

April 3, 1945.

C. M. CAMPBELL

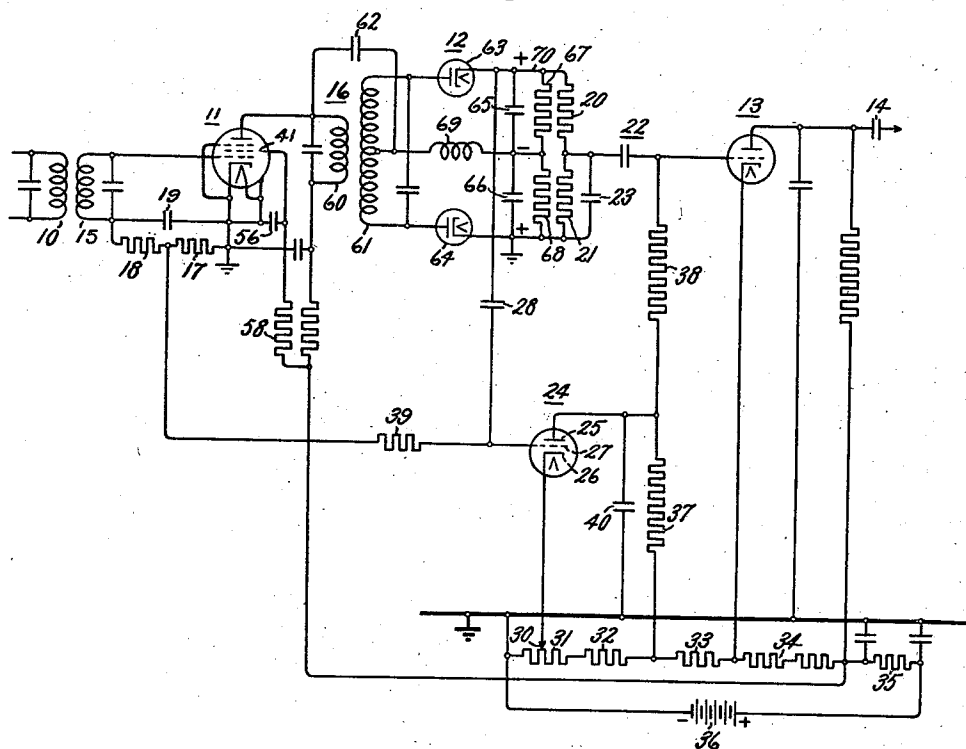
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NOISE SUPPRESSION CIRCUIT

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2 Sheets-Sheet 1

Fig.1.



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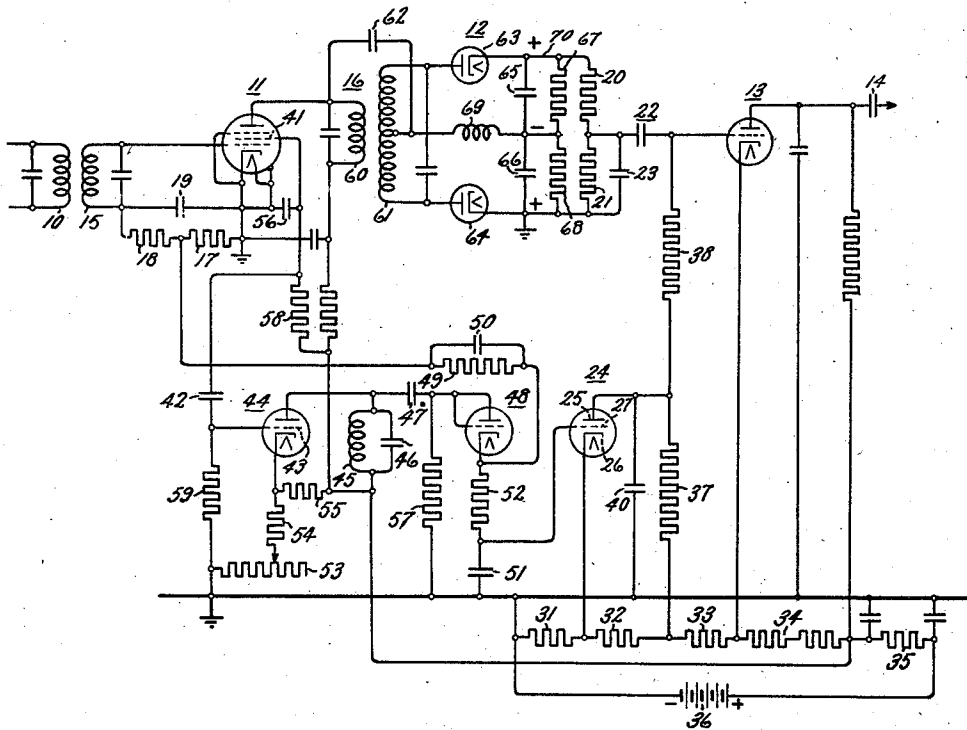
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2 Sheets-Sheet 2

