

Aug. 24, 1948.

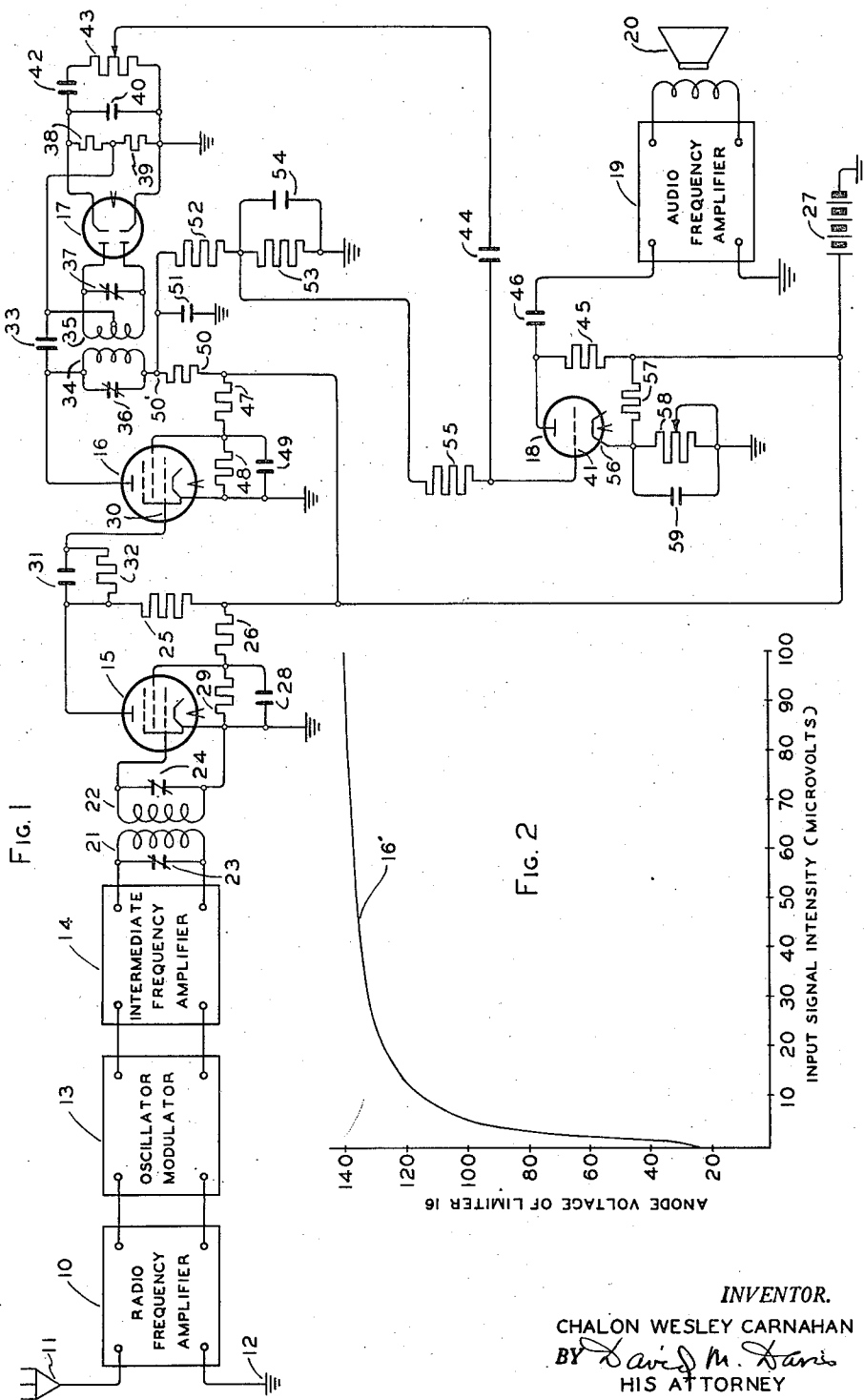
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2,447,564

NOISE REDUCING CIRCUITS

Filed Jan. 30, 1943

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

FIG. 3

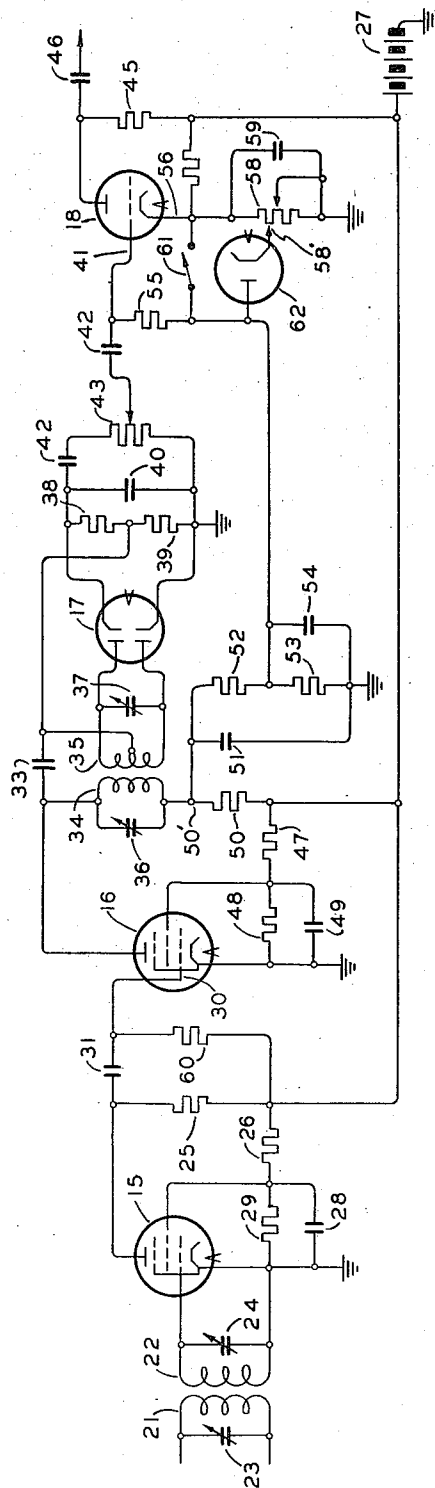
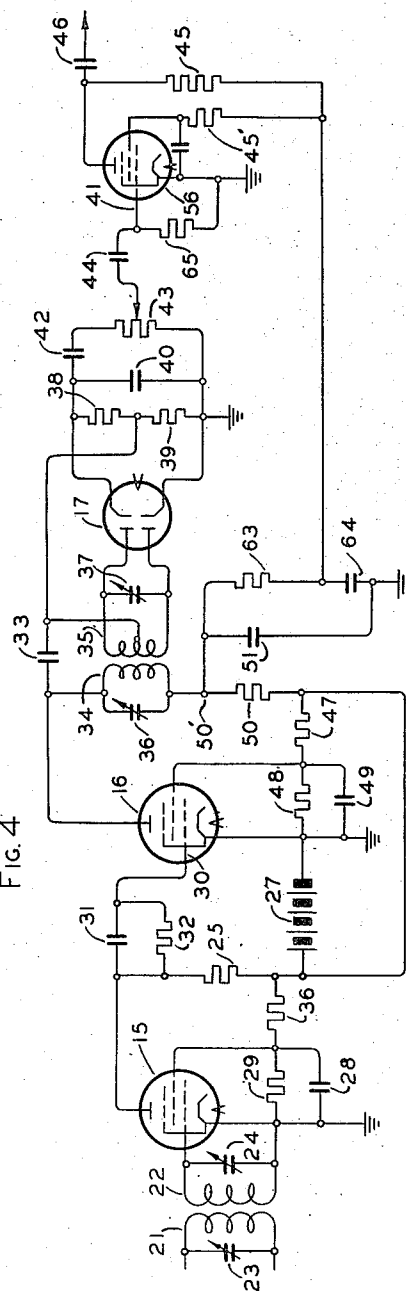


