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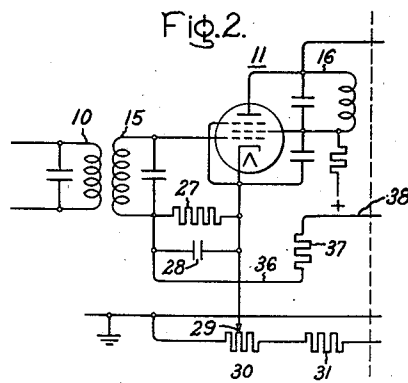
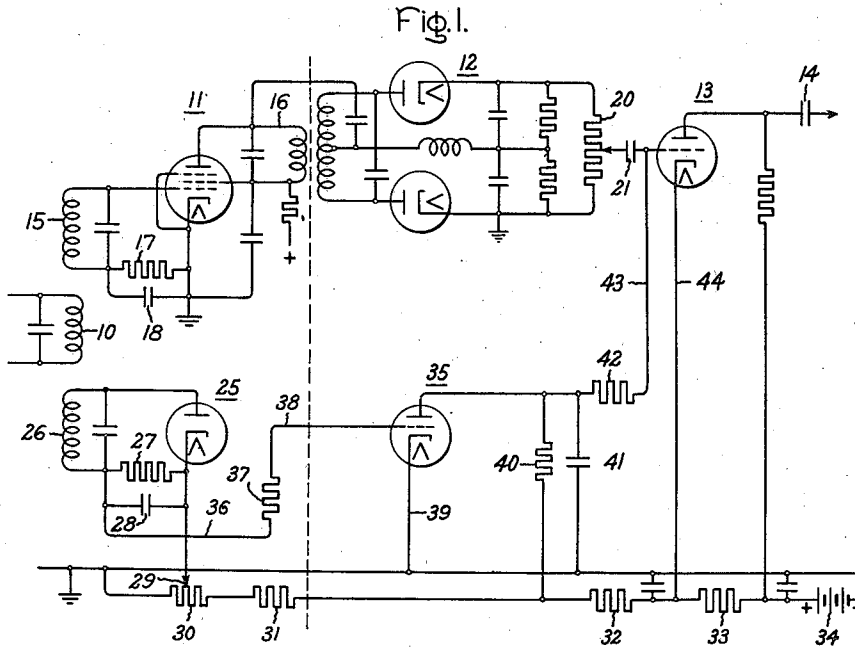
G. M. BROWN