Fig. 2.



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NOISE SUPPRESSION CIRCUITS

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14 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.

Various forms of noise suppression circuits of this general type are well known to the art, most of them being actuated by a voltage responsive to the intensity of the carrier wave of the received signal to render the receiver operative. In the absence of carrier-waves noise, including various forms of interference, such as natural static, thermal agitation in tubes, locally produced high frequency disturbances, etc., may cause very objectionable audible noises in the signal reproducer by creating in the receiver a voltage comparable in magnitude to that resulting from the carrier wave. Accordingly, it is an object of my invention to provide a noise suppression circuit for a radio receiver which, while maintaining the receiver inoperative for such noise responsive voltages, renders the receiver operative for translation of carrier-borne signal, and yet requires a minimum of adjustments under varying receiving conditions.

A further object of my invention is to provide a noise suppression circuit which will not be actuated by over modulated carrier waves to render the receiver partially inoperative.

It is more specifically an object of my invention to provide improved noise suppression circuits which are particularly suitable for use with frequency modulation apparatus and which allow a receiver to reproduce weak carrier-borne signals despite the presence of adverse noise conditions.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may 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 circuit of a frequency modulation receiving apparatus embodying my invention and Fig. 2 represents a modification of the circuit elements of the apparatus of Fig. 1.

In the circuit 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 super-heterodyne receiving apparatus they are the 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 grid resistors 17 and 18 and grid capacitor 19. 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 frequency discriminator circuit 12 comprises a transformer having a primary winding 60 and a secondary winding 61, both of these windings being tuned to the desired fixed intermediate frequency. The primary winding is connected to the mid point of the secondary winding 61 through a condenser 62. The opposite terminals of the secondary winding 61 are connected to the respective anodes of diodes 63 and 64, the cathodes of these diodes being connected together for alternating currents through capacitors 65 and 66 and for direct current through resistances 67 and 68. The cathode of diode 64 is grounded and the mid point between resistances 67 and 68 is connected to the mid point on the secondary winding 61 through a choke coil 69.

The operation of the discriminator thus described is as follows:

If we assume that the tuning control of the radio receiver is adjusted for accurate resonance with the received carrier wave, then the intermediate frequency has the desired value to which the primary and secondary windings 60 and 61 are each tuned. The voltage across the secondary winding of the transformer, in accordance with well-known theory, is displaced in phase from the voltage across the primary by 90°. Because of this quadrature relation between the primary and secondary voltages, the voltage on

one-half of the secondary leads the voltage on the primary by 90° whereas that on the other half of the secondary lags the voltage on the primary by 90°. Thus the voltage applied to the two diodes 63 and 64, when the intermediate frequency is at its desired value, is equal and accordingly equal values of unidirectional current flow through each of the diodes and hence through resistances 67 and 68. It will be observed that these resistances are poled oppositely, that is, the voltages across the two are opposite in polarity in the circuit between conductor 70 and ground with the result that the conductor 70 is at ground potential when the intermediate frequency is at the desired value.