FIG. 4



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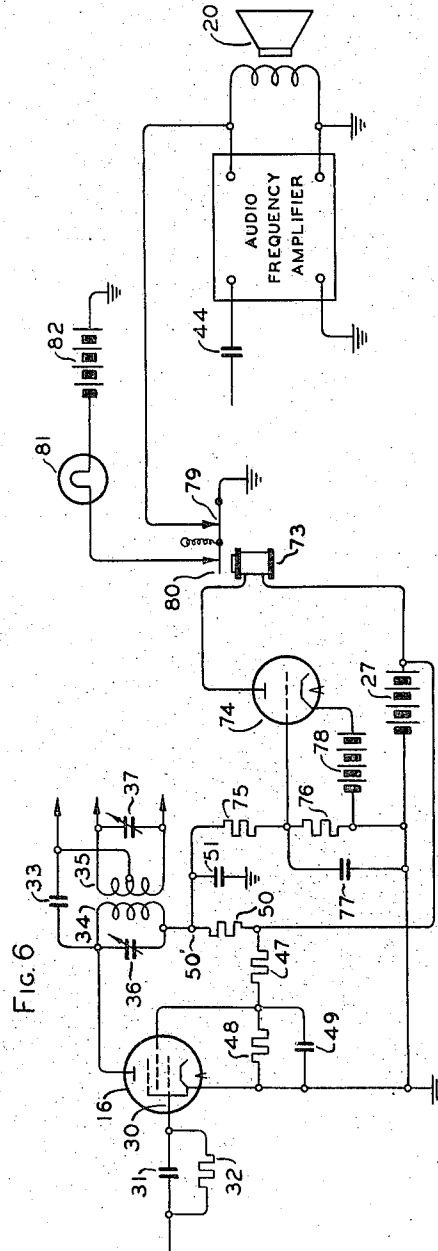
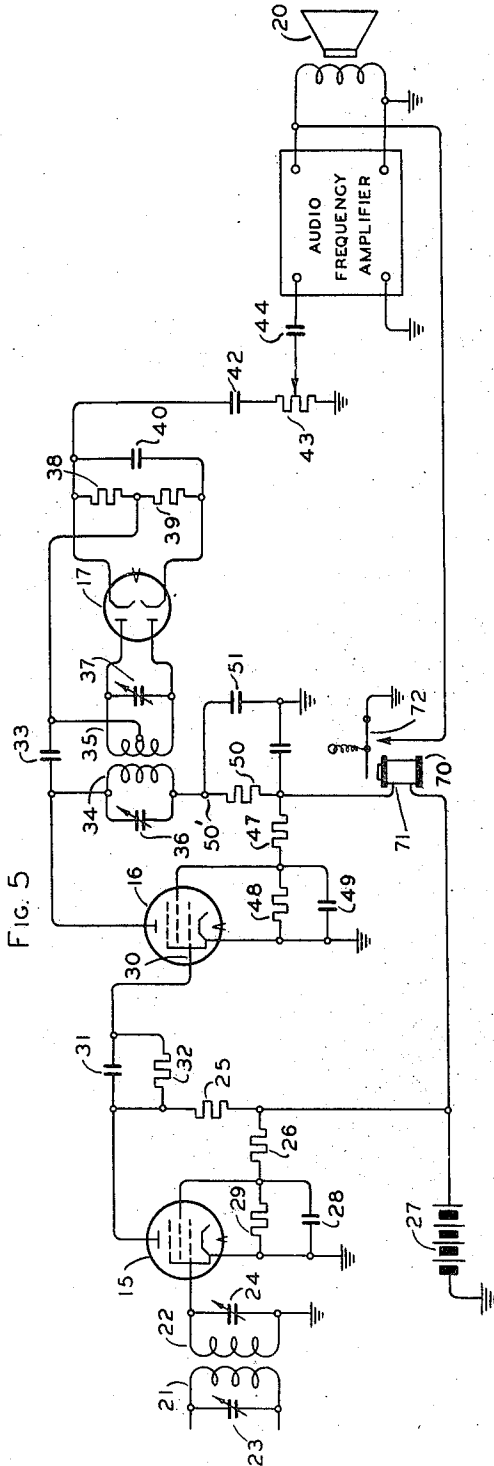
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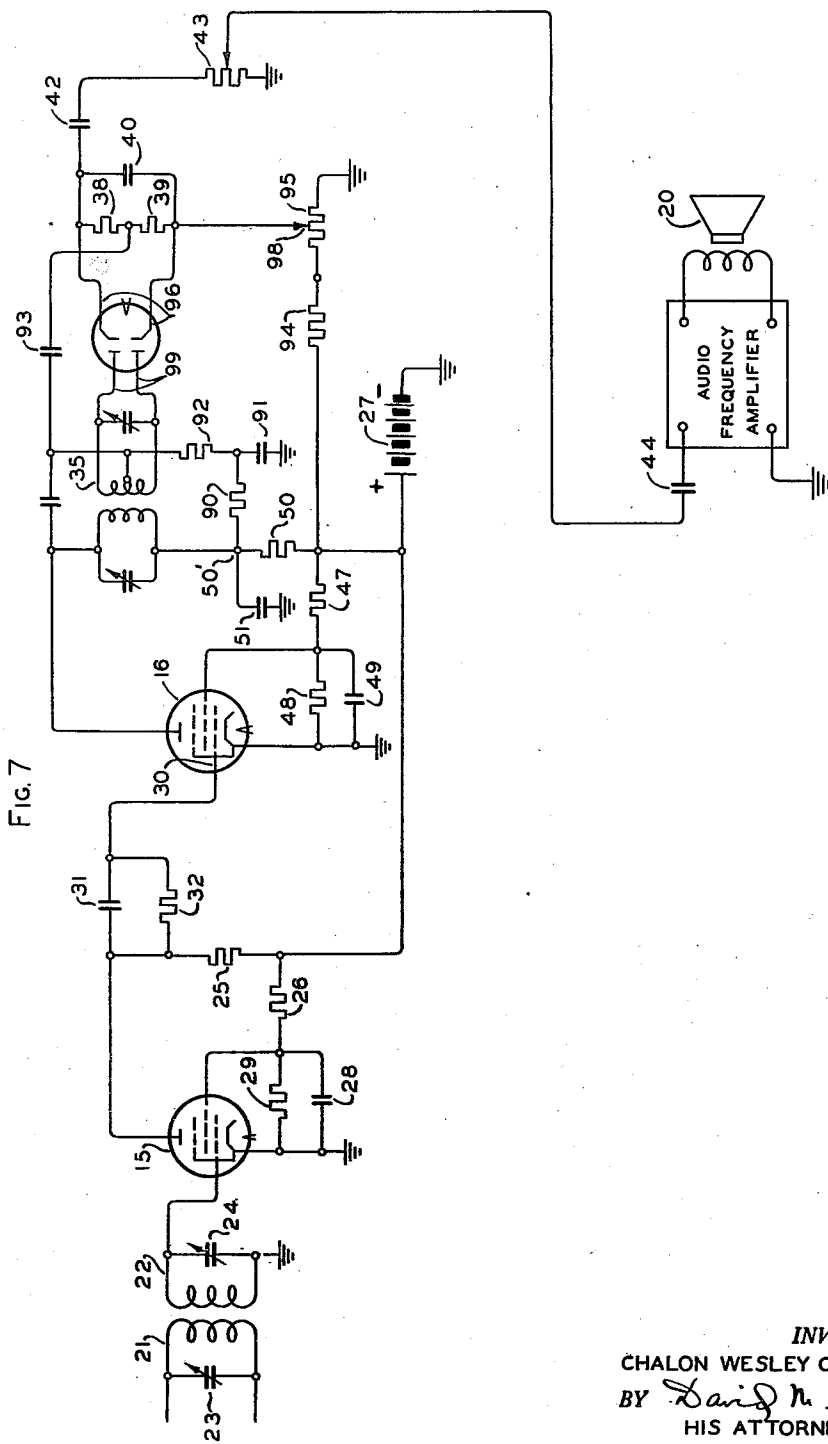
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,447,564

NOISE REDUCING CIRCUITS

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Application January 30, 1943, Serial No. 474,066

29 Claims. (Cl. 250—20)

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This invention relates to signaling apparatus and more particularly to a control network for the reduction of noise in high frequency signaling apparatus.

The performance of radio receivers is commonly limited by the presence of noise. Static crash and tube hiss are well known examples of unpleasant noise, but any undesired disturbance, whether originating within or without the receiver, is properly termed noise.

Noise limits the usable sensitivity of a radio receiver and necessitates a higher level of signal strength for satisfactory communication than is otherwise required. The intelligibility of signals may be reduced by severe background noise to such an extent that even commercial point to point communication is interrupted. It is well known that in ordinary broadcasting, noise frequently disturbs the listener and destroys the entertainment of programs. Noise interference must especially be minimized when operating mobile equipment, which operates under conditions far less favorable than the worst faced by a broadcast receiver in the home.

It is a main object of this invention to provide a new and improved noise reducing arrangement.

