Dec. 16, 1941. E. N. MULLER 2,266,065

AUTOMATIC TUNING DEVICE FOR RADIO RECEIVERS

Filed Oct. 10, 1938 3 Sheets-Sheet 1

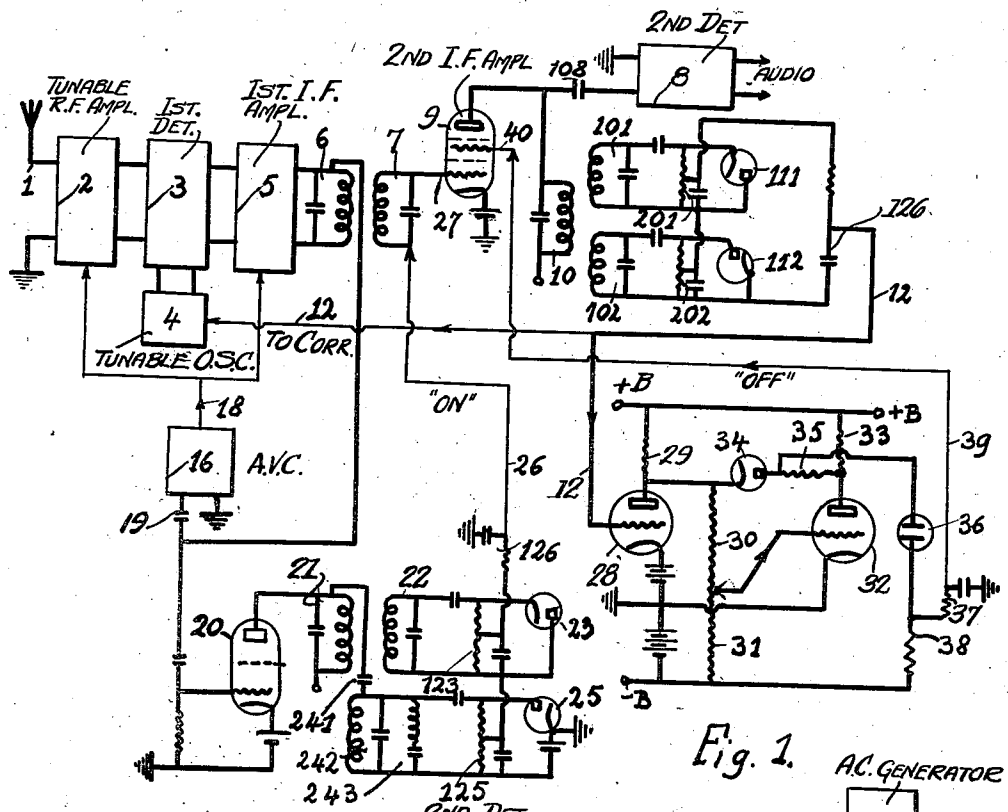


Fig. 1.

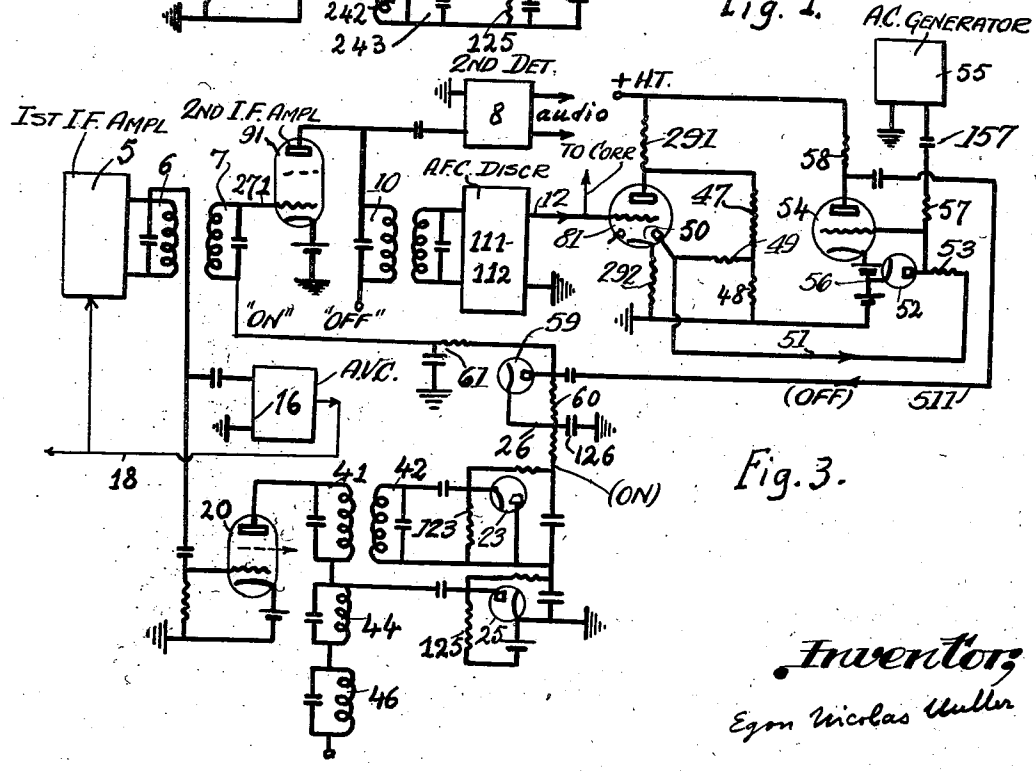


Fig. 3.

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AUTOMATIC TUNING DEVICE FOR RADIO RECEIVERS

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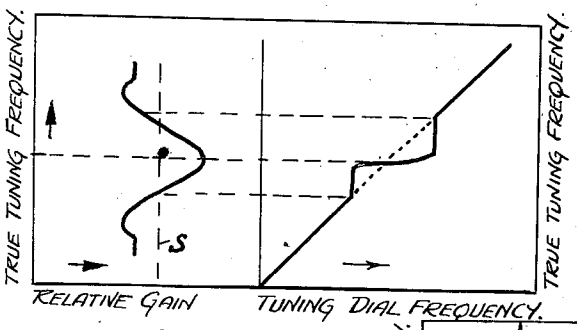


Fig. 2.