The quadrature relations between the primary and secondary voltages exist, however, only when the oscillations applied thereto have the desired intermediate frequency. If this frequency changes in either direction, the phase of the secondary voltage varies from its 90° relation with the primary voltage in one direction or the other dependent upon whether the frequency increases or decreases. For example, if the frequency increases, the phase shift may be in such a direction that the voltage on the upper half of the secondary winding approaches the aiding relation with the primary voltage whereas that on the lower half of the secondary winding approaches the opposing relation with the primary voltage. Thus the voltage applied to diode 63 increases and that applied to diode 64 decreases with the result that the unidirectional potential on resistance 67 increases whereas that on resistance 68 decreases and the conductor 70 thus becomes positive with respect to ground. On the other hand, if the intermediate frequency decreases, an opposite shift in phase of the secondary voltage occurs with the result that the larger alternating current voltage is supplied to diode 64 and the potential on resistance 68 increases whereas that on resistance 67 decreases and the conductor 70 is driven negative with respect to ground.

In this manner discriminator 12 functions to demodulate frequency modulated waves which are coupled thereto from the output circuit 16 of the limiter 11. The demodulated signals appear across the output coupling resistances 20 and 21 from which they are supplied to the control electrode of the signal frequency amplifier 13 in any suitable manner. In the illustrated embodiment, the demodulated signals are coupled to the control electrode of the amplifier 13 through the coupling capacitor 22. Since it is a well-known practice in connection with transmitting signals by means of a frequency modulation transmitter to exaggerate the higher frequency components of the signals prior to transmission, a circuit to reduce or de-emphasize the higher frequency components of the demodulated signals appearing across the resistances 20 and 21 is provided comprising the capacitor 23 connected across the resistance 21.

In order to disable signal frequency amplifier 13 in the absence of carrier waves so that noise present in the aforementioned circuits is not transmitted to the output circuit, a switching tube 24 is provided. Switching tube 24 has, in addition to an anode 25, a cathode 26, and at least one control electrode 27. The output voltage of the discriminator 12 is supplied to the control electrode 27 through a high pass filter consisting of capacitor 28, resistors 30 and 17.

For reasons which will shortly be apparent, the cathode of the switching tube 24 is connected to an adjustable tap 30 upon a source of potential illustrated as the resistor 31 which forms one element of a power supply potentiometer. This potentiometer comprises the resistors 31, 32, 33, 34 and 35 connected in circuit with a suitable power source, illustrated as the battery 36. The anode 25 of the switching tube 24 is connected through a resistor 37 to a source of potential and through the resistor 38 to a control electrode of the signal amplifier 13. The control electrode 27 is likewise connected through resistor 39 to the common point of the resistors 17 and 18 in the grid circuit of limiter 11.

When no carrier wave is present, the tap 30 is adjusted so that noise voltages on the control electrode 27, derived from the output of discriminator 12 through capacitor 28, are sufficient to drive this electrode in a positive direction and cause the electron discharge device 24 to pass a small amount of anode current. This anode current flowing through the resistor 37 causes a voltage drop of such a polarity that the control electrode of signal frequency amplifier 13 is driven in a negative direction and anode current through the amplifier is cut off. Thus, in the manner outlined, noises present in the preceding circuits are utilized to disable the receiver. While capacitor 40 effectively bypasses audio frequency voltages appearing on the anode of switching tube 24, the resistor 38, which serves as a direct current path for the controlling bias of amplifier 13, is sufficiently large to prevent capacitor 40 from being effective to bypass audio voltages derived from the output of discriminator 12 and appearing at the control electrode of amplifier 13.

When no carrier is present, the audio frequency voltages, resulting from internal and external noises which appear in the output of the discriminator of a frequency modulation receiver, have considerable magnitude. However, when a radio frequency voltage of the correct frequency appears on the input of the receiver, the general level of the noise voltages appearing in the receiver output diminishes to a degree depending directly upon the magnitude of the received carrier voltage and inversely upon the magnitude of the external noise voltages. In the circuit of Fig. 1, when no carrier wave is present, noise voltages appearing in the output of discriminator 12 are supplied to the control electrode of switching tube 24 to produce, by means of the anode current of that tube, a negative bias on the control electrode of signal frequency amplifier 13 to cut off the anode current of this amplifier and disable the output of the receiver.