Although the frequency modulation system of radio transmission makes possible the satisfactory reception of signals under extremely unfavorable noise conditions, it too is subject under certain conditions to undesirable noise interference. Unfortunately, a normal frequency modulation receiver in the absence of a signal carrier is operating at its maximum sensitivity. Under such a condition, even though the limiter stages are operating in a satisfactory manner and the demodulator is carefully balanced, the background noise is unpleasant and disturbing. When a broadcast receiver is tuned away from a carrier, a rush of hiss, crackle and sputter is received in disagreeable contrast to the quiet background of a receiver correctly tuned to a signal of satisfactory level.

The noisy operating characteristics of a sensitive frequency modulation receiver in the absence of a carrier signal are particularly objectionable in the case of communication equipment with which the operator commonly wears headphones. Quite often, a receiver must remain tuned for long periods of time to a station which transmits a signal carrier only during the brief moment when messages are being sent. The crash and hiss of background noise deaden the operator's auditory perception and create a nervous strain which reduces his operating efficiency.

Accordingly, it is an object of my invention to provide a new and simplified silencing network particularly adapted for use with a frequency modulation receiver which will prevent

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the reproduction of noise when no signal is being received, or when the signal intensity is too low for satisfactory use.

Certain silencing networks of the type commonly termed "squelch circuits" are known to the art. These noise reducing circuits are more properly designated by such terms as carrier off noise suppressors or interchannel noise suppressors. Some of the prior art circuits have been adapted for use with frequency modulation receivers. In all cases observed, the operating characteristics necessary for satisfactory noise reducing action have been obtained only by recourse to relatively complicated and expensive circuit apparatus.

It is an object of the present invention, therefore, to provide a new and improved noise reducing circuit which can be applied to a conventional frequency modulation receiver without the addition of extra tubes.

It is also an object of my invention to provide a simple and effective noise reducing circuit which lends itself to economical commercial manufacture.

It is a further object of my invention to provide a new and improved network which will permit a radio receiver to become operative in the presence of a very low level of frequency modulated signal, but which holds the receiver inoperative in the presence of a much higher level of noise alone in the absence of receivable signal.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, both as to its organization and manner 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 drawing in which:

Figure 1 diagrammatically represents one embodiment of my invention;

Figure 2 is a curve which illustrates certain operating characteristics of the embodiment of Figure 1; and

Figures 3 to 7, both inclusive, represent other modifications of my invention.

In Figure 1, there is shown a superheterodyne receiver for the reception of frequency modulated signals. This receiver includes a radio frequency amplifier 10 having its input connected to an antenna system 11 and 12 and its output connected to a frequency changer or oscillator-modulator 13. Waves from antenna 11 are transferred successively through the frequency changer 13, an intermediate frequency amplifier 14 of one or more stages, a first amplitude limiter including electron discharge device 15, a combined amplitude limiter and signal responsive

control device including electron discharge device 16, a frequency modulation detector including electron discharge device 17, a first audio frequency amplifier and silencing network including electron discharge device 18, an audio frequency amplifier 19 of one or more stages, and a sound reproducer 20.

It will be understood that the radio frequency amplifier 10, the frequency changer 13, the intermediate frequency amplifier 14, the frequency modulation detector including electron discharge device 17, the audio frequency amplifier 19, and the sound reproducer 20 are of conventional construction and operation.

Considering briefly the operation of the receiver as a whole and neglecting for the moment the silencing network of this invention presently to be described, a desired received signal intercepted by the antenna 11 is selected and amplified by radio frequency amplifier 10, converted to a frequency modulated carrier signal in the frequency changer 13, amplified by the intermediate frequency amplifier 14, limited to a substantially constant amplitude by the cascaded limiters 15 and 16, and detected by the frequency discriminator detector including device 17, thereby to produce an audio signal. The audio signal is then amplified in the audio frequency amplifier including electron discharge device 18, further amplified in the audio frequency amplifier 19 and reproduced by the sound reproducer 20.

The amplitude limiters including electron discharge devices 15 and 16, as shown, successively limit below predetermined intensities the amplitude of alternate half cycles of a wave from amplifier 14. With this arrangement, self-bias in the first limiter may be eliminated, resulting in anode current cut-off in the first limiter for signal voltages only a volt or so on the negative side of the zero axis. The positive half cycles of the signal need not be limited in the first limiter, as they are reversed in phase and applied to the second limiter grid as negative voltages. Since anode current cut-off in the second limiter occurs when the grid becomes negative by a small voltage, effective clipping of the positive peak is obtained in the second limiter. The structure of two limiters connected in this manner is described and claimed in my copending application, Serial Number 371,606, filed December 26, 1940, and matured as Patent No. 2,323,880, dated July 6, 1943, for Wave amplitude limiting device, and assigned to the assignee of the present application.

The first limiter including electron discharge device 15 is coupled to the intermediate frequency amplifier by means of a tuned radio frequency transformer system comprising primary inductance 21, secondary inductance 22 and capacitors 23 and 24. Suitable operating potentials for the pentode shown are provided by means of anode resistor 25, and screen voltage dropping resistor 26 connected to the positive terminal of a source 27 of continuous voltage, the negative terminal of which is grounded. The screen of electron discharge device 15 is bypassed for radio frequencies by the capacitor 28, and the screen voltage is stabilized by the resistor 29 connected in parallel to capacitor 28. The anode of electron discharge device 15 is coupled to the grid 30 of limiter device 16 by a capacitor 31, which is shunted by a resistor 32. The signal output of the limiter device 16 is coupled to a conventional discriminator, or detector of frequency modulated waves, which includes the capacitor 33 and a tuned transformer comprising primary inductance 34, secondary in-

ductance 35 and capacitors 36 and 37. The discriminator also include a pair of rectifier diodes 17, rectifier load resistors 38 and 39, and a high frequency bypass capacitor 40. Audio frequency voltage appearing across serially connected resistors 38 and 39 is applied to the grid 41 of the first audio amplifier 18 through capacitor 42, adjustable volume control resistor 43 and capacitor 44. The anode of amplifier 18 is supplied with operating potential through load resistor 45 connected to the positive terminal of source 27. The amplified audio signal developed on the anode of device 18 is transferred to amplifier 19 through capacitor 46.

Operating potentials for the combination limiter and signal responsive control device 16 are supplied from the positive terminal of source 27. Resistor 47 is connected between the screen and that positive terminal. Resistor 48, connected between screen and cathode, stabilizes the screen voltage, and capacitor 49 bypasses the screen for high frequency currents. The anode of limiter 16 is connected to the positive terminal of source 27 through the primary inductance 34 and resistor 55, a unidirectional voltage being developed between ground and a point 50' between resistor 50 and inductance 34. This unidirectional voltage is applied to a voltage divider comprising resistors 52 and 53 serially connected between ground and point 50'. Capacitor 54 is connected in shunt to resistor 53 across which a portion of the unidirectional voltage between ground and point 50' exists. This last voltage is impressed between the grid and cathode of amplifier 18 through a resistor 55. An adjustable high positive bias voltage is impressed on the cathode 56 of amplifier 18 by a voltage divider including resistor 57 connected between the cathode and the positive terminal of source 27, and by adjustable cathode resistor 58, which is bypassed by capacitor 59.

In considering the operation of the circuit just described, it will first be assumed that no signal of an appreciable amplitude is being received. Under these conditions, the control grid 30 of limiter 15, which grid is connected to the anode of limiter 15 by resistor 32, is maintained at a slightly positive potential with respect to its grounded cathode. Resistor 32 is made large enough so that the voltage drop across it resulting from grid current is almost equal to the potential between the anode of limiter 15 and ground. The resulting small positive voltage on the grid 30 causes a relatively high anode current to flow through resistor 50. The consequent increased voltage drop across this resistor 50 reduces the potential at the anode of limiter 16 and at point 50' to a relatively low value. This reduced unidirectional voltage appears across the voltage divider made up of resistors 52 and 53, and a predetermined part is applied to the grid 41 of audio amplifier 18 through a large grid resistor 55. The cathode 56 of amplifier 18 is maintained at a positive potential, which exceeds that appearing on the grid under these no signal conditions by an amount sufficient to cause cut-off of the anode current and thus render the amplifier inoperative.

The bias voltage on cathode 56 is readily adjustable to obtain this condition by adjustment of adjustable resistance 58. Since in this embodiment of the invention the control voltage used for silencing is applied to the grid of a sensitive audio frequency amplifier, that control voltage must be free of audio and radio frequency components. To that end the resistor 50, across which

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the control voltage appears, is well bypassed by capacitor 51. Resistor 52 and capacitor 54 provide additional radio and audio frequency filter action. The time constant of the resistance and capacity combination in this control voltage divider and audio frequency filter network is desirably such that the control voltage, and thus the silencing, or squelch, action, follow rapid manual tuning of the receiver in order to give inter-station noise suppression as the receiver is tuned away from signals of satisfactory level.

