

Dec. 7, 1948.

R. T. THOMPSON

2,455,450

RADIO RECEIVER NOISE SUPPRESSION CIRCUIT

Filed Jan. 13, 1944

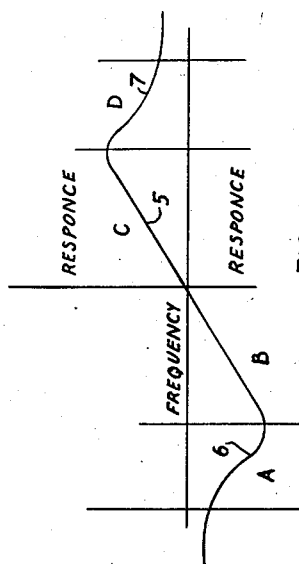
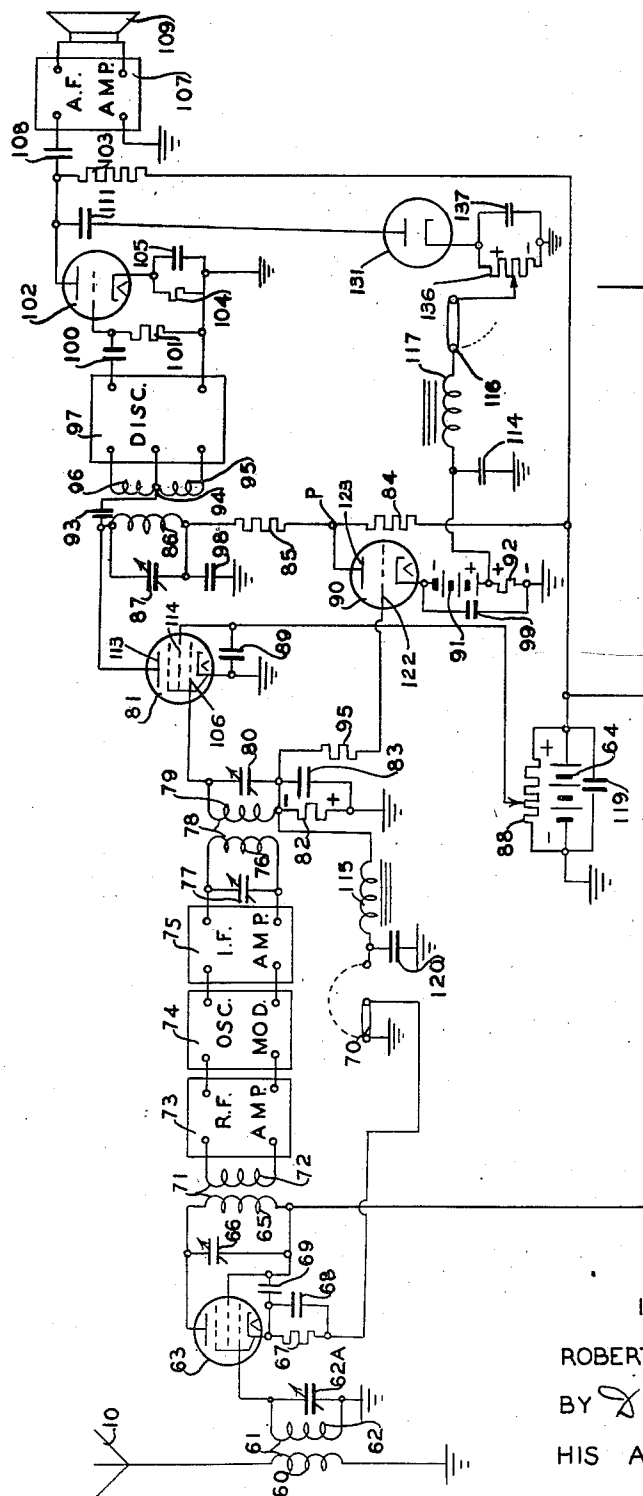


FIG. 1

FIG. 2

INVENTOR

ROBERT T. THOMPSON

BY *David M. Davis*

HIS ATTORNEY

UNITED STATES PATENT OFFICE

2,455,450

RADIO RECEIVER NOISE SUPPRESSION
CIRCUITRobert T. Thompson, Oak Park, Ill., assignor to
Zenith Radio Corporation, a corporation of Illi-
nois

Application January 13, 1944, Serial No. 518,063

3 Claims. (Cl. 250—20)

1

This invention relates to high frequency wave translating apparatus, and more particularly to such apparatus arranged to be responsive to frequency deviation.