When a carrier wave is received, a bias voltage is produced across resistors 17 and 18 in the control electrode circuit of limiter 11 due to rectified current flowing between the control electrode and cathode of this limiter. A portion of this bias potential is supplied to control electrode 27 of switching tube 24 with a polarity such as to cut off the anode current of the switching tube 24 removing the negative bias from signal frequency amplifier 13. Under such conditions signals produced in the output of discriminator 12 are amplified in device 13 and are supplied to the output circuit of the receiver. Thus when a carrier wave is received, two additive effects are produced in the grid circuit of switching tube 24. The first of these, a reduction in noise voltages in the output of the discriminator, tends to allow the fixed negative bias introduced through the potenti-

ometer tap 30 to become effective and cut off anode current in this tube. The second effect, that of the bias derived from resistor 17 in the grid circuit of limiter 11, also drives control electrode 27 in a negative direction insuring that anode current in tube 24 is effectively cut off and that reproduction of signals in amplifier 13 is not disturbed by any grid bias derived from switching tube 24. This second effect is of advantage particularly when over-modulated waves are received, for then, despite the fact that the increased modulation voltages in the output of the discriminator would tend to allow tube 24 to pass current, the opposing bias derived from resistors 17 and 18 is sufficient to prevent any flow of anode current in tube 24 and consequent disabling of the receiver.

In the modification of the invention as illustrated in the circuit of Fig. 2 a potential responsive to noise present in the circuits of the receiver is supplied by screen electrode 41 of limiter 11 through capacitor 42 to control electrode 43 of electron discharge device 44. The anode circuit of device 44 contains a tuned circuit consisting of inductance 45 and capacitor 46. The resonant frequency of this circuit should be well outside of the audio range being used in the transmitter, for example, about 27,000 cycles. The output of noise amplifier 44 is supplied through a coupling capacitor 47 to the diode 48. The rectified output current of diode 48 flowing from the cathode through resistor 49 and resistor 17 to resistor 57 connected to the anode produces a potential drop across resistor 49 that places a positive bias on a control electrode of switching tube 24. The capacitor 51 removes all alternating current components from the direct current bias applied to tube 24. Switching tube 24 is normally biased somewhat beyond cut-off by the voltage appearing across resistor 31 of the power supply potentiometer so that anode current will begin to flow when a predetermined positive bias is provided by the noise amplifying circuit.

Control of the noise level setting of the receiver at which the noise suppression circuit becomes operative is effected by means of resistor 53 in the cathode circuit of noise amplifier 44. Resistor 54 prevents the grid bias on tube 44 from being reduced to too low a value, while resistor 55 serves to maintain the cathode of tube 24 at a high positive potential when the effective resistance of resistor 53 is increased. Such a resistance network results in an improved gain control of noise amplifier 44.

In the operation of the circuit of Fig. 2, audio frequency noise voltages are taken from the screen electrode of limiter 11 through capacitor 42 and supplied to the control electrode 43 of noise amplifier 44. Radio frequency carrier waves are bypassed from this circuit by capacitor 56 connected between the screen electrode and the cathode of the limiter 11 and operating potential for the screen electrode circuit is supplied by resistor 58 connected to the power supply potentiometer. Noise voltages of a frequency corresponding to the resonant frequency of the tuned circuit in the output of noise amplifier 44 are supplied to the diode rectifier 48. In the manner previously outlined, rectified currents of the diode 48 supply a positive bias to the switching tube 24, thus causing an anode current to flow in this tube and bias signal frequency amplifier 13 to cut-off, disabling the receiver.