2,261,643

NOISE SUPPRESSION CIRCUIT

Filed Oct. 23, 1940

2 Sheets-Sheet 1



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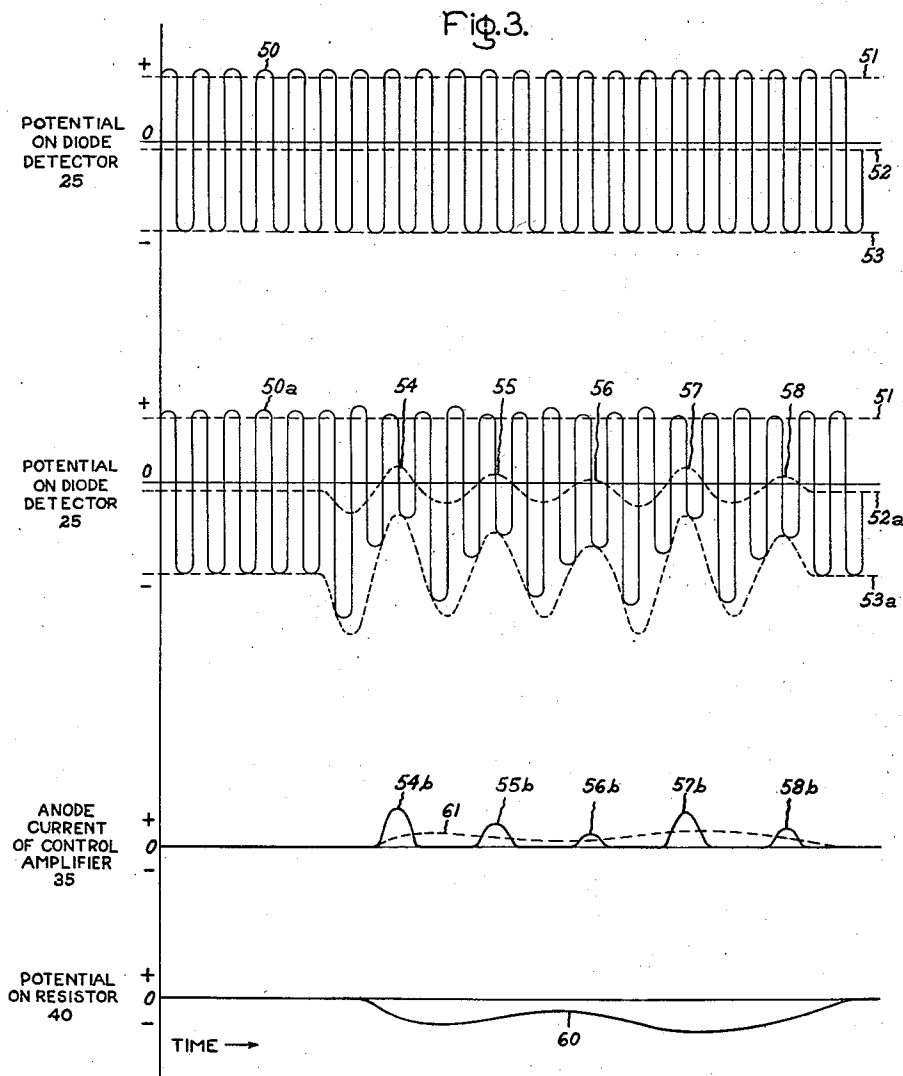
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UNITED STATES PATENT OFFICE

2,261,643

NOISE SUPPRESSION CIRCUIT

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11 Claims. (Cl. 250—20)

My invention relates to noise suppression circuits, and particularly to circuits for automatically rendering a radio receiving apparatus inoperative when no signals are being received or when the received signals are too weak for satisfactory reproduction.

Various forms of noise suppression circuits of this general type are well known to the art. Their action has been variously designated by such terms as interchannel noise suppression, background noise suppression and carrier-off noise suppression. Such circuits are particularly valuable in radio receiving apparatus provided with automatic volume control wherein maximum sensitivity is automatically secured in the absence of a received signal. Under such conditions noise, including various forms of interference, such as natural static, thermal agitation in the tubes, locally produced high frequency disturbances, etc., may cause very objectionable audible noises in the signal reproducer.

It is well known that a satisfactory signal may be derived from a received carrier which is phase or frequency modulated under much less favorable conditions than in the case of an amplitude modulated carrier. In other words, for a particular noise level a phase or frequency modulated carrier may be of lower intensity than the same carrier when amplitude modulated and still maintain a high signal to noise ratio at the receiver output. Furthermore, for reasons apparent to those skilled in the art, when a phase or frequency modulated carrier is also amplitude modulated in some manner, either by a signal or noise interference, the signal to noise ratio at the receiver output may be considerably decreased.

Accordingly, it is a main object of my invention to provide noise suppression circuits which are capable of distinguishing between a signal which is amplitude modulated and one which is unmodulated, or modulated only in phase or frequency.

Another object of my invention is to provide noise suppression circuits which function automatically to render a normally inoperative radio receiver operative above a predetermined threshold level in the presence of a carrier which is unmodulated, or modulated only in phase or frequency, and which automatically provide a higher threshold level in the presence of a carrier which is amplitude modulated.

It is more specifically an object of my invention to provide improved noise suppression circuits

which are particularly suitable for use with phase or frequency modulation apparatus.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, many best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 diagrammatically represents a portion of the circuits of a frequency modulation receiving apparatus embodying my invention; Fig. 2 represents a modification of those circuit elements of the apparatus of Fig. 1 which are shown to the left of the vertical dashed line; and Fig. 3 is a graphical representation of the forms of electrical waves developed at various points in the circuits of Figs. 1 and 2.