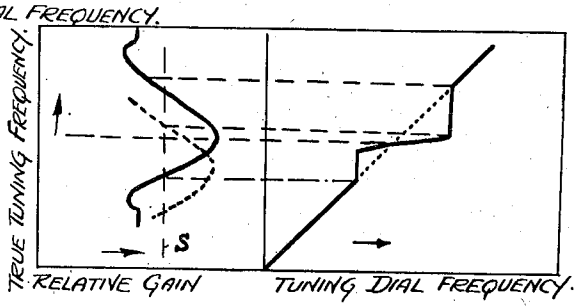


Fig. 5.

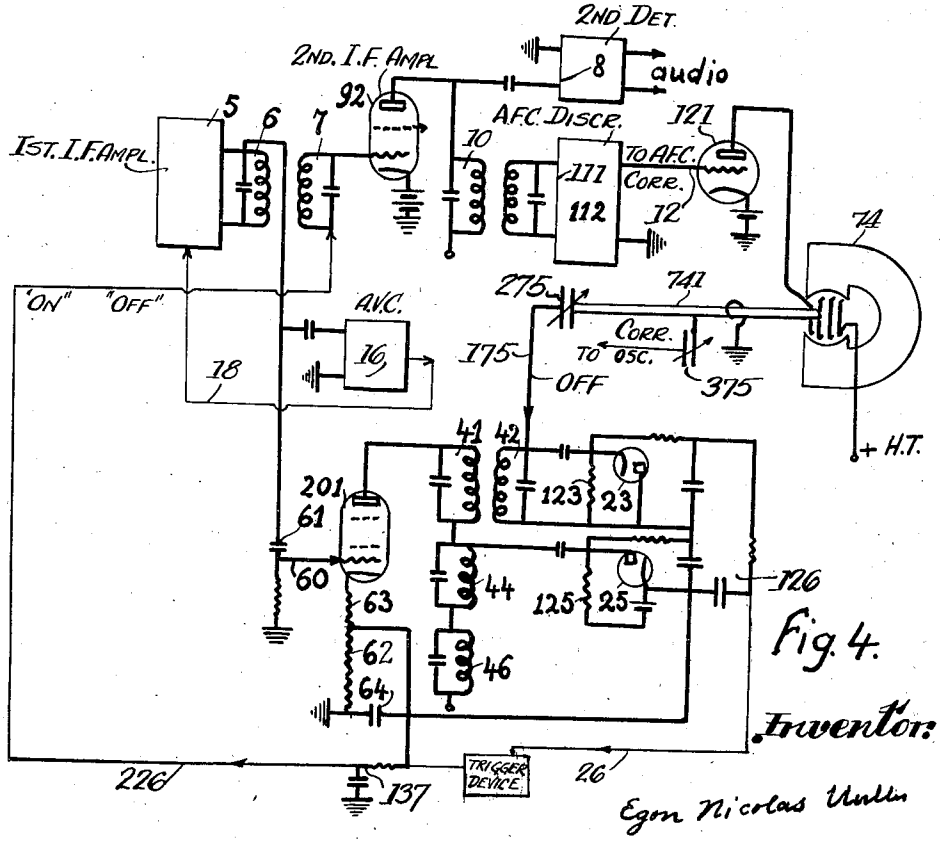


Fig. 4.

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AUTOMATIC TUNING DEVICE FOR RADIO RECEIVERS

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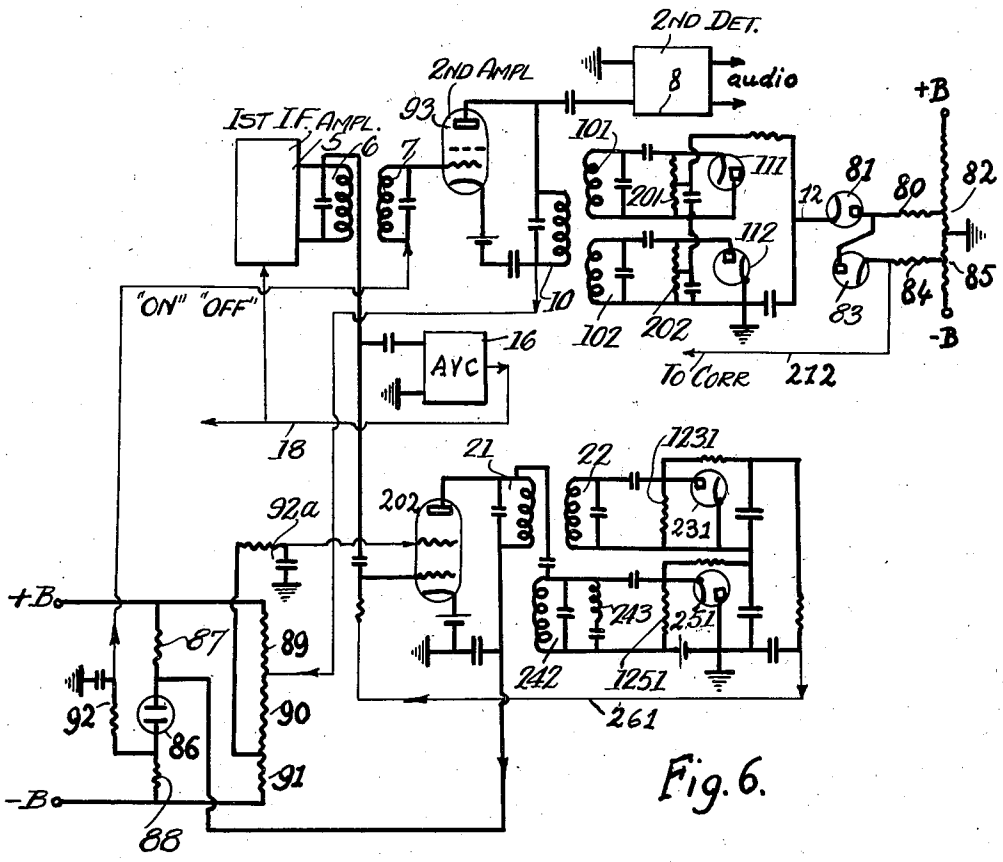


Fig. 6.