When a carrier wave is received, the previously mentioned characteristic of a frequency modula-

tion receiver, that causes the general level of the noise voltages appearing in the receiver output to diminish to a degree depending directly upon the magnitude of the received carrier and inversely upon the magnitude of external noise voltages, reduces the positive bias supplied to device 24, thus tending to render the disabling circuit of the receiver ineffective. At the same time a potential caused by rectification of the carrier voltage appears across resistors 17 and 18 and is applied to control grid 27 of switching tube 24 through resistor 49 and resistor 52. Its polarity is such as to make control grid 27 more negative, causing switching tube 27 to become non-conductive and the disabling circuit of the receiver to be rendered ineffective. Therefore, when a carrier is received, there is both a reduction of the positive bias across resistor 49 because of reduction of noise voltages and also an increase of negative bias from resistor 17. The action of both voltages tends to cut off anode current in the device 24 and to make the signal frequency amplifier operative.

This circuit, moreover, is effective to overcome any tendency of transmitter over-modulation voltages passing through the noise amplifier to disable the audio amplifier, for, by proper proportioning of the values of resistor 17 and resistor 49, the bias voltage supplied to grid 27 by resistor 17 due to the carrier voltage may be made sufficient to overcome completely any positive bias due to such over modulation voltages. In addition, since the tuned circuit consisting of inductance 45 and capacitor 46 resonates well outside the audio frequency range, noise amplifier tube 44 attenuates modulation voltages.

It will be apparent in the foregoing circuit that, when no carrier waves are being received, in the presence of extremely high external noise levels, there is a marked increase of voltage across resistor 17 because of rectification of the increased noise voltages. At the same time, because of the limiting action, the voltage appearing on the screen grid of limiter 11 varies little from that of low noise level conditions. The voltage across resistor 17 in itself tends to cut off plate current in device 24 and to render the receiver audio system operative. Such a condition, of course, is undesirable and is avoided in the following manner. As is well known to those skilled in the art, the grid-cathode circuit of an electron discharge device of the type of the limiter tube 11 has a non-linear characteristic. As a result, its effect on the noise voltages appearing between the grid and cathode is similar to that of an amplitude modulation detector and, in addition to a unidirectional potential, noise voltages of audio frequency appear across resistors 17 and 18. The voltages across resistor 17 are applied through capacitor 50 across the diode 48 and cause rectified current to flow through resistor 49 with the same polarity as the current developed from the noise amplifier 44. Resistor 52 prevents capacitor 51 from bypassing these audio frequency noise voltages. The size of capacitor 50 is selected so that the increase in negative bias across resistor 17 due to the higher external noise level is counterbalanced by an increased positive bias across resistor 49 caused by the increased noise voltages coupled into diode 48 through capacitor 50. The resulting bias effective on device 24 remains essentially unchanged and the audio amplifier remains inoperative.

Upon reception of carrier waves by the receiver, the positive bias on control electrode 27 due to

noise voltages is reduced and the negative bias created by the limiter grid circuit predominates so that switching tube 24 is cut off and the receiver is operative. By properly proportioning resistances 17 and 18, that is, by increasing the magnitude of resistance 17 with respect to resistance 18, the reception of weak signals even may be allowed to render the receiver disabling circuit ineffective. Of course, as the intensity of the signals increases, control electrode 27 is driven more negative so that the receiver continues to function.

It is thus seen that my invention provides a noise suppression circuit which, in the absence of a carrier wave, disables the receiver output for a given minimum noise level and which maintains the receiver output disabled for any noise level exceeding that minimum, the minimum noise level being determined actually by tube noise in the first radio frequency amplifier stages. The noise level at which the receiver is muted is determined substantially by manual adjustment of the potentiometer 53. Moreover, when this adjustment is once made, the circuit is responsive to extremely weak signals and yet does not require readjustment in the presence of high external noise levels. Also, even in the presence of over-modulated waves, the receiver is not rendered inoperative but is allowed to continue to function. My invention is, therefore, particularly suited to the practical requirements of a 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 as the amplitude limiter 11 in accordance with the modification shown in Fig. 2 of the drawings. The amplifiers 13 and 24 were enclosed within a common envelope in a twin-triode tube, type 6C8G. Similarly the amplifier 44 and the rectifier 48 were enclosed within a common envelope in a twin-triode tube, type 6C8G, the control electrode for the rectifier portion of the tube being connected to the anode in the manner shown in Fig. 2. Other circuit constants were as follows: resistance 17, 50,000 ohms; resistance 18, 250,000 ohms; resistances 37 and 38, 500,000 ohms each; resistance 49, 2 megohms; resistance 53, 25,000 ohms; resistance 54, 2500 ohms; inductance 45, 50 millihenries; capacitor 42, 100 micromicrofarads; capacitor 46, 500 micromicrofarads; capacitor 50, 2000 micromicrofarads; capacitor 51, .05 microfarad.