Many types of apparatus, such, for example, as frequency modulation receivers, incorporate a device responsive to frequency deviation of a modulated carrier wave, and it is desirable that such devices be as sensitive as possible to such frequency deviation. That is, it is desirable that the frequency deviation responsive circuit produce as large a voltage as possible upon deviation of the frequency of the incoming wave from a predetermined frequency. Various arrangements have been utilized for producing such a large voltage upon frequency deviation. Such arrangements commonly incorporate a network whose reactance changes linearly very rapidly over a relatively narrow frequency range, whereby, for a constant input voltage, the current which flows through the network changes very rapidly as the frequency of the incoming wave changes over that relatively small frequency range.

It is generally desirable that such frequency deviation responsive devices operate normally about a mean frequency in the relatively small frequency range over which they are linearly responsive. This is particularly true in receivers arranged to receive and to demodulate waves whose frequencies are modulated in accordance with signals. Such frequency modulation receivers are usually of the superheterodyne type and incorporate carrier wave voltage limiters which impress on the input of a frequency variation responsive device a voltage of fixed maximum amplitude whose frequency is modulated in accordance with a signal. The loudness of the reproduced signal does not change substantially as the mean frequency of the frequency modulated carrier wave is shifted through the relatively small linear response band of the frequency responsive network unless the mean frequency of the wave approaches the limits of linearity of the relatively narrow frequency band. In such case, there is not merely a reduction in the apparent loudness of the received signal, but there is considerable distortion. This distortion is accentuated as the mean frequency of the received or transformed carrier wave assumes magnitudes further and further removed from a magnitude within the linear frequency response band of the frequency deviation responsive circuit. Regions, defined by the so-called "back slope" of such frequency deviation devices, just outside of the linear response band of the circuit,

2

are effective to demodulate the carrier wave, but produce effects not linearly proportional to the frequency of the signal and for that reason it is very desirable that for best reception the mean frequency of the received or modified carrier wave be kept inside the linear band and not in the nonlinear regions corresponding to the "back slope" which is present on each side of the linear portion of the frequency response characteristic curve of the frequency deviation responsive circuit.

It is a specific object of this invention to provide an improved frequency modulation receiver which does not reproduce signals except when it is tuned correctly for best reception; that is, to arrange such a receiver so that it will not reproduce undesired fuzzy signals due to demodulation on the "back slopes" of the frequency response characteristic curve of the receiver.

More broadly, it is an object of this invention to provide a new and improved frequency deviation responsive arrangement of high sensitivity in which there is substantially no response except when the frequency of a wave impressed on the frequency variation responsive arrangement lies within the linear portion of its frequency range.

It is another object of the present invention to provide a simple arrangement which suppresses the distorted responses produced when operating in the range of either one of the "back slopes" of a frequency discriminator so that tuning of a frequency modulation receiver incorporating the discriminator is easier.

A corollary object of the present invention is to provide an improved frequency deviation responsive arrangement in which the frequency deviation sensitivity is high when the frequency of a wave impressed thereon is within its linear range and which is low when the frequency of such a wave is outside of its linear range.

It is frequently the practice in radio transmission to reduce the range of intensity variation of signals before modulating the carrier wave in accordance with such signals, in order that sounds of the smallest intensity may be reproduced at the receiving station and in order that sounds of the largest intensity may not produce frequency deviation to such an extent that the frequency of the carrier wave is increased beyond certain assigned limits.

It is another object of this invention to provide a frequency deviation responsive arrangement which is substantially unresponsive to waves outside of its substantially linear response range and

in which the range of intensity variation of demodulated signals may be adjusted as desired.

