that in this case the signal is fed from the center tap of the transformer secondary to the amplifier. It will thus be seen that I have provided a limiter circuit which operates independent of the upper and lower limits of the characteristic curve of the tube providing limiting action regardless of signal strength, and that the amount of its limiting may be made variable. It will further appear that the limiting action in certain cases is a function of the strength of the signal and therefore proportional to the signal and that it is possible to vary the proportion.

Although I have shown the transformer as being a tuned transformer it is mainly with the idea of taking advantage of this tuning to provide an additional stage of intermediate frequency. It is within my concept to leave one coil of the transformer untuned and have it very closely coupled to the other whereby the tuning of one is reflected into the other.

Furthermore, although I have described the operation of the circuit according to the present known concepts, it was not with a view to limiting the invention and merely to a better understanding of its operation, and should it later be discovered that other principles enter into the function of the device, I do not desire to limit myself by the present description.

I am aware that numerous other and extensive departures may be made from those shown in the drawing, but without departing from the spirit or scope of the invention.

I claim:

1. In a voltage limiter for removing high amplitude portions from a frequency modulation signal wave, including a pair of amplifiers coupled to each other for amplifying said signal, a transformer having a primary and a center tapped secondary coil, a double diode rectifier tube, a biasing resistance and a capacity connected to said center tap and to the cathode of said rectifier, the anodes of said rectifier tubes being connected to the ends of said secondary, one of said amplifiers being coupled to said transformer and a source of signal coupled to the primary of said transformer, said resistance providing a negative bias for the anodes of the rectifier during steady or uniform portions of the signal wave to maintain the rectifier against rectification of such portions and said signal upon reaching a predetermined amplitude to overcome said bias and to cause rectification in said circuit to remove said high amplitude portions of said signals being transferred between said amplifiers.

2. In combination with a vacuum tube device adapted to operate as an amplifier, discriminator or the like, and having an input circuit coupled to the output circuit of a preceding vacuum tube, a voltage limiter for said input circuit comprising a transformer having a primary and a secondary tuned to resonance with a predetermined signal frequency, said primary being connected across said input circuit, vacuum tube means having anodes and at least one cathode with the anodes connected to the output of said secondary, said cathode being coupled to a center tap on said secondary by a resistance and a capacity of a value such that when current starts to flow in said secondary circuit, the voltage drop across the resistance provides a negative potential on said anodes and limits said rectification until peak voltages induced in the secondary exceed the bias provided by the resistance, said transformer and rectifier circuit providing a low impedance to bypass signals to the input of said amplifier or the like upon occurrence of rectification in said rectifier circuit to limit the input to said amplifier or the like.

3. In combination with a circuit for transferring signal voltages from a first portion of said circuit to a second portion of said circuit, a voltage limiter comprising a transformer having a tuned primary and a tuned center tapped secondary, said transformer being directly coupled to said first portion of said circuit, a double diode rectifier having a pair of anodes and a cathode, said anodes being connected to the output of the secondary and said cathode being connected through a resistance to said center tap, a condenser in parallel with said resistance, said resistance and condenser maintaining a negative bias on said diode plates proportionate to the amount of signal in said secondary, said secondary diode circuit adapted to divert signals from said main circuit when rectification occurs in said diode to remove peak or impulse voltages from said circuit exceeding a predetermined proportion of the amplitude of the signal.

4. A limiter circuit for frequency modulation receivers comprising a vacuum tube amplifier including among its elements an anode, a second vacuum tube having an amplifier section, and a duo-diode section with a common cathode for both sections, said amplifier section being capacitively coupled to said first mentioned anode, a transformer having a primary tuned to a signal of predetermined frequency and a divided sec-

ondary tuned to said frequency, said secondary being connected to the anodes of said duo-diode section of the second tube and said cathode being connected by a voltage dropping resistance and condenser to the intermediate portion of said secondary to provide a cathode return, said transformer primary being connected to receive signals from said first amplifier tube and cause said signals to be rectified in said duo-diode, said voltage dropping resistor and condenser adapted to maintain a negative bias on said duo-diode-anode in proportion to the signal input to said transformer and to limit current flow in said duo-diode section until the amplitude of the noise or interfering signal exceeds the negative bias on the anodes, and signals of predetermined amplitude to cause a current flow in said duo-diode transformer circuit, the coupling being sufficiently close between the windings of the transformer that current flow causes an effective short circuit across the output of said first amplifier tube to prevent signals exceeding a predetermined amplitude from reaching said amplifier section of said second tube.

5. A limiter circuit for frequency modulation receivers comprising a vacuum tube amplifier having an output anode, a second vacuum tube having an amplifier section and a duo-diode section with a common cathode for both sections, said amplifier section being capacitively coupled to said first mentioned tube for transferring a signal wave therebetween, means for preventing transfer of the high voltage portions of said wave comprising a transformer having a primary and a center tapped secondary tuned to a predetermined frequency, the output of said secondary being connected to the anodes of said duo-diode section of the second tube and said cathode being connected by a voltage dropping resistance and a condenser to the center tap of said secondary, said transformer primary being connected to receive signals from said first amplifier tube and cause said signals to be rectified in said duo-diode, said voltage dropping resistor and capacity adapted to maintain a negative bias on said duo-diode-anode in proportion to the signal input to said transformer and to limit current flow in said duo-diode section until the noise voltage amplitude of the signal momentarily exceeds the negative bias on the anodes, and adapted on higher voltage portions of the signal to rectify the signal and cause a current to flow in said secondary circuit, the coupling between the windings of the transformer being such that current flow causes said higher amplitude portions of said signals to be diverted from said amplifier section of said second tube, the time constant of the circuit being of such value to maintain the normal value of bias on the diodes for the duration of the noise pulse.

6. In a voltage limiter for limiting the amplitude portions of a frequency modulated radio frequency signal wave being transferred to an amplifier or the like, an amplifier for amplifying a signal including an amplifying tube, a transformer having a primary and a center tapped secondary coil, a pair of diode rectifiers, a resistance and a capacity connected between the center tap and the cathode of said rectifiers, said rectifiers having their anodes connected to the ends of said secondary, said amplifying tube having its input coupled to said transformer, said resistance and capacity providing a negative bias for the anodes of the rectifier to maintain the rectifier against rectification for a proportion of the signal into the circuit and said signal upon reaching a predetermined amplitude to overcome said bias and cause rectification in said circuit to remove said high amplitude portion of said signals from said amplifier.

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