While I have illustrated a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto since many modifications may be made in the circuit elements employed and in their arrangement, and I therefore contemplate by the appended claims to cover any such modifications as fall into 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 a radio receiver having a high frequency channel for translating signal modulated carrier waves and noise and a signal channel through which signals and noise are amplified after demodulation of such waves and delivered to output means, the combination of, means responsive to noise voltages in said signal channel for disabling

said output means, and means responsive to a unidirectional voltage derived from said waves in said high frequency channel for rendering said disabling means ineffective.

2. A noise suppressor for a frequency modulation receiver comprising, a source of signal modulated waves, means for amplifying said waves, means for reproducing signals from said waves and for amplifying said signals, input and output circuits connected to said wave amplifying means, means responsive to noise voltages in said output circuit for disabling said signal amplifying means, and means responsive to voltages derived from waves in said input circuit for rendering said disabling means ineffective.

3. In a radio receiver having a high frequency channel for translating received signal modulated waves and a signal channel through which signals are amplified after the demodulation of such waves and delivered to output means, a noise suppressor comprising, an electron discharge device in said high frequency channel having input and output circuits, means responsive to noise voltages in said output circuit for disabling said output means, and means responsive to a unidirectional voltage in said input circuit derived from said signal modulated waves for rendering said disabling means ineffective.

4. In a signaling system including a source of signal modulated waves, means for translating said waves, said means including an electron discharge device having a control electrode and an anode circuit in which waves of limited intensity are produced, means for varying the bias potential of said control electrode in accordance with the intensity of said waves, means coupled to the output of said electron discharge device for reproducing said signals from said waves and supplying said signals to a signal amplifier, means responsive to noise potentials derived from said output for disabling said signal amplifier, and means for supplying a portion of said bias potential to oppose said last means derived from said output thereby to render said disabling means ineffective.

5. A noise suppressor for a frequency modulation receiver comprising, a source of signal modulated carrier waves, means for transmitting substantially only those portions of said waves whose intensities are less than a predetermined intensity, said means comprising an electron discharge device having an input circuit and a plurality of output circuits, means for reproducing signals from said waves and for supplying said signals to a signal amplifier, means responsive to noise potentials developed in one of said output circuits for disabling said signal amplifier, and means responsive to potentials developed in said input circuit for rendering said disabling means ineffective.

6. A noise suppressor for a frequency modulation receiver comprising, a source of signal modulated carrier waves, a limiter having an input circuit and a plurality of output circuits, a balanced frequency discriminator, means for amplifying signals derived from said discriminator, means responsive to noise potentials developed in one of said output circuits for disabling said signal amplifier, and means responsive to potentials developed in said input circuit for opposing the last mentioned means thereby to render said disabling means ineffective.

7. In a noise suppression circuit for a translating network for signal modulated carrier waves, the combination of a high frequency amplifier, a

discriminator, a low frequency amplifier, and means for controlling said low frequency amplifier to prevent the passage of noise and to permit translation of signals, said means comprising an electron discharge device having an input circuit and an output circuit coupled to said low frequency amplifier, means for supplying to said input circuit a potential varying responsively to the intensity of noise present in said discriminator thereby to provide in said output circuit a voltage to prevent the passage of noise by said low frequency amplifier, and means for supplying to said input circuit a unidirectional potential varying responsively to the intensity of waves in said high frequency amplifier, said unidirectional potential having a polarity opposed to that of said potential, thereby permitting translation of signals by said low frequency amplifier.