In addition to the action of the combined amplitude limiter and signal responsive control device 16 in limiting a received carrier wave, producing a rectified unidirectional voltage on the grid 30 of device 16, and amplifying that unidirectional voltage to produce a control voltage at the point 50', whereby in the absence of a carrier wave the signal reproducer 20 is silenced or muted, the device 16 acts by reason of its reduced resistance between its anode and cathode in the absence of a carrier wave or in the presence of a carrier wave of reduced intensity to attenuate very greatly voltages such as carrier wave or noise voltages transferred through the device 16 to the frequency modulation detector including discharge device 17. This attenuation may be viewed as the result of damping which causes mismatching of the anode resistance of device 16 with the input impedance of the frequency modulation detector, and which causes a great reduction in efficiency of the frequency modulation detector thereby, for a given frequency shift of the carrier wave, less signal voltage is produced. Since this attenuation is produced whenever a carrier wave of reduced intensity is received or whenever noise voltage in the absence of a carrier wave is received, such that a control voltage is produced at point 50', two actions simultaneously assist each other in muting or silencing the receiver. One of these actions is the muting or silencing of the receiver by the control voltage developed at point 50', and the other is the great attenuation of signals transferred from the device 16 to the frequency modulation detector and then to the signal reproducer 20. The cooperation of these two simultaneous actions results in a muting or silencing action of the receiver which takes place over a remarkably small range of carrier wave intensities appearing at the input of the receiver.

Assume now that a signal of satisfactory level is received. When a carrier wave is applied to the grid 30 of combination limiter and signal responsive control device 16, the grid assumes a negative bias. This negative grid bias increases with excitation because of the steady component of rectified voltage across resistor 32 arising from rectification of the wave applied to grid 30 through capacitor 31. When the grid becomes negative, the anode current of the limiter 16 becomes relatively low and the voltage drop across resistor 50 is greatly reduced. Since the potential at point 50' is equal to the voltage of source 27 minus the voltage drop across resistor 50, the effective positive potential at the point 50' and therefore at the grid 41 of tube 18 is increased. As has been heretofore explained, the cathode 56 of audio amplifier 18 operates with a positive bias. However, when the bias on the grid 41, which in this case is positive with respect to ground, approaches or becomes equal to the positive bias on the cathode, the amplifier becomes operative.

It is desirable that, in the absence of a carrier wave on the grid 30 of the limiter 16, the

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grid be kept at a slightly positive potential with respect to the cathode of limiter 16. Under usual conditions of reception, noise voltages are received by the receiver and appear on the grid 30 of limiter 16 in sufficient intensity to be rectified there and to maintain the grid 30 at a slightly negative potential with respect to the cathode of limiter 16, unless means be provided to offset this slightly negative potential and maintain the grid positive in the presence of such noise voltages. Without such means for maintaining the grid 30 positive, the impression of a strong carrier wave on the grid 30 would cause relatively little change in the anode current of limiter 16 and would reduce the usefulness of the limiter as an amplifier for the control voltage developed on the grid 30 by rectification of an incoming carrier wave.

By providing the means comprising resistors 32 and 25 for maintaining grid 30 in the absence of a carrier wave slightly positive with respect to the cathode of limiter 16, the space current of limiter 16 is maintained large in the absence of a carrier, even in the presence of noise voltages of substantial magnitude. Consequently, the space current changes over a very large range from this large current to a small current when a carrier wave of satisfactory intensity is rectified upon the grid 30 and produces a control voltage for amplification through limiter 16 to remove silencing or muting from the receiver. It must be borne in mind that, while the provision of means for maintaining grid 30 positive with respect to the cathode of limiter 16 in the absence of a carrier wave is desirable because it enhances the action of limiter 16 in amplifying the control voltage, limiter 16 nevertheless acts to some extent in amplifying a rectified control voltage on the grid 30 even though such a positive voltage is not applied to the grid.

It is at present believed that in large part of maintenance of muting or silencing of the receiver in the presence of large noise voltages, although such muting or silencing is removed in the presence of relatively small carrier waves, is due to the action of the control device 16 as a rather poor integrating circuit. It has been pointed out that rectification of noise and carrier wave voltages on grid 30 of the control device 16 takes place and that these rectified voltages are amplified through the device 16 to appear as control voltages at point 50'. In the presence of a carrier wave continuously received, the rectified voltages on grid 30, which voltages charge coupling condenser 31 so as to change the average voltage of grid 30, stay constant and are a function of the intensity of the received carrier wave. On the other hand, noise voltages of the type whose energy is a discontinuous or irregular function of time are rectified on the grid 30 and charge the condenser 31 but to relatively a much lower average voltage because of the greater losses in the rectification circuit.

In other words, instantaneous rectified voltages of high intensity appearing relatively infrequently on the grid 30 are dissipated at a relatively greater rate than smaller rectified voltages. Therefore, assuming in one case that a continuously received carrier wave is impressed on the grid 30 and has a certain power, it produces a certain rectified voltage across condenser 31. When a noise voltage, whose energy is received in more or less discrete lumps, is impressed on the grid 30, the total power being exactly the same as that for the continuously

received carrier wave, the rate of energy dissipation is much greater for the noise voltage, whose peak intensities are necessarily greater than the intensity of the carrier wave even though such peaks do not occur as frequently as half cycles of the carrier wave, and rectification of the noise voltage therefore produces a smaller average potential across the condenser 31 than does rectification of the carrier waves.

It is desirable that the grid resistor 55 be made high to prevent the impression of high positive voltages on the grid of amplifier 18 which would tend to introduce distortion on very strong signals.

To summarize the operation of this embodiment of the invention, when a signal of satisfactory level is applied to the grid 30 of the limiter and signal responsive control device 16, the grid becomes negative because of the component of rectified voltage across the resistor 32, the anode current drops and a relatively high positive voltage appears between point 50' and ground. Part of this positive voltage is applied by means of an audio frequency filter and voltage divider network to the grid 41 of first audio amplifier 18. This positive bias is approximately equal to a pre-established positive bias on the cathode 56 and the amplifier becomes operative.

When the signal disappears from the grid 30 of limiter-control device 16, the grid becomes positive because of its connection by resistor 32 to a source of high positive voltage, the anode current becomes high, the voltage drop across resistor 50 greatly reduces the potential applied to the voltage divider 52 and 53 from point 50', and the grid 41 of amplifier 18 becomes less positive than the cathode 56 with respect to ground and renders the audio amplifier inoperative, thus silencing the receiver.

It may further clarify the operation of this invention to consider a specific embodiment for which circuit constants are given purely by way of illustration of one form of this specific embodiment. As illustrative of this specific form, the following circuit constants are given for the circuit of Figure 1:

Tube 15—7C7
 Tube 16—7C7
 Tube 18—7F7 (one section)
 Resistor 32—220,000 ohms
 Resistor 50—82,000 ohms
 Resistor 52—500,000 ohms
 Resistor 54—100,000 ohms
 Resistor 55—45 megohms
 Resistor 57—50,000 ohms
 Resistor 58—500–10,000 ohms adjustable
 Capacitor 31—50 μ f
 Capacitor 51—.1 μ f
 Capacitor 54—.1 μ f
 Capacitor 59—15 μ f
 +B power supply 27—250 volts

With the constants shown the following operating conditions may be secured:

	No Signal	Strong Signal
D. C. voltage at the grid 30 of limiter 16....	+½ volts	-6 volts
D. C. voltage at point 50'.....	+25	140
D. C. voltage at junction of resistors 52 and 53.....	+4.0	22.4

For the sake of clarity the explanation of the silencing network of my invention has thus far been limited to the extreme boundary conditions

of no signal and strong signal. While these conditions actually exist with certain types of equipment, it is generally desirable that the silencing network hold the receiver inoperative until there appears a certain minimum level of signal which is necessary for satisfactory noise free reception. This minimum value of signal at which the receiver becomes operative is commonly referred to as the threshold level. The silencing network of my invention is arranged so that the threshold level may be adjusted over a wide range of input signals so as to meet satisfactorily various operating conditions. In the embodiment of Figure 1 this threshold level can be simply and effectively adjusted by varying the value of resistor 58, which action changes the cathode bias on audio amplifier 18.

