June 20, 1939. P. O. FARNHAM 2,162,882

RECEIVER PERCENTAGE MODULATION CONTROL CIRCUIT

Filed Oct. 28, 1936 2 Sheets-Sheet 1

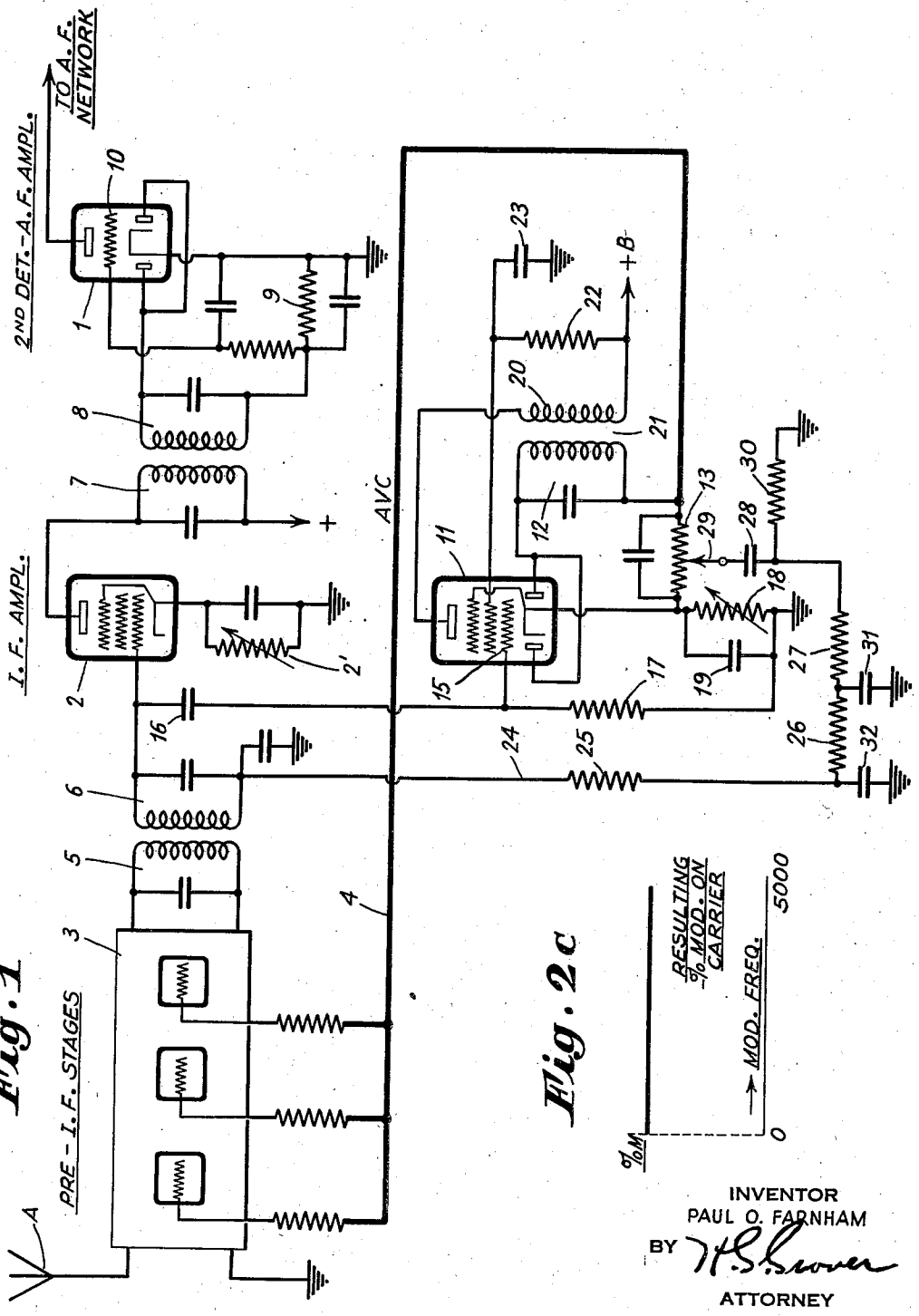


Fig. 1

Fig. 2c

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Fig. 2a

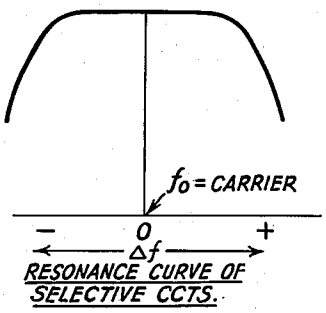


Fig. 2b

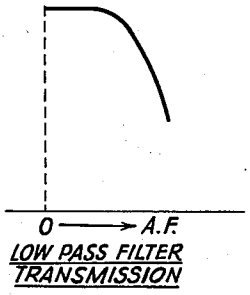


Fig. 3

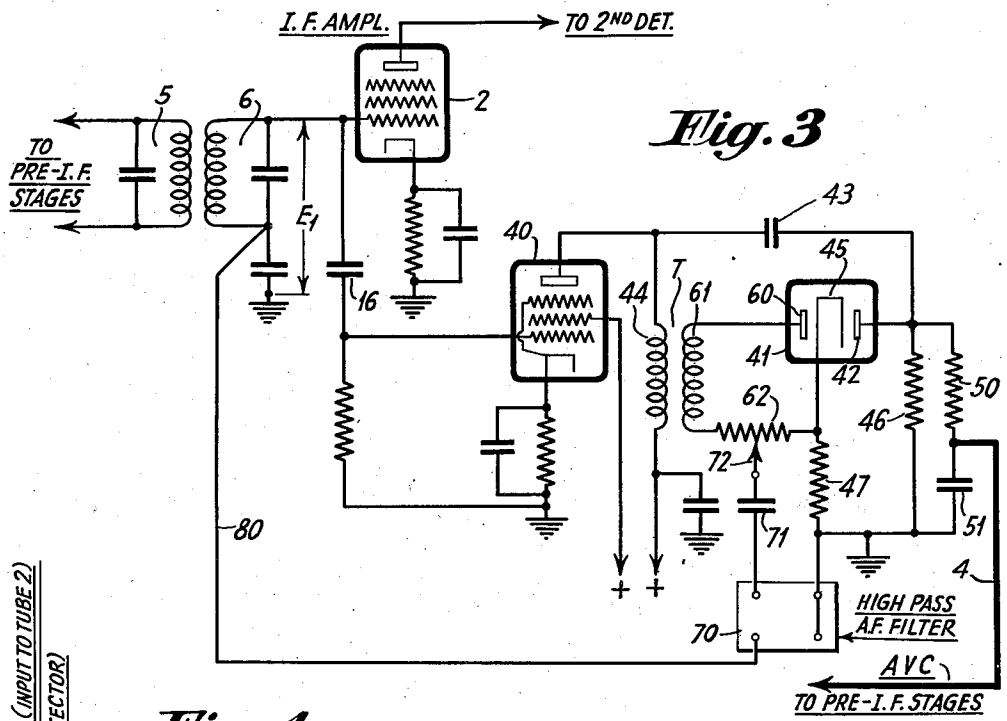
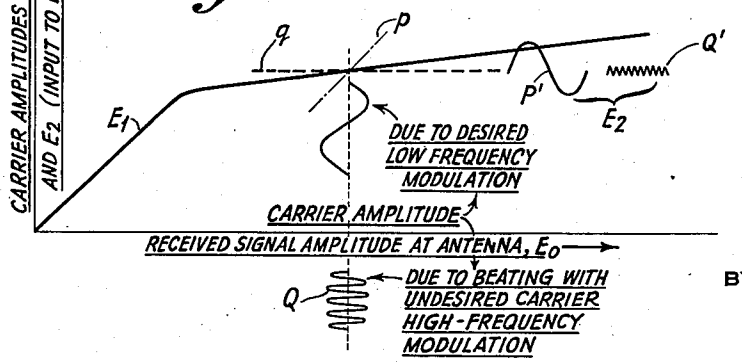


Fig. 4



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RECEIVER PERCENTAGE MODULATION CONTROL CIRCUIT

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Application October 28, 1936, Serial No. 107,928

10 Claims. (Cl. 250—20)

My present invention relates to methods of, and means for, controlling the percentage modulation of received modulated high frequency carrier signals, and more particularly to novel circuits adapted for utilization in radio receivers to adjust the percentage modulation of received signals in a predetermined manner.