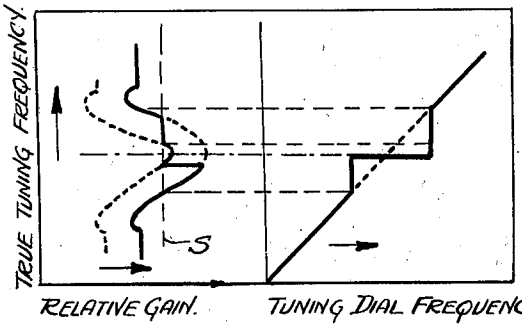


Fig. 7.

Inventor.

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Patented Dec. 16, 1941

2,266,065

UNITED STATES PATENT OFFICE

2,266,065

AUTOMATIC TUNING DEVICE FOR RADIO RECEIVERS

Egon Nicolas Muller, Esch, Alzette, Luxemburg

Application October 10, 1938, Serial No. 234,154
In Luxemburg July 1, 1936

25 Claims. (Cl. 250—40)

My present invention applies to radio receivers of the type preferably wherein the tuning frequency may be varied through a range of substantial width, and relates more particularly to automatic control circuits for facilitating the tuning-in of the desired program.

In most receivers due to the high selectivity thereof some difficulty is experienced iln exactly tuning in the incoming signal. Of course when the receiver is not sufficiently well in resonance with the carrier frequency, this will result in a distored reproduction. It is well known that those receivers wherein the operator must rely on visual or aural indications, are scarcely satisfactory, since a considerable amount of care is required, which most listeners are unwilling or unable to expend. Frequently a so-called inter-station noise suppressor means has been incorporated in modern receivers to render the tuning apparently very sharp whereby to prevent a distorted reproduction. However the operator in such eventuality might tune past the stations unless he tunes very carefully, this making the "searching" of the different programs very tedious. This will readily be understood when it is considered that in selective receivers a program can be adequately listened over a very restricted range of frequencies, not much in excess of 300 cycles wide on either side of the exact position, whereas the spacing of the various stations usually is not less than 10 kilocycles, even if it assumed that there are no idle channels.

According to the invention means are provided for avoiding the above inconveniences by "spreading" the position of exact tuning whereby the tuning control member, when approximately adjusted to provide the tuning-in of a station may be moved in a moderate proportion without causing a substantial variation of the tuning frequency of the receiver.

In accordance with the invention described and claimed more particularly in parent application Ser. No. 150,922, filed June 29, 1937, (now Patent 2,207,467 issued July 9, 1940), the above broad objects may be attained by means of electro-mechanical apparatus. According to the invention specifically set forth in my present application, which is a continuation of parent application Ser. No. 150,922, the above broad objects may be attained substantially in electrical fashion, mechanically moving parts if desired being entirely dispensed with.

To this end a tuning control circuit in accordance with the invention is provided with an automatic resonance adjusting system or so-called A. F. C. device, which may be of conventional design, for automatically correcting departure from exact resonance of the "physical" tuning means i. e. the means which may be under the direct control of the operator and which are generally associated with the tuning dial; and there are also provided means for controlling the action of the A. F. C. system so that, when the operator tunes through the tuning band, substantially each of the different carriers may be properly tuned in and released.

Whereas proper tuning-in of the carrier is not so troublesome with a receiver equipped with A. F. C., especially so if the receiver is provided with a well-designed preselector, the operating conditions as concerns the "dropping" of the station are very severe since a large amount of mistuning of the "physical" tuning means usually corresponds to a very reduced departure from exact resonance of the actual i. e. "corrected" tuning frequency, and this actual mistuning is all the smaller the more effective is automatic correction; usually a large sensitivity of the automatic corrector system is desirable, for obvious reasons. It has been suggested that reception conditions may be controlled by a circuit in substance designed along the lines of the conventional noise suppressors. One of the major drawbacks of such an arrangement is that the initial adjustments are very difficult and the stability of operation of the system risks to be insufficient. It is desirable that substantially at no time reproduction be possible with A. F. C. in a condition of low sensitivity. A highly selective circuit is required in such case to detect the rather minute amount of mistuning which usually is left when A. F. C. is correcting a considerable amount of physical mistuning, making the arrangement expensive. Of course a minute amount of misalignment of the selective means of the suppressor circuit with respect to the frequency of the so-called discriminator of A. F. C. which serves to detect departure from exact resonance and on which the corrector stays locked, would be sufficient to make the system fully inoperative or to give rise to considerable distortion and to suppress the function of noise suppression. It is to be noted in this connection that a modest amount of misalignment between the frequency of the discriminator and the tuning frequency (e. g. the mean frequency of the intermediate frequency circuits in a superheterodyne type receiver) will not affect the operation of A. F. C. and will cause negligible distortion in the reproducer system. Another im-

portant drawback of an arrangement of the broad character referred to consists in the fact that by adjusting the physical tuning means toward resonance and through the point of exact resonance, the suppressor circuit will permit the reception only close to the resonance point whereas it will drop the station a quite considerable amount past this point, while giving rise to so-called hysteresis. This results in apparently lessened dial calibration accuracy, the mean position of the station on the tuning dial being dependent on the sense of actuation of the tuning member, and in a high mean value of the tracking error in the preselector circuits with respect to the intermediate frequency circuits in a superheterodyne receiver.