Another object of this invention is to provide means responsive to an incorrect tuning condition of a frequency modulation receiver for suppressing the unwanted response due to the "back slope" of the discriminator characteristic.

Another object of this invention is to provide means responsive to a condition of correct tuning for enhancing the deviation sensitivity of a receiver for frequency modulated waves.

Another object of this invention is to provide a new and improved limiter in a receiver for frequency modulated signals in which the limiter transmits signals only when the receiver is correctly tuned.

Still another object of the present invention is to provide improved arrangements for controlling the deviation sensitivity of a frequency responsive network in accordance with the intensity of a signal passing through such network.

Yet another object of this invention is to provide improved arrangements for controlling the frequency deviation sensitivity of a frequency responsive system having a limiter circuit in which an electrical characteristic of such limiter circuit controls the deviation sensitivity.

Yet another object of this invention is to provide an improved signal amplitude compression system incorporating frequency deviation responsive apparatus in which voltages developed in either an amplifying stage or limiter stage are utilized to control frequency deviation sensitivity.

Yet another object of this invention is to provide an improved signal amplitude expansion system incorporating frequency responsive apparatus in which voltages developed in either an amplifying stage or limiter stage are utilized to control frequency deviation sensitivity.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This 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 drawings in which:

Figure 1 shows a graphical representation of an operating characteristic of a circuit embodying the present invention;

Fig. 2 shows a circuit embodying the invention.

In Fig. 1, the line 5 illustrates the relation between frequency, plotted as abscissa, of a carrier wave of constant amplitude and output voltage response, plotted as ordinate, in a frequency deviation response network on which such carrier wave is impressed. There is a linear portion of the line 5 in which the output voltage, or response, of the network changes far more rapidly than the frequency of the impressed carrier wave. There are nonlinear "back slopes" 6 and 7 at each end of the linear portion of curve 5, over which output voltage changes nonlinearly as the frequency of voltage applied to such network changes.

One phase of the present invention relates to our arrangement for causing a frequency deviation response network having the characteristic illustrated in Fig. 1 to produce an output voltage, or cause a response, substantially only when the frequency of a carrier wave impressed on the network lies within the limits of the linear part of curve 5. Such an arrangement is useful and highly desirable in a receiver for receiving fre-

quency modulated waves, and when incorporated in such a receiver it is practically impossible to mistune the receiver to the extent of producing demodulation on the "back slopes" 6 and 7.

The term "receiver" as used in this specification, is meant to include any device possessing at least a source of frequency modulated carrier waves and a circuit for detecting the modulation signal on the carrier waves. Purely by way of example, a repeater in which the modulation signal is detected and retransmitted without conversion to sound would fall in the classification of a receiver, in the light of this specification.

Figure 2 is the circuit diagram of a particular type of frequency modulation receiver in which frequency modulated waves intercepted by antenna 10 are detected and the modulation signal is reproduced on speaker 109. This receiver is of the superheterodyne type, including variably tuned circuits in the radio frequency amplifier stages 63 and 73 and tuned circuits in a frequency converter or oscillator modulator stage 74, the tuned circuits being adjustable to adjust the receiver to receive frequency modulated waves of any desired mean frequency.

Signals received on antenna 10 are applied to the primary 60 of antenna transformer 61 which has its output winding 62 tuned by condenser 62A and has one terminal thereof connected to the control grid of variable mu discharge device 63, the other terminal of winding 62 being connected either to the cathode of device 63 through conventional bias resistance 67 shunted by conventional by-pass condenser 68 or connected to the cathode of device 63 through serially connected condenser 120 and resistance 67, depending upon the position of switch 70.

Space current for device 63 is supplied from source 64 which has its positive terminal connected to the screen grid of device 63 and also to one terminal of tuned output circuit 65, 66 comprising the primary winding 65 of output transformer 71 and variable tuning condenser 66, the other terminal of the tuned circuit 65, 66 being connected to the anode of device 63. The negative terminal of source 64 is grounded and connected to the cathode of device 63 through serially connected resistance 67 so that space current flowing from the anode and screen grid of device 63 develops a control grid bias voltage across resistance 67 for causing device 63 to operate over a suitable portion of its operating characteristic curve so as to produce suitable amplification of signals applied across variably tuned circuit 62, 62A. Such signals are amplified by device 63 and then appear across tuned output circuit 65, 66 and then are transferred to the secondary winding 72 of output transformer 71. Such amplified signals are again amplified in another radio frequency amplifier stage 73 and then applied to the input of the oscillator modulator stage 74.