As shown in Fig. 1, high frequency carrier waves are supplied to the primary winding 10 of an input transformer. These waves may be supplied directly from a receiving antenna or a radio frequency amplifier. However, in the usual form of superheterodyne receiving apparatus they will be intermediate frequency carrier waves supplied from the final intermediate frequency amplifier.

The high frequency carrier waves are subjected to amplitude limitation in a limiter circuit 11. They are then demodulated in a detector, or discriminator, 12 and the demodulated signals, which are ordinarily audio frequency signals, are supplied to the low frequency signal amplifier 13. From the output of the amplifier 13 the signals are coupled in any suitable manner, as through a capacitor 14, to further stages of amplification or to a sound reproducer.

The limiter 11 is of well-known form and will not be described in detail. Briefly, however, it comprises a pentode amplifier having an input circuit 15 coupled to the primary 10 and an output circuit 16. Both circuits are tuned to the unmodulated carrier, or intermediate, frequency. The limiter is self-biased by means of a grid resistor 17 and grid capacitor 18. It is adjusted to produce anode current variations only between the limit at which the grid becomes so positive that grid current flows and the limit at which the grid becomes so negative that anode current cutoff takes place.

The discriminator circuit 12 is also of well-known form. For further information on the operation of this circuit, reference is made to Patent No. 2,121,103, Seeley, granted June 21, 1938. The function of the discriminator is to demodulate the frequency modulated waves which

are coupled thereto from the output circuit 18 of the limiter 11. The demodulated signals appear across the output coupling resistance 20 from which they are supplied to the grid of the signal frequency amplifier 13 in any suitable manner. In the illustrated embodiment the demodulated signals are coupled to the grid of the amplifier 13 through the coupling capacitor 21.

Thus far the circuits described are conventional. It might be noted that various forms of circuits known to the art for demodulating a phase modulated signal might be substituted for the frequency demodulation circuits shown. As will be pointed out in detail later, it is immaterial to the practice of my invention whether the receiving apparatus is designed for the reception of phase modulated signals or frequency modulated signals.

In Fig. 1, a diode detector circuit 25 is also illustrated which has a tuned input circuit 26 coupled to the primary winding 10 of the input transformer. The output of the detector appears across the diode load resistor 27 which is bypassed for carrier frequencies by the capacitor 28 in the usual manner.

For reasons which will shortly be apparent, the cathode of the diode detector 25 is connected to an adjustable tap 29 upon a source of potential, illustrated as the resistor 30, which forms one element of a power supply potentiometer. This potentiometer comprises the resistors 30, 31, 32 and 33 which are connected in circuit with a suitable power source, illustrated as the battery 34. The anode end of the diode load resistor 27 is connected to the grid of a triode control amplifier 35 over the conductor 36, resistor 37 and conductor 38. The cathode of the amplifier 35 is connected to the grounded negative terminal of the battery 34 through the conductor 39.

Thus a grid circuit for the amplifier 35 extends from the cathode through conductor 39, an adjustable portion of the bias potentiometer 30, tap 29, resistor 27, conductor 36, resistor 37 and conductor 38 to the grid of the amplifier. An anode circuit for the amplifier 35 extends from the cathode through conductor 39, potentiometer resistors 30 and 31 and an output coupling resistor 40 to the anode. A capacitor 41 is also effectively connected in parallel to the resistor 40 through low impedance elements of the power supply potentiometer to provide a resistance-capacitance network having a predetermined time constant, for reasons that will be outlined shortly.

The anode of the amplifier 35 is connected to the grid of the signal amplifier 13 through a coupling resistor 42 and conductor 43. It will be observed that the grid circuit of the amplifier 13 extends from the cathode through a conductor 44, resistor 32, resistors 40 and 42, and conductor 43 to the grid. The potential drop across the resistor 32 is proportioned to provide the proper normal operating bias for the amplifier 13.