There are many situations in the art of radio reception when it is desired to adjust, in a predetermined sense, the percentage modulation of received signals. For example, interference from a strong adjacent channel signal may be such as to greatly affect reception of a desired channel. Such adjacent channel interference usually manifests itself by a heterodyne whistle, and often by sounds which are representative of the modulation output from the undesired carrier and its side bands. In the presence of such interference one may design the receiver, in accordance with the present invention, so that the amplitude modulation represented by the undesired carrier beating with the desired carrier is removed by a degenerative modulating feed back acting upon the radio amplifier preceding the audio detector.

Accordingly, it may be stated that it is one of the important objects of the present invention to provide a method of improving the selectivity of a radio receiver against an adjacent undesired carrier beat, manifesting itself as a heterodyne whistle, and against the modulation output from the undesired carrier and its side bands, the method essentially comprising the utilization of an auxiliary "quick-acting" automatic volume control network in a radio receiver which functions effectively to reduce the percentage modulation, at the detector of the receiver, of the unwanted higher modulation frequencies imposed by interference with the received carrier.

It may also be stated, in connection with this aspect of the present invention, that it is another important object of the present invention to provide in combination with the conventional slow-acting automatic volume control network of a radio receiver, a quick-acting automatic control network which functions solely to reduce the transmission of the higher modulation frequencies of the received carrier signals whereby the apparent selectivity of the receiver is improved.

Besides the utilization of the present invention described above, it is also desirable to employ the latter when it is desired to secure high fidelity over a wide band of modulation frequencies in a selective radio amplifier system which would normally attenuate the higher frequency side bands. That is to say, the modern radio receiver may be constructed in such a manner that its signal selecting circuits tend to produce side band attenuation. In the past such attenuation effects of the selective circuits has been compensated for by special design of the audio frequency amplifier. The present invention makes it feasible to compensate for such attenuation by operating exclusively on the selective circuits.

Hence, it may be stated that another important object of the present invention is the control of the percentage modulation on the carrier supplied to the audio detector so as to maintain it at a uniformly low value for all modulation frequencies; this action being accomplished by utilizing a relatively quick-acting AVC network in the radio receiver which functions to reduce the percentage modulation of the lower modulation frequencies more than it reduces that of the higher modulation frequencies on the carrier wave fed to the audio detector.

Another important object of this phase of the invention is to provide in a radio receiver a pair of automatic gain control circuits, one of them functioning to vary the gain of one or more signal amplifiers preceding the audio detector in a sense to maintain the signal carrier amplitude at the audio detector substantially constant for slow variations in the received carrier amplitude such as fading effects, and the other gain control circuit acting on a signal amplifier between the first named amplifiers and the audio detector, and operating to maintain the percentage modulation on the carrier at the audio detector at a uniformly low value for all modulation frequencies.

However, from a generic viewpoint, it will be observed that the primary object of the present invention, regardless of its utilization, is to provide in a radio receiver, and in addition to the usual means for maintaining the signal carrier amplitude at the audio detector substantially uniform in value, an auxiliary control circuit which operates on a signal transmission tube disposed between the tubes operated on by the AVC network, and the audio detector, for the purpose of controlling in a predetermined sense the percentage modulation on the signal carrier supplied to the audio detector.

Still other objects of the invention are to improve generally the efficiency of modulated radio frequency reception systems, and more especially to provide improved circuits for controlling the apparent selectivity of the receiver selector

circuits, which improved circuits shall be reliable in operation, and economically manufactured and assembled in radio receivers.