While the silencing network of my invention could be operated with only the limiter and signal responsive control device 16 acting as a limiter and the preceding discharge device 15 operating as a carrier frequency amplifier, it is preferred to use at least two limiters as shown in Figure 1. It is desirable to have other limiters in front of the limiter 16 because of the reduction in noise voltage applied to the grid of the limiter 16. When working with highly sensitive equipment of the type used in point to point communication, weak signals are often accompanied by a substantial level of noise, which in some respects resembles the carrier signal in character. If this noise is amplified in the earlier stages of a receiver and applied to the grid 30 of the limiter and control device 16 without prior limiting, it is rectified and tends to develop a voltage across resistor 32 and thus change the bias on the grid of the limiter. This in turn changes the operating threshold point of the silencing circuits. It can be seen that the multiple limiter, in addition to its advantages when used in connection with conventional frequency modulation receivers, presents the added advantage when used with the invention of maintaining favorable operating conditions for the silencing circuits in the presence of a relatively high level of background noise.

In Figure 2, there is shown a graph of input signal intensities, plotted as abscissae, against corresponding anode voltages of limiter 16, plotted as ordinates. The values are those for a circuit whose constants are those of the illustrative example. Curve 16' illustrates the measured relation between the two named parameters.

The receiver of this example gives effective amplitude limiting action when a signal of 7 microvolts or greater is applied to its input. When no signal is received, point 50' is at a positive potential of 25 volts with respect to ground. As the input signal is increased, the voltage with respect to ground at point 50' increases rapidly and rises to 115 volts when an input signal of 10 microvolts is applied. It rises further to 140 volts when the applied signal is 100 microvolts.

Owing to the steepness of the curve 16' below 10 microvolts input, the threshold level for silencing may be satisfactorily set for a considerable range of signal inputs. That is, over this range of input signal intensity a minimum change of intensity in the input signal is sufficient to change the control voltage at point 50' from a condition in which the receiver is silenced to one in which the receiver is operative.

In Figure 3 is shown an embodiment of the invention which differs somewhat from the embodiment of Figure 1. In Figure 3 many ele-

ments are identical with those shown in Figure 1, and like elements in the two figures have been given identical reference numbers. The limiters 15 and 16 are similar to those of Figure 1 except that resistor 60, which connects the grid 30 of the second limiter 16 to the positive terminal of source 27 is used in place of resistor 32 which is in Figure 1 connected between the grid 30 of limiter 16 and the anode of limiter 15. In the first audio stage which includes amplifier 18, an on-off switch 61 for the muting circuit is provided, which in the off position connects the lower end of grid resistor 55 directly to the cathode 56 of amplifier 18. A diode 62 whose function is to prevent the grid 41 of amplifier 18 from becoming more positive than the cathode 56, is connected from the lower end of grid resistor 55 to a tap 58' on cathode resistor 58.

In operation, the circuit of Figure 3 is similar to Figure 1. The resistor 60 serves essentially the same function as the resistor 32 of Figure 1. That is, in the absence of signal, a positive voltage is applied to the grid 30 of limiter 16. This positive potential is small because the resistance of resistor 60 is high enough so that the voltage drop across resistor 60, resulting from the flow of grid current through 60, is almost equal to the supply voltage of source 27. When an appreciable signal is applied to the grid 30 of limiter 16 through coupling capacitor 31, the grid becomes negative because of the steady component of rectified voltage appearing across resistor 60.

It is sometimes desirable to be able to stop the operation of the noise suppression circuit. This is particularly true in communications receivers. With the noise suppression circuit inoperative, it is possible to listen to signals below the pre-established threshold level or to hear the set noise which exists in the absence of a satisfactory signal. The no signal roar of a sensitive receiver furnishes the operator with a rough indication that his receiver is performing satisfactorily.

For this purpose, the on-off switch 61 provides a convenient means of eliminating or restoring the noise suppressor action. When the switch is open, the silencing network is in operation, and with the switch closed the lower end of grid resistor 55, to which is applied a portion of the control voltage from the point 50', is connected to the cathode 56 of amplifier 18, thus substantially eliminating the control voltage from the grid 41 of amplifier 18 and causing the amplifier 18 to operate as a normal zero bias audio frequency amplifier regardless of the control voltage developed across capacitor 51 and applied to voltage divider 52 and 53.

In the circuit of Figure 1 satisfactory operating conditions for the audio frequency amplifier 18 are maintained, even though the control voltage appearing at the junction of resistors 52 and 53 and applied to grid resistor 55 becomes more positive than the positive fixed bias placed on the cathode 56 of amplifier 18. This result is achieved by using a grid resistor 55 with a relatively high resistance. The voltage drop across the resistor when grid current flows in amplifier 18 is sufficient to prevent the grid from ever becoming objectionably positive with respect to the cathode. If it is desired to use a small grid resistor 55, or if it is necessary to prevent positive swing of the grid at high signal levels, the diode 62, connected as shown in Figure 3, may be used. If the voltage appearing at the junction of resistors 52 and 53 becomes positive with respect to tap 58' of resistor 58 connected to the cathode

of amplifier 18, the diode 62, whose anode is connected to the junction of resistors 52 and 53 and whose cathode is connected to the tap 58', conducts and holds the potential at this point close to the potential at tap 58', which may be adjusted to be at the potential of cathode 56 or may be negative with respect thereto.

It is apparent, of course, that when the cathode of the diode 62 is at the voltage of a point on the cathode resistor 58 somewhere between the cathode and ground, the grid cannot become more positive than a certain pre-established negative potential with respect to the cathode. For example, if the tap 58' be at a point on resistor 58 such that the potential of the cathode of diode 62 is one volt less positive than the positive bias on the cathode 56 of amplifier 18, the potential on the grid 41 of amplifier 18 is limited to a positive voltage which is approximately one volt less positive than the cathode potential of amplifier 18. That is, the grid 41 of amplifier 18 must always be negative with respect to the cathode 56 by at least one volt.

The diode 62 and amplifier 18 may be in one envelope and may, if it is not desired to maintain grid 41 always negative with respect to cathode 56, have a common cathode.

In Figure 4 is shown a circuit embodying another form of the invention in which the first audio frequency amplifier is muted by reducing the voltage applied to an electrode of the amplifier other than the control grid. Many elements of the circuit are identical to those of Figure 1 and like elements in the figures have been given like reference characters. In this embodiment point 50', between which and ground the control voltage exists, is connected through a filter comprising resistor 63 and capacitors 51 and 64 connected between the ends of resistor 63 and ground, and through an anode resistance 45 to the anode of amplifier 18, and through a resistor 45' to the screen grid of amplifier 18. The grid return path for amplifier 18 indicates resistor 65, which is connected from grid 41 to cathode 56 of amplifier 18. Capacitor 44 provides a path for the audio frequency signal from the volume control 43 to the first audio frequency stage. Capacitor 46 provides a path for the audio frequency signal from the output of amplifier 18 to succeeding audio frequency stages or signal utilization apparatus.

While I have illustrated the audio amplifier 18 as a conventionally connected pentode in which the anode and screen grid voltages are supplied from point 50', it is to be understood that this control voltage may be supplied only to the screen grid or, if a triode amplifier be used, may be supplied only to the anode thereof.

The operation of the circuit of Figure 4, whereby a control voltage is developed between point 50' and ground, which voltage is a function of input signal intensity, is the same as the operation described for Figures 1 and 3. In this embodiment of my invention in Figure 4, the positive potential between point 50' and ground, which potential is high when a satisfactory signal is being received and low in the absence of signal, is smoothed by capacitor 51 and further smoothed by the filter formed by resistor 63 and capacitor 64. The unidirectional voltage across capacitor 64 is used as the voltage source for the audio amplifier 18. When no signal is being received, the voltage across capacitor 51 is low. Since this voltage is the anode voltage for amplifier 18, the gain of the first audio stage including amplifier

18 is sufficiently small to provide effective muting of the receiver. When a satisfactory level of signal is received, the voltage across capacitor 51, and thus the anode voltage of amplifier 18, is high enough to operate the amplifier 18 in normal fashion.

This form of my invention, like the embodiment shown in Figure 1, is applicable to conventional frequency modulation broadcast receivers with only the addition of a few relatively low cost resistors and capacitors. Extra tubes are not needed and no complex circuit changes or troublesome manufacturing adjustments are involved.

In Figure 5 there is shown another embodiment of the invention which is similar in operation to that of Figure 1, and in which corresponding circuit elements have been given identical reference characters. In the circuit of Figure 5, the current or voltage change which takes place in the output circuit of the second limiter and signal responsive control device 16, operates a relay 70 whose contacts are connected to a signal translating channel of the receiver to silence the receiver. The use of an electromagnetic relay in the silencing circuit has the advantages that its operation is instantaneous when the threshold signal level is reached and that its characteristics can be controlled so that a time delay on the make or break of the contacts is secured. This latter feature is useful when it is required to tune manually between two stations remote on the dial and hold the receiver silent for all intermediate stations.