It will be observed from Fig. 1 that the input circuits for the limiter 11 and the diode detector 25 are essentially the same since the control grid and cathode elements of the limiter 11 effect grid rectification and thus constitute the elements of a diode rectifier. Furthermore, for the purposes of my invention the circuit constants may be the same for both circuits. Therefore, the input circuit of the limiter 11 may conveniently be utilized to perform the dual function of providing grid bias for the limiter and developing rectified potentials across the resistor 17

for application to the grid of the control amplifier 35. Fig. 2 illustrates such a modification of the portion of Fig. 1 to the left of the vertical dashed line. Corresponding reference numerals have been placed on corresponding elements of the two figures to facilitate their comparison. The operation of the circuit of Fig. 2 is substantially identical to the corresponding portion of Fig. 1 and the description thereof will not be repeated.

Assume now that no signal is being received. No voltage will be developed across the diode load resistor 27. Therefore, there will be a net positive potential upon the grid of the control amplifier 35 equal to the bias supplied from the potentiometer 30. As previously mentioned, this positive bias may be adjusted by varying the position of the tap 29. This will hereinafter be termed the threshold bias. The resistors 30 and 31 are so proportioned that a relatively low anode potential is maintained on the amplifier 35. Therefore grid current flows in the grid circuit of this amplifier. It is preferably limited by the resistor 37.

By reason of the positive bias, anode current will also flow through the resistor 40. The resistor 40 is of relatively high value and an appreciable voltage will be developed across it. It will be observed that the upper end of resistor 40 becomes negative with respect to the lower end. Since resistor 40 is also included in the grid circuit of the signal amplifier 13, a negative potential is applied to the grid from the resistor 40 in opposition to the relatively low normal operating bias supplied from resistor 32. The result is that even a low value of anode current drawn by control amplifier 35 through the resistor 40 is sufficient to bias the signal amplifier 13 below cut-off, rendering it inoperative to translate signals applied to its grid circuit from demodulator 12.

Thus through the action of the noise suppression circuit just described, the amplifier 13 is maintained inoperative in the absence of a received signal and the output circuits of the radio receiver are effectively muted.

The operation of the noise suppression circuit when a signal is applied to the receiver input will best be understood from a consideration of the potential and current waves of Fig. 3 in conjunction with the following description. All of these waves are to be considered as having a common time base, so that points on the several curves on any vertical axis are representative of their values at the same instant of time.

Assume now that an unmodulated high frequency carrier wave is supplied to the primary 10 of the input transformer and that this wave has an average value just slightly exceeding the positive threshold bias supplied to the grid of the control amplifier 35 from the potentiometer 30. This is represented by the high frequency potential wave 50 in Fig. 3. Taking the ground potential as the horizontal reference axis, the dashed line 51 represents the positive potential of the cathode of the diode detector by reason of the threshold bias.

Through the well-known detector action the positive peaks of the wave 50 will be held substantially to the line 51. Under the assumed conditions the average value of the wave 50, i. e., the alternating current axis 52, will be slightly below the zero reference level. Since the wave 50 is also assumed to be unmodulated, its envelope will remain constant as indicated by the constant value

of the envelope wave 53 through the negative peaks.

Under these conditions the potential upon the diode load resistor 27 corresponds to the distance between the lines 51 and 52 which is substantially equal to the average carrier level. Since this unidirectional potential is applied with negative polarity to the grid of the amplifier 35, it opposes the positive threshold bias on the grid of amplifier 35 and the net bias on the grid is slightly negative, corresponding to the distance between line 52 and the zero axis. Since the anode potential on amplifier 35 is relatively low, it is rendered non-conductive whenever the net grid potential appreciably decreases below zero. No anode current is now drawn through resistor 40. Hence, the only bias upon the grid of signal amplifier 13 is the normal operating bias supplied from the potentiometer 32 and the receiver is operative.

It will be appreciated that phase or frequency modulation of the carrier wave 50 has substantially no effect upon operation of the noise suppression circuit as just described since the potential on the diode load resistor 27 depends only on the amplitude of the carrier. Therefore, the receiving apparatus is effective to demodulate the carrier and to supply the demodulated signals to the sound reproducer or other output device. If the carrier amplitude decreases so that the net bias upon the grid of the control amplifier 35 becomes less than cut-off bias for this tube, of course the receiver will again be muted. The tap 29 on the threshold bias potentiometer is manually adjusted so that the amplifier 13 becomes inoperative at the maximum noise level conditions which can be tolerated.