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 diagrammatically shows a receiver embodying one form of the invention when employed to improve the fidelity of a receiver,

Figs. 2*a*, 2*b*, 2*c* show respectively different characteristics of the receiving system depicted in Fig. 1,

Fig. 3 shows a modified form of the invention when utilized to improve the selectivity of a radio receiver,

Fig. 4 illustrates graphically the operation of both slow and quick-acting automatic control networks as it affects the carrier wave amplitude at the detector input.

Referring now to the accompanying drawings, wherein like reference characters in the different figures illustrate similar circuit elements, there is shown in Fig. 1, in conventional manner, the circuits of a well-known type of superheterodyne receiver. The signal collector A may be the usual grounded antenna circuit; a radio frequency distribution line; or even a loop antenna. The second detector, or audio demodulator, is represented by the numeral 1, and the preceding I. F. amplifier tube is designated by the numeral 2. The stages preceding amplifier 2 have been conventionally represented, and those skilled in the art will understand that numeral 3 denotes the usual "Pre-I. F. stages" employed prior to the second detector. For example, the network 3 may comprise one, or more, stages of tunable radio frequency amplification; a first detector electrically associated with a local oscillator to produce the beat energy at the operating intermediate frequency; and one or more stages of I. F. amplification. Regardless of the construction of the stages preceding I. F. amplifier 2, it will be understood that the gain of the tubes of such stages will be automatically regulated by the usual AVC network; for this purpose the AVC lead 4 has been represented as connected to the grids of the various tubes in network 3. Of course, the present invention is not limited to utilization in connection with a superheterodyne receiver; the numerals 3 and 2 may represent cascaded tunable radio frequency amplifier stages.

Employing the superheterodyne receiver as the form of reception system to be illustrated in connection with the present invention, it will be understood that numerals 5 and 6 denote the I. F. resonant circuits which are coupled reactively, and which provide a circuit coupling the output of network 3 to the input electrodes of amplifier 2. The plate circuit of amplifier 2 includes a resonant circuit 7, tuned to the operating I. F., the circuit 7 being reactively coupled to the resonant circuit 8, the latter feeding the second detector electrodes, and being tuned to the operating I. F. By way of example, it is pointed out that the operating I. F. may have a value of 175 kc., this value will be dependent upon the design of the receiver and may even be a much higher frequency. The second detector tube 1 is of the multiple duty type, and 55 or 2B7 type tubes may be utilized. Such a tube is too well known at the present time to require further description, it being only necessary to point out that in the system illustrated the diode anodes are strapped together, and cooperate with the cathode to provide a diode rectifier circuit. The audio component of rectified signal currents produced across resistor 9, which is disposed in the low alternating potential side of the rectified circuit, is impressed on the control grid 10 of tube 1. Thus, the tube functions as a diode second detector and an audio amplifier. The amplified audio currents in the plate circuit of tube 1 may be further amplified in one, or more, stages of audio amplification, and then reproduced in any well-known manner.

The automatic control (AVC) network comprises an auxiliary I. F. amplifier which feeds amplified I. F. energy to an auxiliary diode rectifier. The numeral 11 denotes an electron discharge tube of the 2B7 type, and this type of tube comprises a pentode amplification section, and a pair of diode anodes. In this case the diode anodes are strapped together, and are connected to the cathode of the tube through a path including the resonant circuit 12, which is tuned to the operating I. F., and the diode load resistor 13. The latter may have a magnitude of approximately 100,000 ohms, and is shunted by a by-pass condenser having a magnitude of approximately 100 mmf. The signal input electrode 15 of tube 11 is connected to the grid side of resonant circuit 6 through a condenser 16 having a magnitude of approximately 100 mmf. A resistor 17, having a magnitude of approximately 2 megohms, is connected between the electrode 15 and the grounded side of the cathode bias resistor 18, the latter being shunted by a by-pass condenser 19. The plate of tube 11 is connected to a source of positive potential through a path which includes the primary winding 20 of the transformer 21, the secondary winding of the latter being included in the resonant circuit 12. The screen grid electrode of amplifier 11 is connected to the positive potential source B through a voltage reducing resistor 22, the screen electrode side of resistor 22 being connected to ground through a by-pass condenser 23.