The fixed frequency output voltage of the oscillator modulator or frequency converter 74 is amplified in a fixed frequency intermediate frequency amplifier 75 and is impressed across a tuned circuit including the primary winding 76 of the high frequency transformer 78, connected in shunt with a tuning condenser 77. The tuned circuit comprising elements 76, 77 is adjusted to be resonant at the fixed mean frequency at which the intermediate frequency amplifier 75 is operative.

The secondary winding 79 of the transformer 78 is connected in shunt with a tuning condenser 80 and voltage developed thereacross is ampli-

5

fied, and limited in intensity on both half cycles of a wave, in an amplifying and limiting discharge device 81. The discharge device 81 is associated with a second discharge device 90 and with a circuit arrangement which causes the limiting and amplifying device 81 to pass to its output circuit substantially no signal when the signal impressed on tuned circuit 79, 80 is below a predetermined intensity, and which causes the limiting and amplifying device 81 to pass to its output circuit a signal of substantially constant intensity when the signal impressed on tuned circuit 79, 80 is above a predetermined intensity.

The output of discharge device 81, thus modified, is impressed across a tuned circuit including the primary 86 of a transformer, the primary 86 being connected in shunt with a tuning condenser 87 to form a tuned circuit 86, 87 tuned to the same frequency as is the output circuit of the intermediate frequency amplifier 75. The tuned circuit 86, 87 is associated with a frequency variation response network or frequency discriminator 97 of the well known resonant type, arranged to produce an output voltage whose intensity and polarity varies as the frequency of a constant intensity wave impressed on the tuned circuit 86, 87 varies in amount and direction from a predetermined mean frequency.

The output voltage of the discriminator 97 is applied between the grid and cathode of amplifying discharge device 102, amplified thereby, and a first portion of such amplified voltage is applied through a coupling condenser 111 to the plate of a rectifier such as a discharge device 131, rectified in discharge device 131 and then applied across the resistance 92 for controlling the conductivity of discharge device 90, and a second portion of such amplified voltage is applied to a second amplifying circuit 107 and then applied to sound reproducer 109.

In particular, the audio voltage from discriminator 97 is applied across the serially connected condenser 100 and resistance 101, the resistance 101 being connected between the grid and cathode of amplifying device 102 through conventional cathode biasing resistance 104 having connected in shunt thereto by-pass capacitance 105 for preventing degeneration effects. Space current for discharge device 102 is supplied from voltage source 64 which has its positive terminal connected to the anode of device 102 through serially connected resistance 103. The cathode of device 102 is grounded through cathode biasing resistance 104, and the resulting space current flowing through resistance 104 produces a suitable negative control voltage for the control electrode of device 102 such that device 102 operates along a substantially linear portion of its control voltage versus space current characteristic.

Signal voltages appearing across resistance 101 are amplified by device 102 and, as mentioned previously, such amplified signals have a portion thereof applied to rectifier discharge device 131 for producing a control voltage and another portion thereof which appears across output coupling resistance 103 applied to the terminals of the input circuit of amplifying circuit 107 through coupling condenser 108, condenser 108 being connected to the junction point of resistance 103 and anode of device 102, and one terminal of network 107 being grounded.