It is an object of the different forms of circuits in accordance with my invention to avoid the various drawbacks above set forth and to provide among others the advantages of easy initial adjustments, entirely reliable operation under all tuning conditions in spite of minute accidental changes in the frequencies to which the different circuits are adjusted, and substantially uniform effectiveness of the control system with respect to the mean tuning frequency of the physical tuning means and tuning dial.

According to one of its aspects the invention provides means for properly "dropping" the station on which A. F. C. gets locked, after tuning is a desired amount away from the exact resonance point; these means are operated through received energy of carrier frequency to provide reliable operation, and their action is dependent on that of A. F. C. According to another of its aspects the invention provides distinct means for respectively switching "on" and "off" the A. F. C. channel and likewise if desired the reproducer circuits of the receiver. In accordance with the preferred form of the invention, means for switching "on" the A. F. C. device and if desired the audio system, are closely associated with the circuit of the A. F. C. system whereby errors due to misalignment may be avoided.

The control circuit for switching "on" the A. F. C. device after a carrier wave is tuned in, may be constructed in different possible ways. I may prefer in general to utilize a circuit capable of discriminating between a carrier wave and the back-ground of noise due to "static"; thus the tuning-in of comparatively weak stations is permitted when the local reception conditions permit so without the necessity of providing sensitivity control means or the like, which cannot be actuated readily enough by the user of the receiver.

Other objects of my invention will result from the following detailed description, which is illustrated in Figs. 1–7.

In the accompanying drawings:

Fig. 1 diagrammatically shows an embodiment of the invention wherein the circuit for automatically controlling the tuning frequency is made effective by means of a potential derived from a carrier wave exceeding in a desired minimum proportion the back-ground of noise, and wherein said circuit is blocked again when the magnitude of the potential for controlling the tuning frequency exceeds a predetermined amplitude.

Fig. 2 is a graph explaining the operation of the control circuit in Fig. 1.

Fig. 3 shows a modified circuit arrangement, the operation being in the main the same as in Fig. 1.

Fig. 4 diagrammatically shows another form of the invention, in which the automatic control circuit is made effective substantially in the same way as in Fig. 1, and wherein this circuit is blocked again by the control channel serving to make effective said tuning control circuit after the selectivity characteristics of said channel have been altered in response to the magnitude of the automatic tuning control potential.

Fig. 5 is a graph illustrating the operation of the system in Fig. 4.

Fig. 6 illustrates still another form of the invention, in which the threshold of operation of the channel for making effective the automatic tuning control circuit is normally given a rather low value, which is increased in response to the condition of effectiveness of the automatic tuning control circuit; the operation of the system is improved by the provision of means for limiting the range of effectiveness of the tuning control circuit.

Fig. 7 graphically shows the operation of the system in Fig. 6.

Similar circuit elements are hereinafter given the same or analogous reference numerals.

Reference should now be had to Fig. 1, in which the invention is arranged for use with a superheterodyne receiver. The signal energy from collector 1 is applied to a tunable radio-frequency amplifier 2, the output of which is coupled to a frequency changer device comprising a modulator stage or first detector 3 which co-operates with a tunable local oscillator 4 so as to produce oscillations of a fixed intermediate frequency. As is common practice in modern receivers, the different tunable circuits in the sections 2, 3 and 4 are uni-controlled by a control member which may be actuated manually.

The intermediate frequency oscillations are applied to a tuned amplifier section 5, the output circuit of which is coupled to a further amplifier tube 9 through a transformer with a resonant primary circuit 6 and with a resonant secondary 7, both circuits being tuned to the intermediate frequency, and being moderately coupled by mutual inductance. The anode circuit of amplifier 9 includes a resonant circuit 10 tuned to the intermediate frequency. The energy across this circuit is fed through a condenser 108 to the demodulating detector 8, which feeds the audio-amplifier and reproducer. Resonant circuit 10 is also coupled to a channel for automatically controlling the tuning frequency within restricted limits in response to the amount of mistuning of the receiver with respect to the desired carrier wave, this device being hereinafter referred to as A. F. C. system. Systems of this character are known in the art and it may be stated that in general they comprise a so-called discriminator circuit fed with signal energy to derive a control potential which is applied to a suitable variable impedance system hereinafter referred to as the corrector, the impedance being a function of said potential. In the instance shown the discriminator system by way of example is shown as of a well-known type including two resonant circuits 101 and 102 respectively tuned to frequencies on one side and other of the intermediate frequency, the amount of mistuning being for instance ±4 kilocycles, and these two circuits are coupled to the resonant circuit 10 referred to above. The signal energy derived through circuit 102 is applied to a rectifier 112 of the diode type, to produce a negative potential across a load resistor 202, whereas the energy derived through circuit

101 produces a positive potential across a load resistor 201 of the diode 111. These two potentials are super-imposed with respect to ground to produce a resultant potential in an outgoing lead 12 provided with a filter 412. It is understood that when the receiver is exactly in tune, the two part potentials cancel each other, whereas when the receiver is mistuned, at one side or other of exact resonance, one or other of the component potentials will be predominant and a positive or negative potential with respect to ground is accordingly effective in lead 12. This potential is applied to a variable impedance device associated with the local oscillator 4 and adapted for electrical control whereby to effect the required correction of the tuning.

The signal energy across the tuned circuit 6 is maintained substantially uniform despite variations in the strength of the signals at the input circuit of the receiver, by means of an automatic volume control network of conventional design, which comprises a rectifier-amplifier device 16 fed with signal-energy from the resonant circuit 6 through a condenser 19. The uni-directional potentials which are produced at the output of device 16 are applied to the amplifiers 2 and 5 through a lead 18 whereby to regulate the gain of these receiver sections.