The magnitude of biasing resistor 18 is chosen so as to have a voltage of approximately 3 volts produced across it by the space current flow therethrough, and, therefore, a normal negative bias of —3 volts will be provided on the signal input electrode 15. The anode side of resistor 13 is connected through the AVC lead 4 to the various gain control electrodes of the stages in network 3. Those skilled in the art are fully aware of the operation of an AVC circuit; it is only necessary to point out that, assuming the controlled electrodes to be the signal grids, the signal grids have a normal negative bias provided by the usual cathode bias resistors, and as the signal amplitude increases there is impressed on these grids an increasing negative bias by virtue of the fact that they are connected through a direct current voltage connection 4 to the diode anode side of resistor 13. Obviously, as the received signal amplitude increases the amplitude of the signals impressed on amplifier 11 will increase, and, therefore, the direct current component of the rectified current flowing

through resistor 13 will also increase in magnitude.

Considering now the over-all characteristic of the signal-selecting circuits of the receiver, Fig. 2a illustrates in a purely qualitative manner, the resonance curve characteristic of the various selective circuits. For various reasons, among which is the fact that these various tuned circuits are arranged in cascade, the over-all resonance curve characteristic will be such that there is normally a tendency to attenuate the higher frequency components of the modulation side bands. While it is possible to design the various selective circuits of the receiver to minimize this side band attenuation, it is a costly matter to construct substantially perfect signal band pass networks. By means of the present invention, it is made possible to compensate for the side band attenuation, and to do so with minimum utilization of circuit elements.

The side band attenuation is compensated for by connecting the signal grid of I. F. amplifier 2 to a desired point on resistor 13 through a path which includes the lead 24, resistor 25, resistor 26, resistor 27, condenser 28, and the adjustable tap 29. A resistor 30 is connected between ground and the junction of condenser 28 and resistor 27; the junction of resistors 26 and 27 is connected to ground through condenser 31, the junction of resistors 25 and 26 is connected to ground through condenser 32, and a condenser to ground is connected to the grid side of resistor 25. The condenser 28 has a magnitude of approximately 0.1 mf., and the resistor 30 is given a magnitude of substantially 3 megohms. The network between tap 29 and the signal grid of amplifier 2 provides a degenerative audio frequency feedback path. In other words, the condenser 28 and resistor 30 function, with resistors 25, 26 and 27 and condensers 31 and 32, to provide a low-pass filter for modulation frequency voltages, between the diode load resistor 13 and the input electrodes of amplifier 2, which has a transmission characteristic illustrated in Fig. 2b. From this latter figure, it will be observed that the transmission characteristic of the low-pass filter is such that the lower frequency components of the modulation side bands are transmitted more efficiently than the higher modulation frequencies. Thus the modulated carrier wave passed by amplifier 2 will have the output percentage modulation rates considerably reduced for the lower, but not for the higher modulation frequencies. This occurs because the constants of the low pass filter network have been selected so as to give it a transmission characteristic similar in shape to the transmission characteristic of the selective receiver for frequencies off resonance.

In this manner, for example, a carrier wave modulated 100% by a changing audio frequency voltage would ordinarily reach the audio detector over a selective radio amplifier with a modulation percentage of 100 for low modulation frequencies, for example 100 cycles; a percentage of 50 for 2000 cycles, and a percentage of 10 for 5000 cycles. With the degenerative audio feed back network from the diode load resistor 13, the transmission of the low-pass filter may be chosen so as to result in a modulation percentage of 10 reaching the audio detector independent of modulation frequency from 100 to 5000 cycles. This resulting percentage modulation on the carrier reaching the audio detector is graphically depicted in Fig. 2c.

This method of improving the fidelity of reception is not only as efficient as compensation of side band attenuation due to radio frequency selectivity, by suitable design of the audio amplifier, but has the additional advantage that the percentage modulation on the carrier depicted by the audio detector is kept at a uniformly low value for all significant modulation frequencies thus reducing greatly the amount of distortion introduced by the process of detection. The degree of fidelity can be controlled by a direct current bias applied either to the AVC amplifier 11, or simply by regulating the gain of amplifier 2.