The limiting amplifier device 81 mentioned previously, is arranged to limit the maximum amplitude of both half cycles of an impressed

6

signal wave to less than a predetermined intensity, and to that end its cathode is grounded and its first or control electrode 106 is connected to one terminal of the tuned circuit 79, 80, the other terminal of that tuned circuit being connected to ground through a serially connected resistance 82 connected in shunt with a by-passing condenser 83 for by-passing high frequency currents around the resistance 82. The anode 113 of device 81 is connected to one terminal of the tuned circuit 86, 87, the other terminal of that tuned circuit being connected through serially connected resistances 84 and 85 to the positive terminal of a voltage source 64 of operating potential, the negative terminal of the source 64 being grounded. A voltage dividing resistance 88 is connected in shunt with the source 64, and its adjustable tap is connected to the second or screen electrode 114 of device 81, which screen electrode is connected through a condenser 89 to the cathode of device 81, the reactance of condenser 89 being sufficiently low at high frequencies to prevent substantial potential variation of electrode 114.

Neglecting for a moment the fact that the discharge device 90 is connected in circuit with discharge device 81, and assuming that the potentials of the various electrodes of discharge device 81 are as they would be adjusted by device 90 in the presence of a signal impressed on the tuned circuit 79, 80 above a predetermined intensity such that device 81 limits and transmits a signal wave to the tuned circuit 86, 87; limiting action in the discharge device 81 take place on both half cycles of the wave in known fashion. Rectification of the wave on the control electrode 106 is effective to develop a bias potential across resistance 82, whose polarity is as indicated, and, assuming the intensity of the impressed wave is sufficient, the control electrode 106 is driven far more negative during a part of each half cycle of the impressed wave than the negative potential required to cut off anode current in the device 81. By this process negative half cycles of the impressed wave are limited in intensity and appear on the anode 113 only with such limited intensity.

The potential of the screen electrode 114 is adjusted by the voltage dividing resistance 88 to a low value, such that positive half cycles of the impressed signal wave on control electrode 106 are by certain well known mechanisms also transmitted to the anode 113 in limited intensity.

In order to accomplish some of the purposes of this invention, the discharge device 90 is interconnected with the device 81 to cause the device 81 to cease transfer of the wave to the tuned circuit 86, 87 when the intensity of the wave on the tuned circuit 79, 80 drops below a predetermined intensity. The control electrode 122 of device 90 is connected to that terminal of tuned circuit 79, 80 which is connected to resistance 82. The anode 123 of discharge device 90 is connected to a point P between the serially connected resistances 84 and 85, and the cathode of device 90 is connected to the negative terminal of a source 91 of biasing potential, the positive terminal of which is connected to ground through a coupling resistance 92. A suitable condenser 99 is connected in shunt to the serially connected source 91 and resistance 92 for by-passing high frequency currents around such serially connected circuit elements.

Source 91 maintains the cathode of device 90 negative with respect to ground and also with respect to the control electrode 122, so that in the absence of a signal voltage current tends to flow

from source 91 through resistance 92 to ground, then through resistance 82, through the resistance 95, to the control electrode 122, and through the cathode of device 90 and back to the negative terminal of source 91. Such current flow maintains continuously a bias potential across resistance 82 of such polarity as to maintain control electrode 106 of device 81 negative with respect to ground.

When the signal appearing across tuned circuit 79, 80 is of greater than a predetermined amplitude the conductivity of device 90 changes not only as the result of the increased voltage drop across resistance 82 but also as the result of the increased voltage drop across resistance 92. Enhanced signal rectification between control electrode 106 and the cathode of the device 81 produces a sufficiently large negative bias across resistance 82 to cut off the anode current of device 90 so that ultimately the voltage drop across resistance 84 is only that produced by a relatively small space current flowing to device 81. A correspondingly high direct current potential appears on anode 113 of the limiting amplifier device 81 and its transconductance is correspondingly greatly increased and the signals are efficiently transferred from the tuned circuit 79, 80 to the tuned circuit 86, 87 with an effective limiting of the maximum amplitude of both the positive and negative half cycles of the signals.