Next assume that the average amplitude of the received carrier remains just sufficient to overcome the threshold bias when it is unmodulated but that it is now amplitude modulated in some manner. The carrier potentials on the diode detector 25 might now be represented by the high frequency wave 50a in Fig. 3. The positive peaks of the wave are still held substantially to the threshold bias level 51 as before, but the envelope of the negative peaks varies with the amplitude modulation, for example as indicated by the envelope curve 53a. The potential on the diode load resistor 27 is no longer constant but follows the variations in the modulation envelope as indicated by the dashed curve 52a. The unidirectional potentials appearing on the resistor 27 are substantially proportional to the instantaneous amplitude of the envelope of the carrier wave, i. e., to the distance from the positive peaks of the carrier wave 50a (along the axis 51) to the curve 53a. Expressed another way their magnitudes correspond substantially to the algebraic sum of the average carrier amplitude and the instantaneous amplitude of any modulation components present in the carrier envelope.

It is now seen that the net bias on the grid of the control amplifier 35 becomes positive during portions of the negative modulation peaks of the envelope 53a. This is indicated in Fig. 3 by the portions 54 through 58 of curve 52a which rise above the zero axis. Since the grid of the amplifier 35 is bypassed only for carrier frequencies by the capacitor 28 and is unbypassed for modulation frequencies of lower value, the grid becomes less negative during these portions of the negative modulation peaks. Expressed another way, the time constant of the grid circuit is short enough to permit the grid to follow substantially all fluctuations in the carrier en-

velope at frequencies less than the order of the frequency of the carrier wave.

The result is that pulses of anode current are drawn by the amplifier 35 as indicated by the pulses 54b to 58b in Fig. 3. If the capacitor 41 were omitted, potentials on the resistor 40 would correspond to these current pulses and the bias on the signal amplifier 13 would be reduced during the occurrence of each pulse. However, the muting action of the noise suppression circuit is materially improved by the use of the relatively large capacitor 41 effectively in shunt to the resistor 40 to smooth out the potentials developed on resistor 40. This provides a resistance-capacitance network 40-41 having a relatively long time constant. The time constant is not critical. In general, it should correspond to a time interval which is comparable to, or longer than, the period of the lowest signal frequency to be transmitted by the amplifier 13. Thus, the resultant variation in potential across the resistor 40 and capacitor 41 may be of the form generally indicated by the curve 60 in Fig. 3. This curve corresponds roughly to the average amplitude of the pulses 54b through 58b of the anode current wave, indicated by the dashed curve 61. The amplifier 13 is thus maintained continuously inoperative throughout the entire time of occurrence of the amplitude modulation in the illustrated example.

It will be apparent from the foregoing that the instantaneous amplitude of the modulation envelope of the high frequency carrier waves must always exceed the threshold bias level if the noise suppression circuit is to be held open continuously. This level is determined both by the initial adjustment of the tap 29 on the threshold bias potentiometer 30 and by the instantaneous amplitude of the waves at the crests of the negative modulation peaks of the carrier wave envelope.

It is thus seen that I have provided a noise suppression circuit which is capable of distinguishing between signals which are amplitude modulated and those which are unmodulated or modulated only in phase or frequency. The signal level below which the receiving apparatus is muted is determined substantially by the manual adjustment of the potentiometer 30 during the reception of phase or frequency modulated waves, but in the presence of amplitude modulation the level is automatically increased. The advantages of this will be apparent to those skilled in the art.

My invention is therefore particularly suited to the practical requirements of a phase or frequency modulation receiver although it may of course find utility in other related applications.