In the case of the former method the bias resistor 18, for example, may be made adjustable so that it is possible to regulate the amount of the degenerative modulation voltage feed back to amplifier 2 for low audio frequencies. By adjusting the magnitude of the bias resistor 2', disposed in the cathode circuit of amplifier 2, the gain of the amplifier is regulated so that the degenerative modulation voltage feed back will have less effect at some biases on the amplifier than at others. It will be appreciated, in general, that the auxiliary I. F. amplifier 11 feeds the linear diode rectifier including resistor 13, and that in this case the resulting audio voltage is employed to reduce the percentage modulation on the carrier by applying the audio voltage to the last I. F. amplifier tube 2. It is to be understood that the audio voltage produced at resistor 13 can be applied to any part of the receiving system following the point at which the AVC channel is taken off. In this way, the fidelity of the receiver may be automatically adjusted to compensate for whatever side band attenuation, within wide limits, is present in the selective signal circuits.

In Fig. 3 there is shown a modification of the invention, as applied to a receiving system of the superheterodyne or tuned radio frequency type, but wherein the ultimate result of the arrangement is to improve the selectivity of the receiver so as to effectively eliminate interference caused by undesired adjacent channel signals. Only such portions of the circuits are shown which are believed necessary to a clear understanding of the invention. The I. F. amplifier tube 2 has signal energy from the input circuit thereof impressed upon the input electrodes of amplifier 40; the signal energy being transmitted through the condenser 16. The amplifier tube 40 differs from tube 11 in Fig. 1 in that it does not include the diode anodes. An auxiliary tube 41 is provided, which tube includes a cathode and two anodes.

The anode 42 is connected to the plate circuit of amplifier 40 through a condenser 43, and the connection of the condenser is made to the plate side of primary winding 44 of transformer T. The direct current voltage component for the AVC network is developed across resistor 46, and the latter is connected between the cathode 45 and anode 42, and is arranged in series with resistor 47. The AVC lead 4 is connected to the junction of resistor 50 and condenser 51, and the latter two elements are arranged in series, and both connected in shunt across resistor 46. The resistor 50 and condenser 51 function as a filter for removing all pulsating components from the rectified current flowing through resistor 46.

The diode anode 60 is connected to the cathode 45 through a path which includes the secondary winding 61 of transformer T, and resistor 62. A high-pass audio frequency filter 70 is employed in the auxiliary quick-acting AVC network, in

place of the low-pass audio filter used in Fig. 1. One of the input terminals of the high-pass filter is connected to resistor 62 through condenser 71 and adjustable tap 72, the other terminal being connected to the grounded side of resistor 47. The lead 80 connects the low alternating potential side of resonant circuit 6 to one of the output terminals of the high pass filter 70. It will, therefore, be seen that amplified I. F. energy from amplifier 40 is impressed upon tube 41 for two purposes. In the first place, the diode rectifier network including electrodes 45 and 42 functions as the usual AVC network for regulating the gain of the pre-I. F. stages to maintain the carrier amplitude at the second detector substantially uniform. In the second place, the amplified I. F. energy is transmitted through transformer T to the diode rectifier circuit including electrodes 45 and 60, and the higher audio frequency components of the modulation side bands are fed back to the input electrodes of amplifier 2 by virtue of the high pass filter 70.