With this arrangement, in which the limiter device 81 is made effective or ineffective to pass signals from the tuned circuit 79, 80 to the tuned circuit 86, 87, as such signals in the tuned circuit 79, 80 are above or below a predetermined intensity, the selectivity curves of the tuned circuits 76, 77 and 79, 80 and other tuned circuits in the radio frequency amplifier stages 63 and 73, oscillator modulator 74 and intermediate frequency amplifier 75 are substantially flat topped over a frequency range corresponding to the frequency range illustrated in Fig. 1 as linear within the parts B and C of the curve 5. The selectivity curve outside of the frequency range is such that a very sharply reduced transfer of energy is produced through the above mentioned tuned circuits outside of that frequency range, that is, in the region corresponding to the back slopes 6 and 7 of the curve 5 in Fig. 1 and within the frequency ranges marked A and D. Accordingly, if those tuned circuits are so adjusted in band width that an incoming signal lies within the range A or within the range D shown in Fig. 1 such signal is sufficiently attenuated at the tuned circuit 79, 80 of Fig. 2 so as to be below the predetermined intensity at which the discharge device 81 transfers signals to the tuned circuit 86, 87. It is only when a signal on the antenna 10 lies within the linear frequency range of the curve 5 of Fig. 1, that is, within the frequency ranges B and C of Fig. 1, that it appears in the tuned circuit 79, 80 in sufficient intensity to bias device 90 beyond cutoff, with the result that the signal is amplified by device 81.

As has been mentioned previously, a portion of the audio signal amplified by discharge device 102 is fed to rectifying discharge device 131 through condenser 111. The cathode of device 131 is grounded through a tapped resistance 136 which is shunted by an audio frequency bypass condenser 137. Rectified voltage appearing between the tap on resistance 136 and ground is filtered by serially connected filter inductance 117 and shunt connected filter condenser 114. A portion

of the voltage appearing across resistance 136 is filtered and applied across resistance 92 when a serially connected switch 116 is closed by connecting the movable tap on resistance 136 to one terminal of resistance 92, the other terminal of resistance 92 and one terminal of resistance 136 being grounded. This rectified voltage from device 131 causes the ungrounded terminal of resistance 92 to become more positive as the signal voltage applied to discriminator 97 increases, and the net continuous negative bias voltage appearing on grid 122 of device 90 becomes sufficient to cut off current flow in device 90 with the result that the anode voltage on device 81, and consequently the transconductance of that device, increases. The output signal from device 81 correspondingly increases with a resulting increase in the amplitude of the audible signal from the reproducer 109.

In Figure 2, when switch 70 is connected as shown to the grounded terminal, the deviation sensitivity of the receiver is controlled in accordance with the audio voltage output. When switch 116 is closed and when switch 70 is connected to filter inductance 115, the deviation sensitivity of the receiver is controlled not only by the audio voltage output but also by the signals appearing across the output of intermediate frequency transformer 78.

The receiver shown herein may be tuned by conventional means, for example, the tuning means may comprise variable condensers or variable inductances. Such tuning means are represented by the variable capacitance 62A and 66 shown in Fig. 2. The grid input circuit and the plate output circuit of the radio frequency amplifier 73 may also be tuned. Tuning means may be connected in conventional fashion.

It is preferable, but not essential, to use a pentode type of discharge device in the main signal translating channel. While the auxiliary control discharge device 90 is shown as a triode type, it may be desirable, under certain conditions, to use a tetrode or pentode in place of the triode.

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

I claim:

1. A frequency deviation responsive device including a source of frequency modulated carrier waves of varying amplitudes and various mean frequencies, means for selectively amplifying a carrier wave from said source, a frequency modulation signal detector of the resonant type having a principal linear frequency response region and adjacent non-linear frequency response regions, said amplifying means having a frequency selectivity characteristic with substantially more attenuation in said non-linear regions than in said principal linear region, an electron discharge device having a control electrode, anode and cathode, an input circuit connected between said control electrode and cathode including means for producing self-bias voltage in response to a carrier wave impressed on said control electrode, means for impressing a selected carrier wave from said amplifying means on said input circuit, an output circuit connected between said anode and

cathode and coupled to said detector, said device and circuits being arranged to limit to a predetermined maximum amplitude any carrier wave impressed thereon, a second electron discharge device having a control electrode, anode, and cathode, means for impressing self-bias voltage from the control electrode of said first discharge device on the control electrode of said second device negatively with respect to the cathode of said first device, and means for connecting the anode and cathode of said second device to said output circuit effectively in shunt with the anode and cathode of said first device, said second device having sufficient transconductance with said circuits adjusted for satisfactory signal detection in said principal linear region that substantially no signal detection takes place in said adjacent regions.

