May 27, 1941. R. A. WEAGANT 2,243,141

RADIO RECEIVER CIRCUITS

Filed May 18, 1940 2 Sheets-Sheet 1

Fig. 1

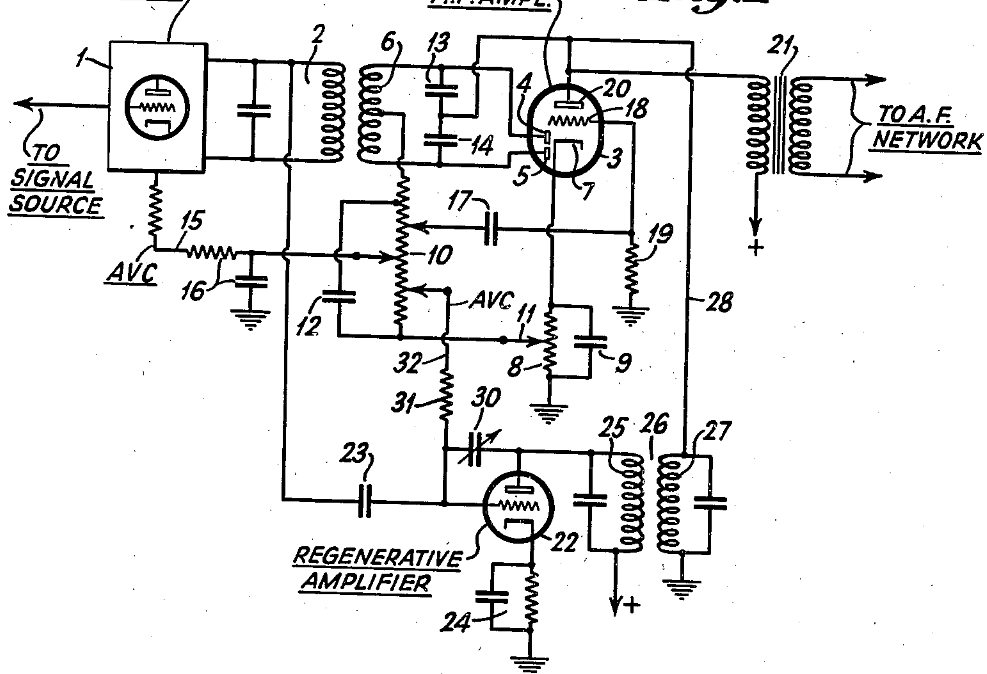

Fig. 2

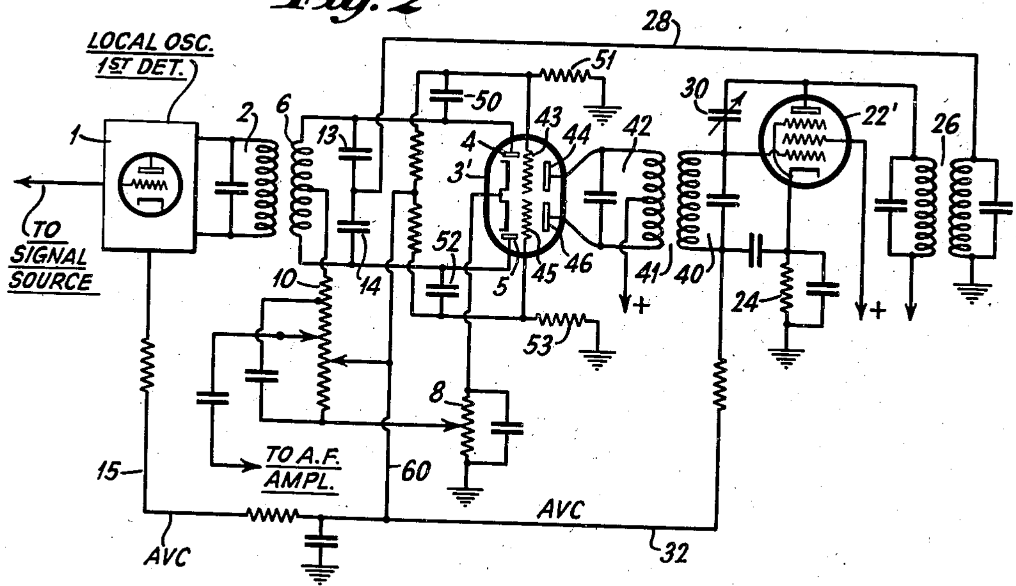

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Fig. 3

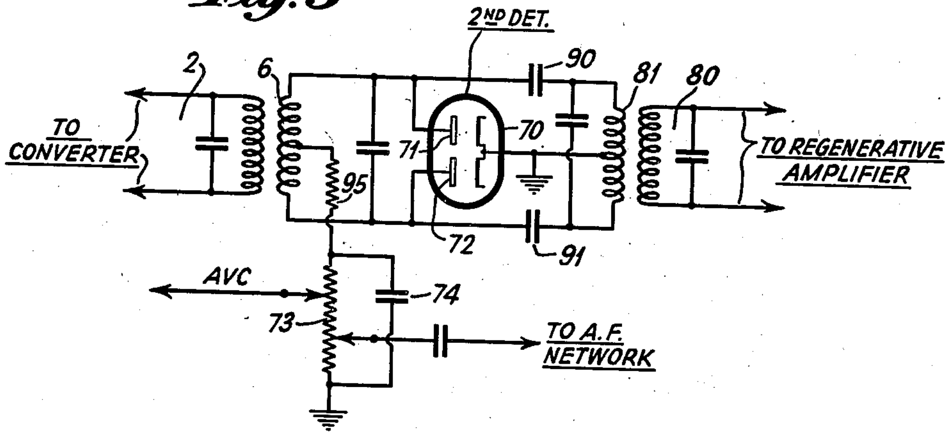
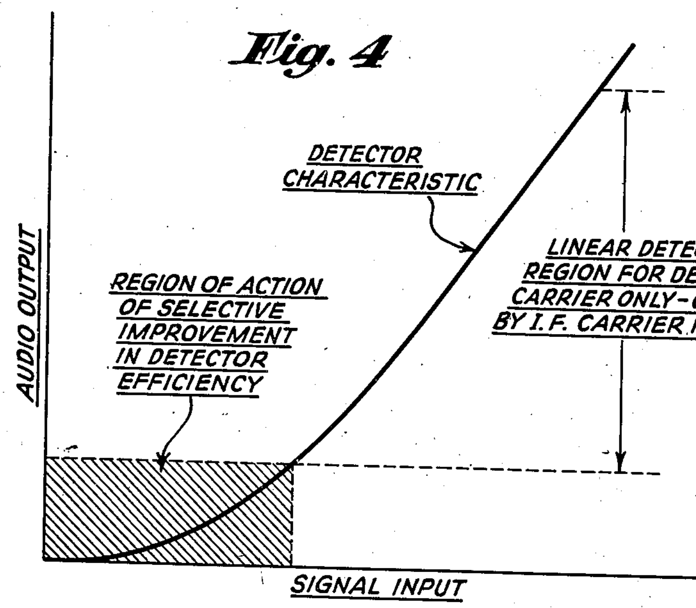


Fig. 4



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2,243,141

UNITED STATES PATENT OFFICE

2,243,141

RADIO RECEIVER CIRCUITS

Roy A. Weagant, Douglaston, Long Island, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application May 18, 1940, Serial No. 335,892

8 Claims. (Cl. 250—20)

My present invention relates to modulated signal carrier receiver systems, and more particularly to receivers utilizing selective improvement in detector efficiency for desired signal carrier reception.

It is one of the main objects of my present invention to provide a modulated carrier detection system wherein selectivity is greatly increased by virtue of an electrical action termed "selective improvement of detector efficiency"; the said action essentially comprising the injection into the detector system of relatively slightly modulated, or unmodulated, energy of the desired carrier frequency, and the injected carrier energy being of such relatively great magnitude with respect to the signal energy at the detector input network that detection is caused to be highly efficient for the modulated carrier energy of the desired frequency while detection is relatively inefficient for signal energy of an undesired interfering frequency.

Another important object of my present invention is to provide a radio receiver of the superheterodyne type which has high selectivity, high fidelity of reproduction and is relatively free of adjacent channel interference; the receiver utilizing a minimum of stages prior to the audio network, and the first detector network being preceded by solely a first detector stage, and the second detector network having means operatively associated therewith for selectively improving the detection efficiency solely for modulated carrier energy of the desired frequency.