Consideration of Fig. 4 will show that due to the action of the normal, or slow-acting, AVC network the signal carrier voltage E_1 at the input electrodes of I. F. amplifier 2 will be held approximately constant with increasing collected carrier voltage E_0. By applying the signal voltage at the input of amplifier 2 through amplifier 40 to another rectifier, whose output circuit is designed to pass modulation frequencies above the range to be transmitted to the second detector and audio system, and applying the output of the high-pass filter back upon the controlled grid of amplifier 2, so as to employ the path of operation represented by q the output carrier voltage of amplifier 2 which is fed to the detector input may be made substantially free of all modulation frequencies, Q', higher than those in the audio band to be reproduced while still retaining at full modulation percentage the desired amplitude modulation, P', since the normal path of operation, p, is here used. In other words, the audio frequency components fed back to the amplifier 2 are those which give rise to the heterodyne whistle, and the sounds resulting from the modulation output from the undesired carrier and its side bands. It can be theoretically demonstrated that this suppression action in the presence of a sufficiently strong desired carrier lead, E_0, and resulting improved apparent selectivity, takes place with the arrangement shown in Fig. 3.

It is only necessary to point out that proper design of the high pass filter 70 will result in suppression of the variations in amplitude of the carrier voltage at the input of amplifier 2, which variations are due to the heterodyne combination of the undesired adjacent channel carrier frequency and the desired carrier frequency. It is also pointed out that if variations in the amplitude of the signal voltage in the output circuit of amplifier 2 due to the presence of an interfering carrier are suppressed for a wide range of amplitudes and frequencies of the interfering carrier, they will be suppressed when the undesired carrier is modulated.

The method shown in Fig. 3 lends itself as well to the reduction of the percentage modulation on the desired carrier for the purpose of selective detection wherein the quick-acting AVC network is made to transmit nearly enough voltage at all significant desired modulation frequencies to cancel approximately all the desired modulation at the output of amplifier 2. Again, it is sometimes useful to take a fraction of the usual, or slow-acting, AVC bias, and apply it to control the effective negative potential of signal grid of amplifier tube 2.

It will now be appreciated that there have been disclosed two circuit arrangements for utilizing the general method of controlling present modulation on the desired carrier wave in a radio receiver. In one of these embodiments, that is to say, Fig. 1, the effect of the control circuit is to supply to the detector of the receiver a desired carrier wave whose percentage modulation is substantially uniform, this being accomplished by the utilization of an audio feed back circuit which functions to decrease the transmission efficiency of the lower audio frequency components of the modulation side bands. In the second arrangement, shown in Fig. 3, the selectivity of a receiver is apparently improved in order to avoid interference effects from an undesired adjacent channel signal, this being accomplished by transmitting over the feed back path the higher audio frequency components of the modulation side bands, which components are due to the beating effects between desired and undesired carrier signals. In both cases, it will be noted, there is employed in conjunction with the usual slow-acting AVC network, a relatively quick-acting AVC circuit which, from a generic viewpoint, controls the present modulation on the desired carrier wave as presented to the detector.

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. A method of receiving signals with a radio receiver of the type comprising at least two cascaded carrier wave amplifiers resonant to a predetermined carrier frequency and a detector, which includes the steps of varying the gain of the first of said amplifiers in response to wave amplitude variations and in a sense to maintain the wave amplitude at the detector input substantially uniform, rectifying received carrier energy, separating from the rectified energy a predetermined fraction of the audio frequency components of the entire modulation frequency band of the carrier wave, and impressing upon the second of said amplifiers said predetermined fraction of the audio frequency components.

2. A method of receiving signals with a radio receiver of the type comprising at least two cascaded carrier wave amplifiers resonant to a predetermined carrier frequency and a detector, which includes the steps of varying the gain of the first of said amplifiers in response to wave amplitude variations and in a sense to maintain the wave amplitude at the detector input substantially uniform, rectifying carrier wave energy derived from the second amplifier input, separating from the rectified energy a predetermined fraction of the audio frequency components of the entire modulation frequency band of the carrier wave, and impressing upon the second of said amplifiers said predetermined fraction of the audio frequency components.

3. A method of receiving signals with a radio receiver of the type comprising at least two cascaded carrier wave amplifiers resonant to a pre-

determined carrier frequency and a detector, which includes the steps of varying the gain of the first of said amplifiers in response to wave amplitude variations and in a sense to maintain the wave amplitude at the detector input substantially uniform, rectifying received carrier energy, and impressing a predetermined band of the high audio frequency components of said rectified energy upon the second of said amplifiers in degenerative phase.