2. A frequency deviation responsive device including a source of frequency modulated carrier waves of varying amplitudes and various mean frequencies, means for selectively amplifying a carrier wave from said source, a frequency modulation signal detector of the resonant type having a principal linear frequency response region and adjacent non-linear frequency response regions, said amplifying means having a frequency selectivity characteristic with substantially more attenuation in said non-linear regions than in said principal linear region, an electron discharge device having a control electrode, anode and cathode, an input circuit connected between said control electrode and cathode including means for producing self-bias voltage in response to a carrier wave impressed on said control electrode, means for impressing a selected carrier wave from said amplifying means on said input circuit, an output circuit connected between said anode and cathode and coupled to said detector, said device and circuits being arranged to limit to a predetermined maximum amplitude any carrier wave impressed thereon, a second electron discharge device having a control electrode, anode, and cathode, means for impressing self-bias voltage from the control electrode of said first discharge device on the control electrode of said second discharge device and for biasing the cathode of said second device negatively with respect to the cathode of said first device, means for connecting the anode and cathode of said second device to said output circuit effectively in shunt with the anode and cathode of said first device, said second device having sufficient transconductance with said circuits adjusted for satisfactory signal detection in said principal linear region that substantially no signal detection takes place in said adjacent regions, means responsive to detected signals for producing a bias voltage, and means for changing the conductivity of said second device in joint response to said last mentioned bias voltage and said self-bias voltage.

3. A frequency deviation responsive device including a source of frequency modulated carrier waves of varying amplitudes and various mean frequencies, means for selectively amplifying a carrier wave from said source, a frequency modu-

lated signal detector of the resonant type having a principal linear frequency response region and adjacent non-linear frequency response regions, said amplifying means having a frequency selectivity characteristic with substantially more attenuation in said non-linear regions than in said principal linear region, an electron discharge device having a control electrode, anode and cathode, an input circuit connected between said control electrode and cathode including means for producing self-bias voltage in response to a carrier wave impressed on said control electrode, means for impressing a selected carrier wave from said amplifying means on said input circuit, an output circuit connected between said anode and cathode and coupled to said detector, said device and circuits being arranged to limit to a predetermined maximum amplitude any carrier wave impressed thereon, a second electron discharge device having a control electrode, anode, and cathode, means for impressing self-bias voltage from the control electrode of said first discharge device on the control electrode of said second discharge device and for biasing the cathode of said second device negatively with respect to the cathode of said first device, means for connecting the anode and cathode of said second device to said output circuit effectively in shunt with the anode and cathode of said first device, said second device having sufficient transconductance with said circuits adjusted for satisfactory signal detection in said principal linear region that substantially no signal detection takes place in said adjacent regions, means responsive to detected signals for producing a bias voltage and means responsive to said last mentioned bias voltage for aiding the change in conductivity of said second device produced by said self-bias voltage.

ROBERT T. THOMPSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,125,723	Henriquez et al. -----	Aug. 2, 1938
2,144,882	Van Loon -----	Jan. 24, 1939
2,152,515	Wheeler -----	Mar. 28, 1939
2,199,350	Shofstall -----	Apr. 30, 1940
2,248,197	Rath -----	July 8, 1941
2,263,645	Rath -----	Nov. 25, 1941
2,271,203	Okrent -----	Jan. 27, 1942
2,286,442	Schock -----	June 16, 1942
2,296,101	Foster -----	Sept. 15, 1942
2,301,649	Thompson -----	Nov. 10, 1942
2,305,842	Case -----	Dec. 22, 1942
2,316,317	Curtis -----	Apr. 13, 1943
2,323,880	Carnahan -----	July 6, 1943
2,330,902	McCoy -----	Oct. 5, 1943
2,338,526	Maynard -----	Jan. 4, 1944

FOREIGN PATENTS

Number	Country	Date
410,549	Great Britain -----	May 24, 1942