The resonant circuit 6 is also coupled to a control channel for detecting the tuning-in and the condition of approximate resonance of a carrier wave. These means might be of the well-known type in which the discrimination between the carrier waves and static results from the proper adjustment of the operating threshold associated with the potential of a rectifier fed through a sharply tuned circuit resonating at the intermediate frequency, or the like. However the means of this general class present the important inconvenience in practice of requiring a manual adjustment of the threshold in accordance with prevailing static conditions, since an incorrect manual adjustment would upset the correct operation of the device; for this reason they are in practice suitable only for the reception of powerful stations. To avoid this inconvenience I prefer to utilize a control circuit of the kind disclosed in U. S. Patent No. 2,216,451 issued October 1, 1940, which is capable of discriminating between the noise and the carrier wave of a station.

The "control" channel just referred to includes a high-frequency amplifier tube 20 the input circuit of which is coupled to circuit 6. The anode circuit of amplifier 20 includes a resonant circuit 21, the selectivity properties of which may be moderate or low and which is tuned to the intermediate frequency. The high-frequency energy across circuit 21 is transferred to the rectifiers 25 and 23 which are indirectly heated diodes. Rectifier 25 is arranged to produce "negative" potentials across its load resistor 125 whereas rectifier 23 is adapted to set up positive potentials across load resistor 123. The load resistors 123 and 125 are connected in series and the resulting super-imposed potential variations with respect to ground are transferred to the main grid 27 of the amplifier 9 through line 26 and tuned circuit 7. The coupling path between rectifier 25 and resonant circuit 21 comprises a condenser 241 and a network 242—243 which consists of a parallel-resonance circuit 242 shunted by a series-resonant circuit 243, both circuits being separately tuned to the intermediate frequency. The resonance curve of such a network is double-humped, the peaks of maximum response being for instance at 2.5 kilocycles off resonance on both sides of the exact intermediate frequency. These response peaks should be sufficiently pronounced so that when the selectivity characteristics of the receiver portion ahead of condenser 241 are taken into account, the peaks of maximum response are left sufficiently pronounced, for instance at ± 1.5 kilocycles off resonance, with a sufficiently marked response depression at the exact intermediate frequency, the difference between the peak and dip response values being for instance 1:2.5. The response to the frequencies of the adjacent carrier waves is preferably kept very low. Rectifier 23 is coupled to circuit 21 through a resonant circuit 22 tuned to the intermediate frequency, the selectivity thereof being preferably rather sharp, although in actual fact this requirement is not essential.

The level of energy of true intermediate frequency is arranged to be the same across both rectifiers. The circuit of rectifier 25 includes a biasing source of potentials, the anode of diode 25 being for instance biased at —2.5 volts with respect to ground, to prevent the appearance of rectified potentials across load resistor 125 until the high-frequency energy impressed on the rectifier exceeds the threshold bias. The potentials across the load resistors 123 and 125 are filtered to avoid undesired inter-action between the associated circuits, the time constant of both filters being conveniently given the same value. A filter 126 comprising a resistor and condensor may also be arranged in line 26. When no high-frequency energy is impressed on the diodes 23 and 25, the potential of grid 27 is that of the biassing source of potentials associated with load resistor 125, and the cathode potential of tube 9 is moderately positive with respect to ground. The resulting negative bias of the (main) grid 27 of tube 9 with respect to its cathode is thus considerable whereby the tube is normally ineffective. It will be observed that tube 9 is in the path of signals feeding the A. F. C. channel as well as the channel of the second detector, whereby normally both channels will be blocked. However if desired these channels might be controlled separately.

The amplifier action of tube 9 is also controlled in response to the output of a second channel closely associated with the A. F. C. potentials of line 12. This further channel includes a tube 28, to the control grid of which are applied the A. F. C. potentials of line 12. The cathode is appreciably positive with respect to ground, so that the tube amplifies correctly both the positive and negative potential swings of the A. F. C. line. Amplified potential variations appear across an anode load resistor 29, the sense of variation of these potentials with respect to ground being reversed as compared with the input potentials of the tube. Part of the anode potential variations is tapped off by means of a potentiometer 30—31 connected between the anode and a source of negative potential with respect to ground. The tap is connected to the grid of a further D. C. amplifier tube 32 and the magnitude of the potential swings is approximately the same at both control grids. The anode of tube 32 comprises a load resistor 33, and the amplitudes of the potential variations across the resistors 29 and 33 are approximatively the same, but the senses thereof are in opposition. The anodes of the two tubes are connected by a potentiometer

including a diode 34 in series with a resistor 35, the cathode of the diode being connected to the anode of tube 28. The tap of the potentiometer is connected to the series combination of a neon lamp 36 with a resistor 38, and the second terminal of the resistor is connected to a source of negative potential with respect to ground. The common end of the neon lamp and of resistor 38 is associated with a resistance-capacity filter 37 of moderate time constant such as ¼ second, and the resulting potentials are applied over line 39 to a second control grid 40 of tube 9 to control the gain of this tube, a hexode or a tube of similar characteristics being for instance made use of.

The operation of the control system in Fig. 1 is as follows:

Assume that by means of the tuning control member the receiver is tuned broadly into resonance with a station of substantial amplitude with respect to the back-ground of noise. An appreciable amount of energy will be transferred to the rectifiers 23 and 25 to set up potentials across the associated load resistors 123 and 125. The excess of influence of rectifier 23 will reach a sufficient value to bring the potential of line 26 more nearly toward ground potential. Tube 9 will thereby be permitted to pass a small amount of energy to the A. F. C. discriminator channel. The small resulting potential in line 12 will bring the receiver near to the exact resonance point, and the potential of line 26 will be closer to ground potential, whereby tube 9 may amplify more effectively. A trigger action thus rapidly builds up, and line 26 will speedily be substantially exactly at ground potential. It will be observed that since at exact resonance equal amounts of energy are effective across both rectifiers 23 and 25, their influences will mutually cancel exactly; the potential of line 26 as well as the operation of the system do not therefore depend on the effectiveness of the A. V. C. device, and the potential variation of line 26 a certain distance off resonance is solely defined by the characteristics of the networks associated with the rectifiers 23 and 25.