By way of illustration only, and not in any sense by way of limitation, the following representative values are those which have been found suitable in a particular frequency modulation receiver embodying my invention. In this receiver a type 6SJ7 tube was employed in the dual capacity of the amplitude limiter 11 and the diode rectifier 25, in accordance with the modification shown in Fig. 2 of the drawings. The amplifiers 35 and 13 were enclosed within a common envelope in a twin-triode tube, type 6C8G. The bias threshold potentiometer 30 could be adjusted manually to vary the initial threshold bias on the amplifier 35 over a range of from about zero to five volts. The potential on the anode of amplifier 35 was about 20 volts, and the normal operating bias on amplifier 13, derived from the drop across resistor 22, was

about one volt. Other circuit constants were as follows:

Resistor 27=300,000 ohms
Capacity 28=50 micro-microfarads
Resistor 37=one megohm
Resistor 40=500,000 ohms
Capacitor 41=.1 microfarad

It was found in a particular test that, with a certain setting of the threshold bias potentiometer 30, an unmodulated carrier having an average level of about 4.5 microvolts at the receiver input was required to open the noise suppression circuit and render the receiver operative. With the same carrier modulated in amplitude approximately 30 per cent by a test signal, an average carrier level of about 7.5 microvolts was required to produce the same effect.

While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since various modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In combination, a signal translating network, means supplying signal-bearing high frequency carrier waves to said network for translation therethrough, means responsive to said carrier waves for developing potentials substantially proportional to the instantaneous amplitude of the envelope of said waves, and means responsive to reduction of the instantaneous amplitude of said potentials below a predetermined threshold level for preventing translation of said waves through said network.

2. In combination, a signal translating network, means for impressing signal-bearing carrier waves on said network, means for rectifying said waves to provide unidirectional potentials corresponding substantially to the instantaneous amplitude of the envelope of said waves, and control means responsive to the instantaneous amplitude of said potentials for rendering said network operative when said potentials exceed a predetermined threshold level and for disabling said network whenever the instantaneous amplitude of said potentials decreases below said level.

3. In a noise suppression circuit, the combination of a signal translating network, means for impressing signal-bearing carrier waves on said network, means for rectifying said waves to provide unidirectional potentials corresponding substantially to the instantaneous amplitude of the envelope of said carrier waves, means including an electron discharge device for disabling said network when said device is operative, and means for applying said potentials to said device to render it inoperative so long as said potentials exceed a predetermined threshold level and operative whenever the instantaneous amplitude of said potentials decreases below said level, said last means comprising a coupling network having a time constant short enough to cause said device to respond substantially instantaneously to said potentials.

4. In a radio receiving apparatus comprising an amplifier of high frequency signal modulated waves, a demodulator and a low frequency signal amplifier, the combination of means comprising a detector circuit coupled to said high frequency amplifier for developing unidirectional potentials whose magnitude corresponds substan-

tially to the algebraic sum of the average carrier amplitude and the instantaneous amplitude of any modulation components present in the carrier envelope, an amplifying device, means normally biasing the grid of said amplifying device to a predetermined threshold level and in a sense to cause current flow in its output circuit, means responsive to said current flow to bias said low frequency amplifier to an inoperative condition, and means for applying said potentials to the grid of said amplifying device in a direction to reduce said bias, said last means comprising a coupling network having a time constant short enough to cause said device to respond substantially instantaneously to said potentials.

5. The combination with a radio receiving apparatus having means for supplying signal-modulated carrier waves to an input circuit, means coupled to said circuit for separating said signals from said waves and means including a grid-controlled signal amplifier for translating said signals, of rectifying means coupled to said circuit for developing unidirectional potentials corresponding substantially to the instantaneous amplitude of the envelope of said waves, a thermionic control device having a control grid and an output circuit, means for impressing a predetermined positive bias potential on said grid to render said device normally conductive, means for impressing said unidirectional potentials on said grid in opposition to said bias, said last means comprising a coupling network having a time constant short enough to cause said device to respond substantially instantaneously to said potentials, whereby said device is rendered inoperative whenever said potentials instantaneously exceed a predetermined threshold level, means conductively connecting the grid circuit of said signal amplifier to said output circuit, and means in said connection for biasing said signal amplifier to cutoff when said control device is operative.