Another important object of this invention is to provide in combination with a pair of diode rectifiers arranged for full wave rectification, means for impressing upon the common input circuit of the diodes combined modulated carrier energies of desired and undesired frequencies, there being utilized a network for deriving from the signal energies amplified oscillations of the desired carrier frequency, and the amplified oscillations being applied to the diodes in such a manner that the rectification of the modulated carrier energy of desired frequency is relatively more efficient than the rectification of the signal energy of undesired interfering frequency.

Still other objects of my present invention are to improve generally the efficiency, selectivity and fidelity of reproduction of radio broadcast receivers, and more especially to provide a receiver of the superheterodyne type which not only possesses the above desirable characteristics, but is constructed in a compact manner and is economically manufactured and assembled.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings—

Fig. 1 shows one embodiment of the invention,

Fig. 2 illustrates a modified arrangement,

Fig. 3 shows a modification of the second detector network, and

Fig. 4 graphically illustrates the selective improvement in detection efficiency which is utilized in the present invention.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 a receiving circuit of the superheterodyne type which may be constructed for use in the standard broadcast band of 550 to 1600 kilocycles (kc.). Of course, the invention may also be used in the television and telegraph bands. When embodying the present invention in a receiver, such a receiver need utilize but three tubes prior to the audio network, and yet possess relatively greater selectivity and a fidelity of reproduction of much higher order than usual broadcast receivers. The numeral 1 designates a converter stage which may be of the combined local oscillator-first detector type. For example, the stage 1 can utilize, as is well known to those skilled in the art, a pentagrid converter tube of the 6A7 type which produces in its output circuit 2 modulated carrier energy at intermediate frequency (IF). Such networks are too well known to describe in any further detail, and it is merely necessary to point out that the signal input grid of the 6A7 type tube will be connected to a tunable signal input circuit. The latter will be coupled to any desired type of signal collector device, such as a usual antenna circuit, a loop antenna, a radio frequency distribution line, an automobile antenna device, or any other well known signal collection instrumentality. Of course, the tunable signal and local oscillation circuits are varied in unison by the usual common tuning element, and by virtue of the electron coupling action within the converter tube there may be developed across the output circuit 2 the I. F. voltage. Circuit 2 may be resonated to any desired I. F. value in a range of 75 to 465 kc.

The tube following the converter stage is designated by numeral 3, and it may be one of the duo-diode-triode type. The two diode elements are utilized in the second detection network, while the triode section may be utilized for audio amplification. However, if it is desired to utilize a double diode tube without the inclusion of any audio amplifier electrodes, then a tube of the 6H6 type should be used. Considering the connections to the tube 3 in detail, the diode anodes 4 and 5 are connected to opposite ends of the input circuit coil 6, while the cathode 7 is connected to ground through a bias resistor 8 shunted by an I. F. bypass condenser 9. The mid-point of coil 6 is connected to any desired point on the bias resistor 8 through a path which includes the load resistor 10 and the adjustable contact element 11, the I. F. by-pass condenser 12 being shunted across a major portion of the resistor 10.

In shunt with coil 6 are arranged condensers 13 and 14 connected in series, and it will be understood that the circuit 6—13—14 is resonated to the operating I. F. value, and that primary circuit 2 is magnetically coupled to the input coil 6 of the second detector network. I. F. signal energy impressed on the detector input circuit is rectified in well known full wave rectification manner, and there is developed across the portion of the load resistor 10 shunted by condenser 12 both a direct current voltage component and an audio, or modulation voltage component. An automatic volume control (AVC) circuit taps off the direct current voltage component and numeral 15 denotes the AVC connection. The latter includes the filter network 16 for eliminating any pulsation voltage components from the AVC bias. The latter bias may be applied to the signal grid of the converter tube so that there is secured the usual and well known automatic gain control action. Another reason for employing the AVC circuit is to maintain the signal energy amplitude at the second detector input circuit of a substantially uniform low amplitude for a reason to be given in detail at a later point.