It will be observed that when the receiver is too considerably off resonance with respect to a carrier wave, no "negative" potential will be set up across biased rectifier 25, whereas "positive" potentials will still be produced across rectifier 23. By virtue of the provision of resonant circuit 22 these cannot however reach a sufficient value to bring about the effectiveness of tube 9.

The receiver is prevented from responding to intense static only, in the following way. Since the "noise" energy is rather uniformly effective over a wide range of frequencies and since the feed path of rectifier 23 is predominantly effective at or about the exact intermediate frequency, it will be clear that the output of rectifier 23 will in the main be defined by the intensity of "static" of the intermediate frequency, the effect thereof being substantially that of a carrier wave having exactly the intermediate frequency. On the other hand since the feed path of rectifier 25 is predominantly effective at frequencies moderately spaced from the intermediate frequency and more particularly at the peak response frequencies, the potential due to static for a certain amplitude of static at the input of the receiver will predominantly be defined by the sensitivity of response at about the peak frequencies, the effect being rather analogous to that of a carrier wave moderately off resonance as considered above. Since the sensitivity or response at these peak frequencies is comparatively higher than the sensitivity at the intermediate frequency and since the latter response is approximatively the same as the predominant response at the intermediate frequency across rectifier 23, there will be a predominant influence of the negative output of rectifier 25. The grid bias of tube 9 cannot therefore reach a sufficiently lowered negative bias, so that "static" will never cause the erroneous operation of the device. Furthermore the excess output of 25 is practically constant whichever may be the intensity of static and depends only on the ratio of peak to crevasse response of the resulting resonance curve characteristic effective across rectifier 25.

Brief interfering impulses due to atmospherics or to sparking engines or the like will simultaneously set up potentials across both rectifiers, the potential due to rectifier 25 being somewhat higher than in the above case of uniform "static", and they cannot therefore cause an erroneous operation of the control channel.

When a station is exactly in tune, line 26 being at ground potential as indicated in the foregoing, the anodes of the tubes 28 and 32 and the tap of potentiometer 34—35 will assume a predetermined reference potential, which is such that the striking voltage of the neon lamp 36 is appreciably exceeded. A potential is accordingly set up across resistor 38; this potential may be rather constant for moderate changes of the neon lamp voltage, the neon tube being for instance given an appropriate saturation characteristic.

When line 12 carries a positive or negative potential with respect to ground, the potential of the anode of one of the tubes 28 or 32 is decreasing, whereas the potential of the other tube is increasing. The tap of elements 34 and 35 at any time assumes the potential of that one of the two associated anodes which has the relatively lower potential. For instance when the potential of the anode of tube 28 decreases with respect to its reference value, diode 34 is conducting and its resistance is low as compared with the resistance of resistor 35. When the anode potential of tube 32 is relatively lower, the diode presents a nearly infinite resistance, resistor 35 being given a moderate value. In either case the neon lamp is extinguished as soon as the variation of the potential of line 12 with respect to ground exceeds a predetermined value. Accordingly current will no longer flow through resistor 38 as soon as the amount of mistuning is excessive. The grid 40 is thus overbiased negatively so as to inhibit the amplification of tube 9. This control action may take place when the A. F. C. potential tends to correct an amount of mistuning of some ±2.5 or 3 kilocycles. At the instant at which tube 9 is being disabled, the amount of "physical" mistuning just indicated may be reduced to a low value of actual mistuning of some 50 cycles.

After tube 9 has been blocked again, the corrector action disappears rapidly since the time constant of A. F. C. line 12 is very small, e. g. 1/10th second. The time constant of filter 37 in line 39 for blocking again tube 9 is given a larger value so that the neon lamp may be lightened rapidly as soon as the potential of A. F. C. line 12 has reached a value sufficiently close to ground potential, without the blocking action of line 39 being thereby affected. However after about 1/5th second the bias of grid 40 also is again close to its initial value. However tube 9 cannot now amplify by virtue of the excess bias of grid 27

through line 26, and the receiver is restored to its initial condition in readiness for the reception of the next station.

The above operation of the receiver will be more fully understood with reference to the double graph in Fig. 2, in which the left-hand portion shows the actual tuning frequencey of the receiver on the ordinates whereas the potential due to a carrier wave of line 26 is indicated on the abscissae. The right-hand portion shows the actual tuning frequency (vertically) as a function of the "physical" tuning setting as shown off by the tuning dial, the tuning frequency varying in the sense of the arrow. The A. F. C. channel is rendered effective as soon as the potential of line 26 exceeds the threshold value *s*, and the actual amount of mistuning, which was considerable, falls to a very low value. At the instant at which the A. F. C. device is blocked again after mistuning has reached an excessive value, the amount of "physical" mistuning is somewhat larger than the initial value, so that the threshold *s* may not be exceeded again, whereby the device is now prevented from being controlled again in response to the carrier wave originally tuned in.

The arrangement shown in Fig. 3 serves to illustrate some modifications in the disposition of the channels for producing the potentials responsive to the selection of the carrier wave and responsive to the magnitude of the A. F. C. potential respectively, and, of the means for applying these potentials to control the action of the A. F. C. device.