6. The combination with a radio receiving apparatus having means for supplying signal-modulated carrier waves to an input circuit, means coupled to said circuit for separating said signals from said waves, and means including a grid-controlled signal amplifier for translating said signals, of rectifying means coupled to said circuit for developing unidirectional potentials corresponding substantially to the instantaneous amplitude of the envelope of said waves, a thermionic control device having a control grid and an output circuit, means for impressing a predetermined positive bias potential on said grid to render said device normally conductive, means comprising a non-resonant coupling network having a relatively short time constant for impressing said unidirectional potentials on said grid in opposition to said bias, whereby said device is rendered inoperative whenever said potentials instantaneously exceed a predetermined threshold level, means conductively connecting the grid circuit of said signal amplifier to said output circuit, and means in said connection for biasing said signal amplifier to cutoff when said control device is operative, said last means comprising a non-resonant network having a relatively long time constant.

7. In combination with a radio receiving apparatus serially comprising an amplifier of high frequency carrier waves, a demodulator, and a signal amplifier, means comprising a unilaterally conducting discharge path coupled to said high frequency amplifier and an impedance in cir-

cuit therewith for developing unidirectional potentials across said impedance, said potentials being proportional to the algebraic sum of the average amplitude of said carrier wave and any modulation components present in the envelope of said wave, an electron discharge amplifier having a grid and an output circuit, a resistance-capacitance network in said output circuit having a relatively long time constant, means including said network for applying a negative bias to said signal amplifier in response to current flow in said output circuit, a source of threshold bias potential for said amplifier, and a grid circuit for said amplifier including means for impressing said threshold bias potential upon said grid in a positive sense and said unidirectional potentials upon said grid in a negative sense, said grid circuit having a time constant short enough to cause said grid to respond substantially instantaneously to said potentials.

8. The combination with a high frequency amplifier for signal modulated carrier waves, a signal demodulator and a signal amplifier, of a detector circuit coupled to said high frequency amplifier and adapted to develop a voltage wave corresponding to the instantaneous amplitude of the envelope of said wave, a threshold control amplifier, a grid circuit for said amplifier including means for applying a predetermined positive threshold bias to said grid and means for applying said voltage wave to said grid in opposite polarity, an anode circuit for said amplifier including a source of relatively low operating potential and a resistance-capacitance output network, said grid circuit being unbypassed for frequencies as low as signal frequencies and said network having a time constant comparable to the period of the lowest signal frequencies, and means including said network for biasing said signal amplifier to an inoperative condition when said control amplifier is operative.

9. In combination with a network adapted to translate high frequency carrier waves which may be modulated over a predetermined band of signal frequencies, means for supplying said waves to said network for translation there-through, means for normally disabling said network, means responsive to the envelope of said carrier waves of rendering said disabling means

ineffective when said envelope continuously exceeds a predetermined threshold level, and means responsive to negative amplitude modulation peaks which occur at frequencies including said band of signal frequencies and which instantaneously reduce the magnitude of said envelope below said threshold level for rendering said disabling means effective.

10. A noise suppression circuit comprising, in combination, a signal channel adapted to translate signal-modulated high frequency carrier waves, means for supplying said waves to said channel, control means for disabling said channel when the amplitude of the envelope of said waves is less than a predetermined threshold level and for restoring said channel to operative condition when said envelope exceeds said level, and means to give said control means a fast disabling action capable of following said envelope at all modulation frequencies and a slow restoring action incapable of following said modulation envelope, whereby said threshold level is automatically increased in response to amplitude modulation in said waves.

11. A noise suppression circuit comprising, in combination, a signal channel adapted to translate carrier waves which may be frequency or phase-modulated by desired signals extending over a predetermined frequency band and which may also be amplitude-modulated at frequencies within said band due to noise or interfering signals, means for supplying said waves to said channel, a threshold control amplifier having grid and anode circuits, threshold level adjusting means for normally biasing said grid circuit to maintain current flow in said anode circuit, means responsive to said current flow for disabling said channel, and means responsive to the envelope of said carrier waves for biasing said amplifier to cutoff when the value of said envelope exceeds said threshold level, said grid circuit having a time constant short as compared to the period of the highest signal frequency in said band and said anode circuit having a time constant long as compared to the period of the lowest signal frequency in said band.

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