The action of the circuit which results in a change of current in the anode circuit of limiter 16 and a change in the potential at point 50' has been explained in the descriptions of Figures 1 and 3.

In the circuit of Figure 5 the relay 70 is connected so that the anode and screen current of the limiter 16, which current is supplied from source 27, passes through the electromagnetic coil 71 of the relay. The relay contacts 72 are connected between ground and the ungrounded terminal of the sound reproducer 20, so that closing the relay contacts silences the receiver.

Considering now the operation of the system just described, the relay 70 is adjusted so that, when a signal above the desired threshold level is present, the sum of the anode and screen currents passing through the electromagnetic coil 71 of the relay are insufficient to close the contacts 72 and the receiver operates in a normal manner. Whenever the input signal drops below the threshold level, the anode current increases, as has been previously explained, and the relay acts to close contacts 72 which short circuit the sound reproducer 20 and thus render the receiver inoperative.

Figure 6 illustrates a muting relay 73 connected with an amplifier 74 to produce silencing in response to changes of potential at point 50'. While it is convenient and economical to place a relay directly in the supply voltage circuit of the limiter and control device 16, increased sensitivity is attained in the arrangement of Figure 6 by placing the relay in the output circuit of an amplifier which amplifies the control voltage at point 50' or other control characteristic developed by limiter and control device 16 and influences relay 73 correspondingly. Resistors 75 and 76 constitute a voltage divider across which the voltage between point 50' and ground is impressed. Capacitor 77 smooths the voltage across resistor 76

which voltage is applied between the grid and cathode of amplifier 74. Voltage source 78 provides a positive bias for the cathode of amplifier 74 with respect to its grid and voltage source 27 provides the anode current for amplifier 74 which current operates the relay 73. Relay contacts 79 short circuit the sound reproducer 20 and thus render the receiver inoperative, and contacts 80 complete a circuit including pilot lamp 81 and voltage source 82. Many elements in this Figure 6 are similar to those illustrated in previously described figures and are given like reference characters.

Considering now the operation of the circuit of Figure 6 and referring particularly to such details as distinguish it from circuits 1, 3, 4 and 5, the positive bias on the cathode of amplifier 74 is so adjusted that the amplifier is operating at or near anode current cut-off when the voltage across resistor 76 is equal to that which exists when a signal at or near the desired threshold level is applied to the input of limiter 16. The anode current of amplifier 74 is then below the current required to open the contacts of relay 73, so that the normally closed contacts 79 short circuit the sound reproducer 20, silencing the receiver. Contacts 80 under the same conditions maintain the circuit of lamp 81 keeping it lit, and indicating that the receiver is in operation, even though no audio signal is heard.

When a signal above the threshold is applied to the input of limiter 16, the positive potential across capacitor 51 increases and the positive potential on the grid of amplifier 74 also increases, so that anode current flows, causing relay 73 to open contacts 79 and 80 to remove the receiver silencing and turn out pilot lamp 81. While the lamp 81 is shown connected so that it lights when the receiver is silenced, it is clear that a simple change of relay contact connections makes it possible to have the lamp light when muting is removed in the presence of a satisfactory signal.

Figure 7 illustrates an embodiment of my invention in which silencing is achieved by rendering the frequency modulation detector inoperative. Many elements are similar to those of previous circuits and are given the same reference characters. The unidirectional control voltage appearing across capacitor 51 is applied between ground and the center of the discriminator transformer secondary inductance 35 through a filter comprising resistor 90, capacitor 91 and resistor 92. The center of inductance 35 is also connected to the junction of load resistors 38 and 39 through coupling capacitor 93. Resistors 94 and 95 serially connected from the positive terminal of source 27 to ground constitute a voltage divider. The cathodes 96 of the double diode 97 are maintained at a positive potential with respect to ground by connecting them to an adjustable tap 98 on resistor 95. Other elements of the circuit of Figure 7 have been explained in the description of previous circuits.

In operation, and referring particularly to the elements which are important in the operation of this embodiment of the invention, the positive bias voltage on cathodes 96, when no signal is applied to the input of limiter 16, is enough greater than the positive voltage between point 50' and ground, which voltage is applied to the diode anodes 99 through the filter comprising resistors 90 and 92 and capacitor 91, to make rectification in diodes 97 impossible and thus prevent

the development of an audio frequency signal across load resistors 38 and 39.

When a signal of satisfactory level is applied to the input of limiter 16, there is an increase in the positive voltage between point 50' and ground which results in an increase in the positive potential of diode anodes 99 so that they become at least as positive as cathodes 96. This restores normal operation of the frequency modulation detector. Resistor 92 serves to isolate the diode anodes 99, as well as the center of inductance 35, from ground for high frequencies. It is desirable that the other resistor 90 of the filter, taken together with resistor 92, be of high enough resistance to prevent the diode anodes from assuming a potential so positive with respect to their cathodes 96 that appreciable discharge current is drawn. It is, however, not desirable that resistor 92 be so large with respect to resistors 38 and 39 that appreciable signal voltage is developed across resistor 92. This embodiment of my invention is best suited for application in a frequency modulation receiver which is used for the reception of intermittent transmissions.

My invention has been explained in terms of the well known and extensively used frequency modulation system of carrier signal transmission and reception. It is clear, however, from the description that the principles of my invention are equally applicable to any system using any signal transmission system other than the commonly used amplitude modulation system. The terms phase modulation, wave length modulation, and timing modulation are sometimes used to indicate certain known systems of carrier modulation which in general depend on other than amplitude modulation.

In fact, systems utilizing modulation of various characteristics of pulses, including the modulation of the intensity thereof, may be used with my invention, so long as the system utilizes means for limiting intensity of the carrier wave in the receiver. When the term "frequency modulated carrier waves" or the like is used herein, the term signifies any carrier wave which has some characteristic other than amplitude modulated in such a fashion that the wave may be limited in intensity and the signal modulated thereon may subsequently be reproduced. It is to be understood that it is within the scope of my invention to use a suitable detector for any particular type of such "frequency modulated wave."

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

I claim:

1. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying said carrier wave to produce a unidirectional voltage, for amplifying said unidirectional voltage to produce a control voltage, and for limiting the intensity of said carrier wave below a predetermined intensity, means for utilizing a component of said carrier wave limited by said device, and means responsive to said control voltage for changing said utilizing means from an inoperative condition to an operative condition.

2. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged to be effective upon the reception of a carrier wave of greater than a predetermined intensity to limit the intensity of said carrier wave below a predetermined intensity, and effective upon the reception of any carrier wave to rectify said carrier wave by utilizing said resistor means to produce a unidirectional voltage and to amplify said unidirectional voltage to produce a control voltage, means for detecting and reproducing a signal in accordance with which a carrier wave limited by said device is modulated, and means responsive to said control voltage for changing said detecting and reproducing means from an inoperative condition to an operative condition.

3. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying said carrier wave to produce a unidirectional voltage, for amplifying said unidirectional voltage to produce a control voltage, and for limiting the intensity of said carrier wave below a predetermined intensity, means for utilizing said carrier wave limited by said device, and means responsive to said control voltage for altering operation of said utilizing means.

4. In combination, a source of frequency modulated carrier waves, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means arranged for limiting below a predetermined intensity on said anode the intensity of said carrier wave impressed on said control electrode, means including said control electrode and said resistor means for rectifying said carrier wave to produce a unidirectional voltage, means for maintaining said control electrode at a positive potential with respect to said cathode in the absence of a carrier wave whereby noise voltage impressed on said control electrode in the absence of a carrier wave does not substantially reduce the electron discharge between said anode and cathode, means including said discharge device for amplifying said unidirectional voltage to produce a control voltage on the anode of said discharge device, means for utilizing said carrier wave on said anode, and means responsive to said control voltage for altering the performance of said utilizing means.

5. In combination, a source of frequency modulated carrier waves, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for limiting below a predetermined intensity on said anode the intensity of said carrier wave impressed on said control electrode, means including said control electrode and said resistor means for rectifying said carrier wave to produce a unidirectional voltage, means for maintaining said control electrode at a positive potential with respect to said cathode in the absence of a carrier wave whereby noise voltage impressed on said control electrode in the absence of a carrier wave does not substantially reduce the electron discharge between said anode and cathode, means including said discharge device for amplifying said unidirectional voltage to produce a control voltage on the anode of said discharge device, means for utilizing said carrier wave on said anode, and means responsive to said control voltage for changing said carrier wave utilizing means from

an inoperative condition to an operative condition.