4. A method of receiving signals with a radio receiver of the type comprising at least two cascaded carrier wave amplifiers resonant to a predetermined carrier frequency and a detector, which includes the steps of varying the gain of the first of said amplifiers in response to wave amplitude variations and in a sense to maintain the wave amplitude at the detector input substantially uniform, rectifying received carrier energy, and impressing in degenerative phase upon the input circuit of the second of said amplifiers a predetermined band of the higher audio frequency components of said rectified wave energy.

5. A method of receiving signals with a radio receiver of the type comprising at least two cascaded carrier wave amplifiers resonant to a predetermined carrier frequency and a detector, which includes the steps of varying the gain of the first of said amplifiers in response to wave amplitude variations and in a sense to maintain the wave amplitude at the detector input substantially uniform, rectifying received carrier energy, and impressing in degenerative phase upon the input circuit of the second wave amplifier a band of the lower audio frequency components of said rectified wave energy.

6. In combination in a radio receiver, a detector, a tuned carrier wave amplifier having its output circuit coupled to the input circuit of the detector, and at least one tuned carried wave transmission tube network preceding said amplifier, an automatic volume control network for varying the direct current bias of a gain control electrode of said transmission tube in response to variations in carrier wave amplitude, and an auxiliary automatic volume control network for impressing upon a gain control electrode of said amplifier, audio voltages of frequencies included within a predetermined portion of the modulation frequency band of said carrier wave.

7. In combination in a radio receiver, a detector, a tuned carrier wave amplifier having its output circuit coupled to the input circuit of the detector, and at least one tuned carrier wave transmission tube network preceding said amplifier, an automatic volume control network for varying the direct current bias of a gain control electrode of said transmission tube in response to variations in carrier wave amplitude, an auxiliary automatic volume control network for impressing upon a gain control electrode of said amplitude, audio voltages of frequencies included within a predetermined portion of the modulation frequency band of said carrier wave, and said auxiliary control network including a carrier wave rectifier having a wave input connection to the input circuit of said amplifier.

8. In combination in a radio receiver, a detector, a tuned carrier wave amplifier having its output circuit coupled to the input circuit of the detector, and at least one tuned carrier wave transmission tube network preceding said amplifier, an automatic volume control network for varying the direct current bias of a gain control electrode of said transmission tube in response to variations in carrier wave amplitude, an auxiliary automatic volume control network for impressing upon a gain control electrode of said amplifier a voltage representative of the modulation on said carrier wave, and said auxiliary control network including a carrier wave rectifier having a connection to the amplifier input circuit for transmitting the lower audio frequency components of the carrier wave modulation more efficiently than the higher audio components.

9. In a radio receiver of the superheterodyne type, a second detector, an intermediate frequency amplifier coupled to the input of said detector, at least one signal transmission network preceding the amplifier, a plurality of resonant circuits cascaded between said amplifier and preceding network, and which resonant circuits tend to attenuate the higher audio components of the modulation side bands of the received carrier, an automatic volume control circuit for varying the signal transmission to said amplifier in a sense to maintain the carrier amplitude at the second detector input substantially uniform, and a control circuit comprising a rectifier adapted to have signal energy from the input of said amplifier impressed on it, and means for feeding back upon the input circuit of said amplifier a predetermined band of higher audio frequency components of the rectified signal energy.

10. In a radio receiver of the superheterodyne type, a second detector, an intermediate frequency amplifier coupled to the input of said detector, at least one signal transmission network preceding the amplifier, a plurality of resonant circuits cascaded between said amplifier and preceding network, and which resonant circuits tend to attenuate the higher audio components of the modulation side bands of the received carrier, an automatic volume control circuit for varying the signal transmission to said amplifier in a sense to maintain the carrier amplitude at the second detector input substantially uniform, and a control circuit comprising a rectifier adapted to have signal energy from the input of said amplifier impressed on it, and means for feeding back in degenerative phase upon the input circuit of said amplifier a predetermined band of the higher audio frequency components of the rectified signal energy.

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