8. In a noise suppression circuit for a translating network for frequency modulated carrier waves, the combination of, a limiter, a discriminator, a low frequency amplifier having a control electrode, and means for controlling said low frequency amplifier to prevent the passage of noise and to permit translation of signals, said means comprising an input circuit and an output circuit for said limiter, means for supplying to said control electrode a bias potential varying responsively to the intensity of noise in said output circuit thereby to prevent the passage of noise by said low frequency amplifier, and means for supplying to said control electrode an opposing bias potential varying responsively to the intensity of waves in said input circuit, thereby to permit the translation of signals by said low frequency amplifier.

9. In a noise suppression circuit for a translating network for signal modulated carrier waves, the combination of, a high frequency amplifier, a balanced frequency discriminator, a low frequency amplifier having a control electrode, and means for controlling said low frequency amplifier to prevent the passage of noise and to permit translation of signals, said means comprising an input circuit and an output circuit for said high frequency amplifier, means for supplying to said control electrode a control potential varying responsively to the intensity of noise in said output circuit thereby to prevent the passage of noise in said low frequency amplifier, means for deriving a bias potential for said input circuit from said carrier waves, and means for supplying to said control electrode an opposing control potential varying responsively to a portion of said bias potential, thereby to permit the translation of signals by said low frequency amplifier.

10. In a noise suppression circuit for a frequency modulation receiver, the combination of, a limiter having input and output circuits, means for disabling said receiver, said means including rectifying means responsive to noise voltages in said output circuit, means for establishing in said input circuit both unidirectional and alternating voltages varying as a function of the noise present in said receiver, means responsive to said unidirectional voltage for opposing said disabling means, and means responsive to said alternating voltage for assisting said disabling

means, said assisting means including said rectifying means.

11. In a noise suppression circuit for a frequency modulation receiver, the combination of, a limiter, a balanced frequency discriminator, a signal amplifier, input and output circuits for said limiter, a first means responsive to noise voltages in said output circuit for disabling said amplifier, means for establishing both unidirectional and alternating voltages in said input circuit, means responsive to said alternating voltage for assisting said first means, and means responsive to said unidirectional voltage for opposing said first means.

12. In an angle modulated wave receiver of the type utilizing an amplitude limiter followed by a demodulator and a modulation signal network; the method which includes deriving from the limiter output a control voltage whose magnitude is proportional to the amplitude of noise voltage components, deriving from the limiter input a control voltage whose magnitude is proportional to the wave intensity at the limiter input, combining the two control voltages to provide a residual control voltage whose magnitude is proportional to the amplitude of said noise components, and employing the residual voltage to prevent utilization of said modulation signals.

13. In a frequency modulation receiver of the type including an amplitude limiter stage having input and output electrodes, a frequency modulation detector and a modulation signal amplifier; the improvement comprising a rectifier coupled to the limiter output electrodes for providing a rectified voltage whose magnitude is proportional to noise voltage appearing in the limiter output circuit in response to a substantial reduction in the signal-to-noise ratio at the receiver input terminals, means for deriving from the input limiter electrodes a control voltage whose magnitude depends upon the amplitude of received signal energy, means combining the voltage output of the rectifier and said control voltage to provide a residual voltage which is positive, an electron discharge device responsive to said positive voltage for producing a space current, and means responsive to the last-named space current for rendering said modulation signal amplifier inoperative.

14. In an angle modulated wave receiver of the type utilizing an amplitude limiter followed by a demodulator and a modulation signal utilizing network, the method which includes deriving from the limiter output a control direct current voltage whose magnitude is proportional to the amplitude of noise voltage components, deriving from the limiter input a control direct current voltage whose magnitude is proportional to the wave intensity at the limiter input, combining the two control voltages to provide a residual control voltage whose magnitude is proportional to the amplitude of said noise components, and utilizing the residual direct current voltage to prevent utilization of said modulation signals.

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