The control channel for producing a potential in response to the broad selection of the desired carrier wave includes the amplifier tube 20, which is fed from the intermediate frequency circuit 6 whereat the signal level is substantially uniform as in the foregoing arrangement due to the automatic gain control device 16, and the two rectifiers 25 and 23 associated respectively with load resistors 125 and 123 effectually connected in series and performing the functions of the corresponding elements in the foregoing arrangement. The anode of tube 20 is connected to the high-tension supply through the series-connection of three rejector circuits 41, 44, 46, of which circuit 41 is sharply tuned to the intermediate frequency whereas the circuits 44 and 46 are tuned separately to frequencies on one side and other respectively of the intermediate frequency, mistuning being about 2.5 or 3 kilocycles. Rectifier 23 which produces positive potentials is associated with a tuned circuit 42 which may be flatly resonating at the intermediate frequency, and which is coupled by mutual inductance to resonant circuit 41; the relative response across this circuit does not depend appreciably on the response across the further circuits 44, 46. The biased rectifier 25 which produces potentials of negative polarity is coupled capacitatively to the junction of the resonant circuit 41 and of the series-connected circuit 44 and 46. The relative response across the series-connected circuits 44 and 46 presents a substantial value at frequencies moderately spaced from the intermediate frequency, and a very low response at the exact intermediate frequency, and it will be observed that the response curve characteristic of network 41—44—46, from the point of view of rectifier 25, is substantially similar to that of network 242—243 in Fig. 1. The super-imposed potentials of the rectifiers 23 and 25 serve to control the gain of the tube 91 of the A. F. C. channel, as detailed hereinafter.

The control channel for producing a potential responsive to the magnitude of the A. F. C. potential includes a D. C. amplifier tube 81, which may be considered as performing the functions of the tubes 23 and 32 in Fig. 1; tube 81 is provided with a cathode resistor 292 and with an anode load resistor 291, which are connected between the cathode and ground and between the anode and the high tension supply respectively. The A. F. C. discriminator schematically indicated at 111—112 is of conventional design and may for instance be constructed as illustrated in Fig. 1. The output line 12 of the A. F. C. device is connected to the grid of tube 81 and is effective between the grid and ground. The potential variations across the cathode load resistor 292 are approximately those of the A. F. C. potential, the gain of the tube effective across this load resistor being slightly less than unity and not dependent in practice on the resistance values of the cathode and anode load resistors. The resistance of anode load resistor 291 is considerably higher than the resistance of cathode load resistor 292, and in a practical embodiment may be approximately ten times higher, and the magnitude of the A. F. C. potential across load resistor 291 may accordingly be about 10 times higher than across load resistor 292; furthermore the polarity of the potential changes is reversed, with respect to the variations of the A. F. C. potential across the input of tube 81 and of the potential across the resistor 292. The anode of tube 81 is connected to ground through a potentiometer formed by the series-connected resistors 47 and 48, the resistance value of resistor 47 connected to the anode being about 9 times higher, in the numerical instance just considered, than the resistance of resistor 48 connected to ground; thus the magnitude of the potential variations effective between ground and the junction of resistors 47, 48 may be about $\frac{1}{10}$th the magnitude available across the anode load resistor 291, and may be about the same as the magnitude of the potential changes available across the cathode load resistor 292 but of opposite polarity.

Means including the series-connection of a diode 50 and of a resistor 49 are provided between the cathode of tube 81 and the tap 47—48; the cathode of the diode is connected to the cathode of the amplifier tube and the "free" terminal of the resistor is connected to the tap 47—48, whereby the control line 51 connected to the junction of said diode and resistor may have its potential defined by the lowest potential relative to ground which may be assumed at any particular instant by the cathode and the junction 47—48 respectively. In the embodiment shown, the diode 50 is enclosed in the same bulb as the amplifier tube 81, and utilizes part of the common cathode sleeve construction, thermionic tubes of such construction being well-known in the art.

To improve the operation of the control channel which causes the A. F. C. device to resume the ineffective condition, means are provided whereby after the potential of line 51 just referred to and responsive to the magnitude of the A. F. C. potentials has reached a certain critical value, a minute further change of that potential caused by an increased magnitude of the A. F. C. potential may give rise to a considerable variation of the control potential causing the blocking

of the A. F. C. device. In the embodiment shown these means rely on the considerable variation of the internal resistance of a diode indicated at 52 (or of some other rectifier) in response to the impression thereacross of a certain critical potential. The associated circuit is of the type disclosed in the specification of Luxemburg Patent No. 22,997 issued March 3, 1937, (see also U. S. application No. 181,317 filed December 23, 1937). Diode 52 is connected in the grid circuit of an auxiliary amplifier tube 54 which may amplify at high-frequency; the input of tube 54 is coupled to an auxiliary generator 55 of A. C. potentials of a desired frequency which is not critical; such a generator in many cases may serve for various other purposes in the receiver. Diode 52 is connected in series with a resistor 53 of high resistance value; the "free" end of the resistor is connected to line 51 and the anode of the diode is connected to the other terminal of the resistor, while the cathode of the diode is connected to a point of fixed potential 56 which is lower, by a predetermined amount, than the reference potential of line 51, i. e. the potential assumed in the absence of any A. F. C. potential. The junction of diode 52 and resistor 53 is connected to the grid of tube 54; the cathode potential of tube 54 is a few volts higher than the potential of point 56 which latter may conveniently be tapped off from the cathode circuit of tube 54. The output of generator 55 is connected to the grid of tube 54 through a condenser 154 and a resistor 57 of a comparatively high resistance; this resistor from the point of view of the high-frequency voltages effectually forms a potential divider including diode 52 and resistor 53 as the second impedance arm, the two latter impedances being effectually connected in parallel from the high frequency point of view. Since as stated above the potential of the cathode of diode 52 is lower than the reference potential of line 51, the diode is normally conducting and its internal resistance is low with respect to the resistance of 57, so that the A. C. voltage effectively impressed upon the grid of tube 54 may be very low. This condition is left unchanged when the potential of line 51 decreases moderately with respect to the reference potential.

The anode circuit of amplifier 54 is provided with a load resistor 58, and the voltage across this resistor is applied to rectifier 59 of the diode type through lead 511. The rectified potential of negative polarity which is produced across load resistor 60 of this rectifier is derived through a resistance-capacity filter 61 and serves to control the action of the A. F. C. device, and more particularly the gain of amplifier tube 91 in the high-frequency path thereof. Normally there is no appreciable potential across load resistor 60. Tube 91 may have a single control grid, and the potential across load resistor 60 is super-imposed upon the potential across load resistor 123 and 125 and thus injected in the circuit of said control grid.