The audio voltage developed across the second detector load resistor is taken off through the audio coupling condenser 17, and is applied to the control grid 18 of the amplifier section of tube 3. A leak resistor 19 connects grid 18 to ground so that the proper negative bias may be applied to grid 18. The plate 20 of tube 3 is connected to the positive terminal of a desired direct current source, and the audio transformer 21 has its primary winding included in the plate circuit of tube 3. The audio voltage amplified by the amplifier section of tube 3 is amplified in one or more audio amplifier stages, and may be finally reproduced in any well known manner as by a loudspeaker.

According to the present invention, there is applied to the second detector network amplified oscillations of the I. F. value. The amplified oscillations are derived from the I. F. circuit 2, and this is done in the manner disclosed in my application Serial No. 234,938, filed Oct. 14, 1938. The tube 22 has its input grid connected to the high potential side of circuit 2 through an I. F. coupling condenser 23. The cathode of tube 22 is connected to ground through a self-biasing resistor 24, the latter being shunted by an I. F. by-pass condenser. The plate of tube 22 is connected to the positive terminal of a direct current source through the primary winding 25 of transformer 26. The secondary 27 of transformer 26 has one end thereof at ground potential, while its opposite end is connected by lead 28 to the junction of condensers 13 and 14. Each of windings 25 and 27 is shunted by its own condenser, and each of the windings is fixedly tuned to the operating I. F. value. In this way the transformer 26 provides a pair of cascaded I. F.-tuned circuits, and the network is sharply tuned to the I. F. value.

The plate and grid of tube 22 are connected by the condenser 30, and the latter is made adjustable so that the degree of regeneration provided by the condenser 30 can be established at some predetermined magnitude. It will now be seen that the modulated I. F. carrier energy impressed upon the grid of the regeneratively-coupled tube 22 has its modulation side bands removed to a great extent from the I. F. carrier, and the resulting relatively slightly modulated I. F. carrier energy is transmitted through the highly selective transformer 26 and impressed upon the pair of diodes which comprise the second detector network. The effect of the regenerative tube is to remove the modulation to the extent of about 400 cycles. This causes reinforcement of the bass notes. Of course, substantially complete removal of modulation may be used.

The grid of tube 22 is automatically controlled in bias by connecting it to a desired point on load resistor 10 through a filter resistor 31 and lead 32. In the absence of signal energy the grid of tube 22 will be established at a normal negative bias with respect to the cathode. Upon the impression of signal energy upon the full wave rectifier network, direct current voltage developed across the rectifier load resistor will be applied over the AVC lead 32 to the grid of tube 22. In this way the gain of tube 22 is automatically controlled, and the magnitude of the injected, or exalted, I. F. carrier oscillations is maintained at a substantially constant magnitude with respect to the signal energy applied to the input circuit of the second detector network. It will be noted that adjustment of tap 11 along bias resistor 8 controls the initial, or delayed, negative bias applied to the diode anodes 4 and 5. It will, also, be observed that the tube 22 not only functions substantially to strip the modulation off the I. F. carrier, but that the regeneratively-coupled tube functions as an amplifier of the I. F. carrier voltage. The I. F. carrier voltage oscillations injected into the second detector network are in phase with the signal energy applied to one of the anodes, while they are in opposite phase with the signal energy applied to the other diode anode. This is the optimum operating condition to secure the selective improvement in detector efficiency.

The functioning of the second detector network will now be explained with particular reference to Fig. 4. In the latter there is shown a full line curve which graphically indicates the detector characteristic of a diode. It will be noted that "Signal input" is plotted against "Audio output." As is well known, such a characteristic has a lower curved portion for weak signal input which follows substantially a square law, while the upper portion thereof is substantially linear.

Detection over the square law portion of the curve is variable; it is extremely inefficient at the bottom, and equal to the linear portion at the top. Extremely small amplification is used for the signal energies applied to the detector in order that even with interference present, for example more than 1000 times stronger than the signal, the interference will be detected as nearly as possible at the bottom of the characteristic curve. When the exalted carrier energy is applied, and when the exalted carrier voltage is from ten to one hundred thousand times as strong as the signal energy, the latter will be detected on the efficient part of the curve. Without injection of the exalted carrier energy, detection occurs near the lower end of the characteristic. Since the slope of a square law curve at the exact zero point is zero, the relative efficiency at the top of the curve as compared to a very small input at the bottom approaches infinity. This means that an enormous increase in desired signal output without effect on interference is possible.