6. In combination, a source of high frequency voltages including noise voltages and carrier wave frequency modulated voltages whose relative intensity varies from time to time, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, and arranged for limiting said frequency modulated voltages below a predetermined total intensity, for rectifying said voltages by utilizing said resistor means to produce a unidirectional voltage, and for amplifying said unidirectional voltage to produce a control voltage, means for reproducing a signal from a characteristic modulation of said voltages limited by said device, and means responsive to an increase of said control voltage above a predetermined intensity for changing said reproducing means from an inoperative condition to an operative condition.

7. In combination, a source of high frequency voltages including noise voltages and carrier wave frequency modulated voltages whose relative intensity varies from time to time, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for limiting said voltages below a predetermined total intensity, for rectifying said voltages by utilizing said resistor means to produce a unidirectional voltage, and for amplifying said unidirectional voltage to produce a control voltage, means for reproducing a signal from a characteristic modulation of said voltages limited by said device, means responsive to an increase of said control voltage above a predetermined intensity for changing said reproducing means from an inoperative condition to an operative condition, and means for adjusting the predetermined intensity above which said control voltage causes said last means to change said reproducing means from an inoperative to an operative condition.

8. In combination, a source of a frequency modulated carrier wave, said source including a source of potential, a single electron discharge device having a cathode, an anode, and a control electrode and arranged for limiting below a predetermined intensity on said anode the intensity of said carrier wave impressed on said control electrode, means including said control electrode for rectifying said carrier wave to produce a unidirectional voltage, means including said discharge device for amplifying said unidirectional voltage to produce a control voltage on the anode of said discharge device, means including said potential source for maintaining said control electrode at a positive potential with respect to said cathode in the absence of a carrier wave whereby a carrier wave rectified on said control electrode substantially reduces the electron discharge between said anode and cathode and amplifies said unidirectional voltage in great degree, means for utilizing a component of said carrier wave limited on said anode, and means responsive to said control voltage for altering the performance of said utilizing means.

9. In combination, a source of a frequency modulated carrier wave comprising an electron discharge amplifier device having an anode on which said carrier waves appear and on which a positive potential exists, a single electron discharge device having a cathode, an anode, and a control electrode and arranged for limiting below a predetermined intensity on said anode the intensity of said carrier wave impressed on

said control electrode, means including said control electrode for rectifying said carrier wave to produce a unidirectional voltage, means including said single discharge device for amplifying said unidirectional voltage to produce a control voltage on the anode of said single discharge device, means including a conductive connection between the anode of said amplifier device and said control electrode for maintaining said control electrode at a positive potential with respect to said cathode in the absence of a carrier wave whereby a carrier wave rectified on said control electrode substantially reduces the electron discharge between said anode and cathode and amplifies said unidirectional voltage in great degree, means for utilizing a component of said carrier wave limited on said anode of said single discharge device, and means responsive to said control voltage for altering the performance of said utilizing means.

10. In combination, a source of a frequency modulated carrier wave subject to interfering noise voltages, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying said carrier wave to produce a unidirectional voltage, said discharge device being so arranged that a carrier wave in which the energy is substantially uniformly distributed produces a rectified voltage by said discharge device substantially greater than is produced by noise voltages of substantially the same energy content in which the energy is non-uniformly distributed with respect to time, said discharge device being arranged for amplifying said unidirectional voltage to produce a control voltage and for limiting the intensity of said carrier wave below a predetermined intensity, means for utilizing a component of said carrier wave limited by said discharge device, and means responsive to said control voltage for altering the performance of said utilizing means.

11. In combination, a source of a frequency modulated carrier wave, a pair of cascade connected electron discharge devices arranged for limiting the intensity of said carrier wave below a predetermined intensity, the second of said two cascade connected discharge devices being connected to associated resistor means and being arranged for rectifying said carrier waves to produce a unidirectional voltage and for amplifying said unidirectional voltage to produce a control voltage, means for utilizing a component of said carrier wave limited by said second device, and means responsive to said control voltage for altering the performance of said utilizing means.

12. In combination, a source of a frequency modulated carrier wave, resistor means, a single electron discharge device for limiting the intensity of said carrier wave below a predetermined intensity, said single electron discharge device having an anode and a cathode and being of the type in which large changes of voltage between said anode and cathode do not substantially affect the discharge current therebetween, said discharge device being connected and associated with said resistor means and being arranged for rectifying said carrier wave to produce a unidirectional voltage and for amplifying said unidirectional voltage to produce a control voltage on said anode, means for utilizing a component of said carrier wave limited by said device, and means responsive to said control voltage for altering the performance of said utilizing means.

13. In combination, a source of a frequency

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modulated carrier wave, a single electron discharge device for limiting the intensity of said carrier wave below a predetermined intensity, said single electron discharge device having a cathode, a control electrode, a screen electrode, an anode, and associated resistor means, said carrier wave being impressed on said control electrode and appearing in limited intensity on said anode, said screen electrode being arranged to provide electrostatic shielding between said control electrode and said anode, whereby the intensity of said limited carrier wave on said anode is not undesirably increased by capacitive coupling of said unlimited carrier wave on said control electrode to said anode, said discharge device being arranged for rectifying said carrier wave by utilizing said resistor means to produce a unidirectional voltage and for amplifying said unidirectional voltage to produce a control voltage on said anode, said discharge device by reason of the presence of the screen electrode between said anode and said control electrode being of the type in which large changes of voltage between said anode and cathode do not substantially affect the discharge current therebetween, whereby said amplifying means amplifies said unidirectional voltage greatly, means for utilizing a component of said carrier wave limited by said discharge device, and means responsive to said control voltage for altering the performance of said utilizing means.

14. In combination, a source of an unlimited frequency modulated carrier wave, means for deriving a control voltage from said carrier wave, means for limiting the intensity of said carrier wave below a predetermined intensity, means for utilizing said limited carrier wave, said limiting means being arranged to reduce substantially the sensitivity of said utilization means upon reduction in intensity below said predetermined intensity of said unlimited carrier wave, and means responsive to said control voltage for making said utilization means inoperative substantially simultaneously with a reduction of sensitivity of said utilization means.

15. In combination, a source of an unlimited frequency modulated carrier wave, means for deriving a control voltage from said carrier wave, means for limiting the intensity of said carrier wave below a predetermined intensity, means for detecting and reproducing a signal in accordance with which said carrier wave is modulated, said limiting means being arranged to reduce substantially the sensitivity of said detecting and reproducing means upon reduction in intensity below said predetermined intensity of said unlimited carrier wave, and means responsive to said control voltage for making said detecting and reproducing means inoperative substantially simultaneously with a reduction of sensitivity of said detection and reproducing means.

16. In combination, a source of a carrier wave whose frequency is modulated in accordance with a signal, means for limiting the intensity of said carrier wave below a predetermined intensity and for deriving a control voltage from said carrier wave, means for detecting the signal in accordance with which the frequency of said carrier wave is modulated and for reproducing said signal, means for producing increasing amounts of attenuation of said carrier wave between said limiting means and said detecting means as the intensity of said carrier wave decreases below said predetermined intensity, and means responsive to said control voltage for mut-

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ing said detecting and reproducing means substantially simultaneously with an increase of attenuation of said carrier wave upon a reduction below said predetermined intensity.

17. In combination, a source of frequency modulated carrier waves, tuning means for selecting a desired one of said carrier waves of a particular frequency, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying a selected carrier wave to produce a unidirectional voltage and for amplifying said unidirectional voltage to produce a control voltage, said discharge device being arranged for limiting below a predetermined intensity said selected carrier wave, means for reproducing a signal in accordance with which said selected and limited carrier wave is modulated, and means responsive to said control voltage to make said reproducing means operative to reproduce a signal from a selected and limited carrier wave only after a predetermined time after the appearance of said control voltage, said predetermined time being sufficiently short that operation of said tuning means at normal speed makes said reproducing means inoperative at substantially all times except when a carrier wave is selected.

18. In combination, a source of frequency modulated carrier waves, tuning means for selecting a desired one of said carrier waves of a particular frequency, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying a selected carrier wave to produce a unidirectional voltage and for amplifying said unidirectional voltage to produce a control voltage, said discharge device being arranged for limiting below a predetermined intensity said selected carrier wave, means for reproducing a signal in accordance with which said selected and limited carrier wave is modulated, and means responsive to said control voltage to make said reproducing means operative to reproduce a signal from a selected and limited carrier wave only after a predetermined time after the appearance of said control voltage, said predetermined time being at least sufficient to prevent said reproducing means from becoming operative in the presence of a transient voltage from said source when no carrier wave is selected.

19. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode and associated resistor means arranged for limiting the intensity of said carrier wave below a predetermined intensity, said discharge device being arranged for rectifying said carrier wave by utilizing said resistor means to produce a unidirectional potential and for amplifying said unidirectional potential to produce a control voltage, means for detecting and reproducing a signal in accordance with which said limited carrier wave is modulated, said detecting and reproducing means comprising an electron discharge device having a cathode, a control electrode, an anode, and means for impressing said detected signals between said control electrode and cathode to appear in amplified intensity between said cathode and anode, means in circuit between said cathode and anode for adjusting the potential of said cathode with respect to said control electrode whereby the point may be adjusted at which said discharge device ceases to transfer said detected signal from said control

electrode to said anode upon increasingly negative potentials on said control electrode with respect to said cathode, and means for impressing said control voltage on said control electrode comprising a resistance in series between said amplifying means and said control electrode of sufficient size to prevent said control electrode from assuming a substantially positive potential with respect to said cathode upon great increase of said control voltage, whereby great changes of said amplified control voltage may be utilized to control said detecting and reproducing means without destroying said control electrode or causing substantial distortion of said detected signal.

20. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for limiting the intensity of said carrier wave below a predetermined intensity, said discharge device being arranged for rectifying said carrier wave by utilizing said resistor means to produce a unidirectional potential and for amplifying said unidirectional potential to produce a control voltage, means for detecting and reproducing a signal in accordance with which said limited carrier wave is modulated, said detecting and reproducing means comprising an electron discharge device having a cathode, a control electrode, an anode, and means for impressing said detected signals between said control electrode and cathode to appear in amplified intensity between said cathode and anode, means for manually adjusting the potential between said control electrode and cathode whereby the point may be adjusted at which said discharge device ceases to transfer said detected signal from said control electrode to said anode upon increasingly negative potentials on said control electrode with respect to said cathode, and means for impressing said control voltage on said control electrode comprising a resistance in series between said amplifying means and said control electrode of sufficient size to prevent said control electrode from assuming a substantially positive potential with respect to said cathode upon great increase of said control voltage, whereby great changes of said amplified control voltage may be utilized to control said detecting and reproducing means without destroying said control electrode or causing substantial distortion of said detected signal.

21. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying said carrier wave to produce a unidirectional voltage, for amplifying said unidirectional voltage to produce a control voltage, and for limiting the intensity of said carrier wave below a predetermined intensity, means for utilizing said carrier wave limited by said first means, discharge device responsive to said control voltage for changing said utilizing means from an inoperative condition to an operative condition, and means for manually disabling said last means whereby said discharge device and said utilizing means may be operated without being affected by said changing means.

22. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying said carrier wave to pro-

duce a unidirectional voltage, for amplifying said unidirectional voltage to produce a control voltage, and for limiting the intensity of said carrier wave below a predetermined intensity, a second electron discharge device arranged for detecting and reproducing a signal in accordance with which said limited carrier wave is modulated, said second discharge device being normally maintained in a condition without electron discharge, means responsive to said control voltage for impressing upon said second discharge device a potential with such polarity as to render said second discharge device conductive whereby a signal is reproduced by said detecting and reproducing means, said control voltage being subject to such large changes of intensity that said potential applied to said second discharge device produces undesirable results, and means comprising a unilaterally conducting device so connected with said second discharge device as to prevent the production of such undesirable results by said bias potential.

23. In combination, a source of a frequency modulated carrier wave, a single electron discharge device having a cathode, an anode, and a control electrode, and associated resistor means, arranged for rectifying said carrier wave to produce a unidirectional voltage, for amplifying said unidirectional voltage to produce a control voltage, and for limiting the intensity of said carrier wave below a predetermined intensity, a second electron discharge device arranged for detecting and reproducing a signal in accordance with which said limited carrier wave is modulated, means for maintaining said second discharge device in non-conductive condition to prevent reproduction of a signal, and means for impressing said control voltage upon said second discharge device in such polarity as to render said second discharge device conductive in the presence of a carrier wave and the signal demodulated therefrom, whereby said detecting and reproducing means is operative only in the presence of a carrier wave.

24. In combination, a source of a frequency modulated carrier wave, resistor means, a single electron discharge device being connected to said resistor means for rectifying said carrier wave to produce a unidirectional potential, for amplifying said unidirectional potential to cause a decrease in the discharge current flowing through said discharge device upon an increase in the intensity of said carrier wave, and for limiting the intensity of said carrier wave below a predetermined intensity, means for detecting and reproducing a signal in accordance with which said limited carrier wave is modulated, and an electromagnetic relay responsive to the discharge current through said discharge device responsive to an increase in the discharge current through said discharge device for disabling said detecting and reproducing means whereby said reproducing means is operative only in the presence of a carrier wave.

25. In combination, a source of a frequency modulated carrier wave, resistor means, a single electron discharge device being connected to said resistor means for rectifying said carrier wave to produce a unidirectional potential, for decreasing the discharge current flowing through said discharge device in response to an increase of said unidirectional potential upon an increase in the intensity of said carrier wave, and for limiting the intensity of said carrier wave below a predetermined intensity, means for utilizing said limited carrier wave, and an electromagnetic re-

lay responsive to a change in the discharge current flowing through said discharge device for producing a control operation.

26. In combination, a source of a frequency modulated carrier wave, means for deriving a control voltage from said carrier wave, means for limiting the intensity of said carrier wave below a predetermined intensity, means for detecting a signal in accordance with which the frequency of said limited carrier wave is modulated, means for reproducing said detected signal, means for producing increasing amounts of attenuation of said carrier wave between said limiting means and said detecting means as the intensity of said carrier wave falls below said predetermined intensity, and means responsive to said control voltage for making said detecting means inoperative substantially simultaneously with an increase in attenuation of said carrier wave between said limiting means and said detecting means.

27. In combination, a source of a frequency modulated carrier wave, means for deriving a control voltage from said carrier wave, means for limiting the intensity of said carrier wave below a predetermined intensity, means comprising a second electron discharge path for detecting a signal in accordance with which the frequency of said limited carrier wave is modulated, means for reproducing said detected signal, means for producing increasing amounts of attenuation of said carrier wave between said limiting means and said detecting means as the intensity of said carrier wave falls below said predetermined intensity, means for maintaining said second discharge path non-conductive in the absence of a carrier wave, and means responsive to said control voltage for making said second discharge path conductive substantially simultaneously with a decrease in attenuation upon approach of the intensity of a carrier wave to said predetermined intensity, whereby said reproducing means is operative only in the presence of a carrier and changes from operative to inoperative condition upon minimum change of carrier wave intensity.

28. In combination in a frequency modulation receiver including means for receiving a frequency modulated carrier wave and for limiting the intensity of said carrier wave below a predetermined intensity, and means for detecting and reproducing a signal in accordance with which the frequency of said carrier wave is modulated, said limiting means and said detecting and reproducing means each including at least one electron discharge path, means utilizing only

the discharge path of said limiting means for rectifying a carrier wave to produce a unidirectional potential and for amplifying said unidirectional potential to produce a control voltage, and means utilizing only the discharge path of said detecting and reproducing means for disabling said detecting and reproducing means in response to a change in said control voltage resulting from a reduction in the intensity of said carrier wave.

29. In a frequency modulation receiver having a wave translating channel including in part a wave intensity limiting device, first means including a translating device to be operated to produce signal components of said wave in response to reception of waves by said receiver, second means normally rendering said first means inoperative for the reproduction of signal components, a source of frequency modulated waves arranged to be applied to said channel and to be limited in intensity by said wave limiting device, means for developing a control voltage in said limiting device in response to the appearance of the wave applied to said limiting device, said limiting device being arranged to amplify said control voltage, and means operated in response to the amplified control voltage for at least partially nullifying operation of said second means to thereby allow operation of said first means whereby said signal components may be reproduced.

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Certificate of Correction

Patent No. 2,447,564.

August 24, 1948.

CHALON WESLEY CARNAHAN

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 4, line 2, for "include" read *includes*; column 5, line 33, for "thereby" read *whereby*; column 10, line 43, for "indicates" read *includes*; column 12, line 49, and column 13, lines 67 and 68, for "undirectional" read *unidirectional*; column 19, line 63, after "first" insert *discharge device*; line 64, strike out ", discharge device"; column 22, line 15, for "produce" read *reproduce*; lines 22 and 23, for "voltage" read *voltage*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 30th day of November, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.