The shaded area of Fig. 4 is the "Region of action of selective improvement in detector efficiency." It is the curvature of this area that makes the action possible. The circuits are so arranged that both the signal and undesired interference are in the shaded region and as near the bottom of the curve as is possible for ordinary detection. The results are obtainable with either a diode (having a curve as in Fig. 4), or with a biased triode, which has only a square law of detection. The detector tubes, whether diodes or triodes, may be in balanced or unbalanced relation.

The injection of the amplified I. F. oscillations into the second detector network results in an automatic and enormous improvement of the modulated I. F. carrier energy of desired frequency, while not in any way affecting the inefficient detection of the undesired interfering carrier energy. This high selective improvement in detection efficiency occurs only when the ratio of the signal input to the second detector to the magnitude of the injected amplified I. F. oscillations is very low. Experimental operation has completely verified the detection operation qualitatively depicted in Fig. 4. For example, at Miami, Florida, it was possible to receive a station from Tampa (about 150 miles away) which is on 620 kc., and of 1 kw. power, even though the local station WIOD operated on 610 kc. (3 miles from receiver), with 1 kw. power. In general, any shape of detection curve will function provided that there is a marked change in detection efficiency for strong signals as compared to weak signals. The amplified I. F. oscillations injected into the second detector network should, for a square law detector, be strong enough to carry the signal to the upper limit of the curved lower portion of the characteristic, but not beyond it. While it is not believed necessary for the purposes of the present application to outline any particular theoretical background for the selective improvement in detection efficiency secured by my invention, it is stated, in addition to the aforementioned theoretical explanations, that the selectivity obtained is due to the action of the injected I. F. oscillations in greatly increasing the efficiency of signal detection without at the same time increasing the efficiency of the detection of the undesired interfering carrier energy.

Insofar as the AVC action of the receiver is concerned it will be observed that the amplified I. F. oscillations injected into the second detector network will give rise to an augmented AVC bias, and, therefore, there will be an augmented AVC action in the receiver. Furthermore, by providing a delayed bias for the diode anodes 4 and 5, and the delay bias is produced by the voltage drop between ground and the point on resistor 8 on which tap 11 is connected, the advantage results that a threshold potential is set up for the desired and interfering signal voltages to overcome before any detection whatever takes place. This means that when the interfering signal is very strong relative to the signal, it will be detected near the bottom of the curved part of the characteristic, while at the same time the desired signal, by virtue of the strong exalted carrier energy, will be detected on the linear portion, or on the upper part of the curved portion. It may be noted in this connection that the accentuated I. F. carrier may, if desired, be of enormously greater value than the normal carrier simply by employing greater amplification in the circuit feeding the regeneratively-coupled tube. When the exalted I. F. carrier energy is injected into the second detector network there is a great improvement in selectivity, and there is secured an equal improvement in fidelity of reproduction due to both bass amplification and amplification of the treble notes.

It will now be seen that in addition to producing a very high order of selectivity, the present arrangement results in an extremely high order of sensitivity for a given number of tubes. Insofar as the regeneratively-coupled tube is concerned, it is pointed out that the specific type of circuit shown is extremely stable, and capable of the required I. F. oscillation-amplification.

In Fig. 2 there is shown a system of the type shown in Fig. 1, but differing therefrom in that there is provided additional I. F. amplification prior to the regeneratively-coupled tube 22'. Tube 22' is of the pentode type, and it is connected to function in the same manner shown in Fig. 1. However, the input electrodes of tube 22' are coupled to the tuned secondary circuit 40 of an I. F. transformer 41. The tuned primary circuit 42 of transformer 41 is resonated to the operating I. F. value, as is the secondary circuit 40. The anodes 4 and 5 of the full wave rectifier are included in a tube 3', which includes a pair of independent triode sections. Thus, the cathode, grid 43 and plate 44 provide one triode section, while the cathode, grid 45 and plate 46 provide the other triode section. Plates 44 and 46 are connected to the opposite ends of the tuned primary circuit 42, the mid-point of the primary coil of transformer 41 being connected to the positive terminal of a direct current source.

The cathodes of tube 3' are connected to ground through the bias resistor 8 as in the case of Fig. 1. Grid 43 is connected to one side of the input coil 6 through an I. F. coupling condenser 50, the grid side of the condenser 50 being connected to ground through a grid leak resistor 51. Grid 45 is connected through I. F. coupling condenser 52 to the low potential end of input coil 6, while the grid leak resistor 53 connects the grid side of condenser 52 to ground. Thus grids 43 and 45 are established at a desired negative bias with respect to the cathode of tube 3'. It will now be seen that the triode sections of tube 3' provide a stage of push-pull I. F. amplification between the second detector input circuit and the input electrodes of the regeneratively-coupled tube 22'. It is possible to produce amplified I. F. oscillations whose amplitude relative to the signal or interference input to the second detector network is of the order of 100,000, assuming that the regenerative circuit has a Q of 2000.

The discrimination against interfering signal voltage will be extremely high, and the discrimination is still further increased by the utilization of the delay bias derived from resistor **8**. The AVC bias is shown in Fig. 2 as applied to converter tube **1**, and to the signal grid of the regenerative tube **22'**. AVC bias may, also, be applied to the signal grids **43** and **45** of tube **3'** by means of the direct current voltage connection **60** and special filter resistors. The selective improvement in detection efficiency in this case is the same as described in connection with Fig. 1.

In Fig. 3 there is shown a modification of the second detection network wherein the second detector is a double diode tube **70** of the 6H6 type. The diode anode **71** is connected to the high potential end of input coil **6**, while the diode anode **72** is connected to the opposite end of the input coil. The detector load resistor is designated by the numeral **73**, and is connected between the mid-point of coil **6** and ground. The resistor **73** is shunted by the I. F. bypass condenser **74**. The resistor **95** is in series with resistor **73**. AVC voltage and audio voltage are tapped off from the load resistor **73** and used for the purpose shown in the case of Fig. 1. The amplified I. F. oscillations from the regenerative amplifier tube are impressed upon the double diode tube by coupling the primary tuned output circuit of the regenerative tube, and which output circuit is denoted by numeral **80**, to the tuned secondary circuit **81**. The circuits **80** and **81** are magnetically coupled, and are each resonated to the operating I. F. value. The cathode lead of diode tube **70** is connected to the mid-point of the coil of secondary circuit **81**, and the lead is established at ground potential.

Diode anode **71** is connected to one end of the tuned secondary circuit **81** by a very small condenser **90** adapted to pass the amplified I. F. oscillations, while the equally small I. F. coupling condenser **91** connects anode **72** to the opposite side of the circuit **81**. The advantage of the circuit arrangement shown in Fig. 3 resides in the fact that exalted I. F. carrier energy is subjected to full wave rectification, as is the signal energy applied to the input circuit of the full wave rectifier. Whereas in the arrangements of Figs. 1 and 2 the exalted I. F. carrier energy combines only with one half of the applied signal energy, in the arrangement of Fig. 3 the exalted carrier affects the signal energy detection on both halves of the signal wave.

It is to be clearly understood that the present invention is equally applicable to the balanced type of detector shown in my aforesaid patent application. Further, the reduction of static by the present system is significant.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In combination with a detection network provided with an input circuit tuned to a desired signal carrier frequency, a source of signal energy coupled to the input circuit for impressing upon the input circuit signal energy of a relatively small magnitude, means operatively associated with said source for deriving therefrom signal carrier energy of said signal frequency, said last means being constructed to amplify the derived energy to a relatively high amplitude with respect to the amplitude of the signal energy at said detection network, and means for applying the amplified derived energy to said detector network whereby detection of desired modulated carrier energy occurs with high efficiency and detection of undesired interfering signal energy is of relatively low efficiency.

2. In combination with a detection network provided with an input circuit tuned to a desired signal carrier frequency, a source of signal energy coupled to the input circuit for impressing upon the input circuit signal energy of a relatively small magnitude, means operatively associated with said source for deriving therefrom signal carrier energy of said signal frequency, said last means being constructed to amplify the derived energy to a relatively high amplitude with respect to the amplitude of the signal energy at said detector network, and means for applying the amplified derived energy to said detector network whereby detection of desired modulated carrier energy occurs with high efficiency and detection of undesired interfering signal energy is of relatively low efficiency and said deriving means comprising a regeneratively-coupled electron discharge tube having its input electrodes coupled to said source and its output electrodes coupled to said detection network.

3. In combination with a detection network provided with an input circuit tuned to a desired signal carrier frequency, a source of signal energy coupled to the input circuit for impressing upon the input circuit signal energy of a relatively small magnitude, means operatively associated with said source for deriving therefrom signal carrier energy of said signal frequency, said last means being constructed to amplify the derived energy to a relatively high amplitude with respect to the amplitude of the signal energy at said detector network, and means for applying the amplified derived energy to said detector network whereby detection of desired modulated carrier energy occurs with high efficiency and detection of undesired interfering signal energy is of relatively low efficiency, said detection network comprising a pair of diodes arranged as a full wave rectifier and having said input circuit as the input circuit of said rectifier.

4. In combination with a detection network provided with an input circuit tuned to a desired signal carrier frequency, a source of signal energy coupled to the input circuit for impressing upon the input circuit signal energy of a relatively small magnitude, means operatively associated with said source for deriving therefrom signal carrier energy of said signal frequency, said last means being constructed to amplify the derived energy to a relatively high amplitude with respect to the amplitude of the signal energy at said detector network, and means for applying the amplified derived energy to said detector network whereby detection of desired modulated carrier energy occurs with high efficiency and detection of undesired interfering signal energy is of relatively low efficiency said detector comprising a pair of diodes connected as a full wave rectifier, and means responsive to the unidirectional voltage component of rectified signal en-

ergy for controlling the efficiency of said deriving means.

5. In combination with a detection network provided with an input circuit tuned to a desired signal carrier frequency, a source of signal energy coupled to the input circuit for impressing upon the input circuit signal energy of a relatively small magnitude, means operatively associated with said source for deriving therefrom signal carrier energy of said signal frequency, said last means being constructed to amplify the derived energy to a relatively high amplitude with respect to the amplitude of the signal energy at said detector network, and means for applying the amplified derived energy to said detector network whereby detection of desired modulated carrier energy occurs with high efficiency and detection of undesired interfering signal energy is of relatively low efficiency, said deriving means including an amplifier stage coupled to said source, and means responsive to the unidirectional voltage component of detected signal energy for controlling the efficiency of said deriving means.

6. In a superheterodyne receiver, a signal converter having an intermediate frequency output circuit, a second detector having an intermediate frequency input circuit coupled to the latter output circuit, said detector network consisting of a pair of diodes connected with said input circuit to provide a full wave rectification network, a regeneratively-coupled tube having an input circuit coupled to a point between the converter and said rectification network, said regenerative tube output electrodes being coupled to said intermediate frequency input circuit, a highly selective coupling network, tuned to said intermediate frequency value, arranged to couple the regenerative tube output electrodes to said second detector input circuit, and means responsive to the direct current voltage component of rectified intermediate frequency energy for controlling the gain of said regenerative tube.

7. In a superheterodyne receiver, a signal converter having an intermediate frequency output circuit, a second detector having an intermediate frequency input circuit coupled to the latter output circuit, said detector network consisting of a pair of diodes connected with said input circuit to provide a full wave rectification network, a regeneratively-coupled tube having an input circuit coupled to a point between the converter and said rectification network, said regenerative tube output electrodes being coupled to said intermediate frequency input circuit and said regenerative tube and its associated circuits being arranged to amplify derived intermediate frequency oscillations to a point such that the amplitude of the latter is sufficiently greater than the signal voltage amplitude at the detector input circuit thereby to cause detection of the desired signal energy to take place along the linear portion of the detection characteristic and the gain between said converter and detector being sufficiently low to permit detection of undesired signal energy along the lower inefficient portion of the detection characteristic.

8. In combination with a demodulation network having a signal input circuit, means for producing oscillations of a frequency equal to the frequency of desired signal energy at the demodulator input circuit, said demodulator network having a detection characteristic which follows a law other than linear for weak signal amplitude at the demodulation input circuit, and follows a linear law for signal amplitudes above that said amplitude, means for applying undesired interference signals and desired signals to said demodulator input circuit at said weak signal amplitude, and means for applying to said demodulation input circuit said produced oscillations in amplified form, said applied oscillations having an amplitude such that detection for solely desired signal voltage is of high efficiency and means responsive to signal energy variation for controlling the amplitude of said produced oscillations.

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