The operation as a whole of the circuit in Fig. 3 will be understood more easily with reference to Fig. 2 and is as follows: By a proper adjustment of the cathode potential of tube 91 it is arranged that this tube is biased to cutoff in the absence of a carrier wave, the grid potential being defined by the delay bias of rectifier 25. This condition is left unchanged during the reception of static whichever may be the intensity of reception, since the peak response across rectifier 25 is higher than the peak response across rectifier 23, whereby the negative rectified potential across 25 is predominant. If the receiver is tuned broadly to the frequency of a carrier wave, the amount of mistuning being lower than some 2.5 kilocycles, the input of rectifier 23 may become nearly as high as the input of rectifier 25, and the super-imposed potentials may cause the grid of tube 91 to reach a potential slightly less than ground potential and may reduce accordingly the negative bias thereof. Tube 91 may now amplify in a reduced proportion and a certain A. F. C. potential may become effective, which improves the tuning of the receiver. Due to the consequent improved response across rectifier 23, a further decrease of negative bias of tube 91 may take place, and normal operation of the tube may be ensured speedily. The A. F. C. device and the reproducer channel 8 under these conditions may operate correctly. Since the misalignment of the physical tuning means is supposed to be rather considerable, a comparatively high control potential will be applied to the control grid of tube 91, and the potential of line 51 will be decreased in a substantial proportion. Point 56 is arranged reliably to have a lower potential than said line 51 so that diode 52 may be left conducting, and there will consequently be no appreciable potential across resistor 60 susceptible of changing the grid bias of tube 91. Now suppose that the amount of mistuning is increasing appreciably, the operator for instance tuning past the station, as indicated by the arrow in the right-hand portion of the graph in Fig. 2. The magnitude of the A. F. C. potential will be increased, and according as this potential is negative or positive with respect to ground, the potential of the cathode of tube 81 or of the junction 47—48 will decrease appreciably with respect to the reference value (i. e. its potential in the absence of a signal). In the first case the diode will be conducting, whereas in the second case it will be non-conducting, and in either case the decrease of potential will be transferred to line 51; as the magnitude of the A. F. C. potential reaches a sufficient value, the potential of line 51 may become more considerably negative than point 56, and diode 52 may become non-conducting or at least its internal resistance may be increased very considerably, so that the effective resistance in shunt across the grid-cathode path of amplifier tube 54 may be increased considerably and an appreciable A. C. voltage from source 55 may become effective across the grid and the cathode. This A. C. voltage after amplification in the tube is applied to rectifier 59, and the thus produced negative potential substantially increases the negative bias of tube 91.

The effectiveness of the A. F. C. device may thereby be considerably lowered, and the resulting higher amount of mistuning of the receiver may cause a substantial drop of potential of line 26, hence a further decreased gain of tube 91, which in turn causes a further increased amount of mistuning. The A. F. C. device may thus be rendered ineffective speedily and the reproducer channel 8 may simultaneously be restored to the ineffective condition.

As the A. F. C. potential is disappearing, the potential of line 51 simultaneously is reaching again its reference value, and the high-frequency energy due to source 55 applied to rectifier 59 may speedily disappear, while the potential of line 26 still is continuing to decrease as set forth above. However an appreciable negative potential is maintained for a brief period of time

such as 1/5th second across the condenser of filter 61 associated with rectifier 59, and serves to ensure a sufficient reliable operation by disabling amplifier 91 until the potential of line 26 reaches its reference value.

Reference should now be had to the alternative form of the invention illustrated in Fig. 4. The control channel for producing a potential in response to the tuning-in of a carrier wave includes an amplifier tube 201, to the main control grid 60 of which is applied signal energy from the intermediate frequency amplifier 5, through the resonant circuit 6 whereat the signal level is maintained substantially uniform by means of the automatic gain control network 16. The rectifier 23 may be considered as coupled to the anode circuit of amplifier tube 201 through a transformer with a resonant primary 41 and a resonant secondary 42, both circuits being normally tuned exactly to the intermediate frequency. The negatively biased rectifier 25 is coupled capacitively to the anode circuit of tube 201 through the intermediary of a network including the series-connected resonant circuits 41, 44, 46, the two latter circuits being tuned to frequencies on one side and other respectively of the intermediate frequency to provide a double-humped resonance curve characteristic with a sufficiently pronounced dip or crevasse at the intermediate frequency. It will be observed that the disposition just considered is quite similar to those shown in Figs. 1 and 3. The rectified potentials across load resistors 123 and 125 of rectifiers 23 and 25 are of positive and negative polarity respectively and are super-imposed in the lead 26; these super-imposed potentials are utilized to render effective amplifier tube 92 in the feed path of the A. F. C. device in response to the broad selection of a carrier wave, through the intermediary of a device represented schematically and marked "trigger device," having its input connected to line 26, and its output connected to the lower terminal of circuit 7 in the grid circuit of tube 92 through a resistance-capacity filter 137 having a rather small time constant and through lead 226.

This device serves to provide a comparatively sharp variation in the amplitude of the control potential derived through lead 26, when said potential assumes a certain critical value, whereby the grid bias of tube 92 may be altered comparatively abruptly and the operation of the system may be improved. This "trigger device" may be of any well-known construction and may perform substantially the function of neon lamp 36 and resistor 38 in Fig. 1 or of the thermionic circuit in Fig. 3 including auxiliary A. C. source 55, tube 54, impedances 52, 53, 57 and rectifier 59.

The A. F. C. discriminator 111—112 is coupled to the anode circuit 10 of amplifier tube 92 and may be of any well-known construction, for instance as explained with reference to Fig. 1. The A. F. C. potential besides controlling the frequency of the local oscillator associated with the frequency changer device, is applied to control the level of signal energy applied to rectifier 23, by causing a progressive mistuning of resonant circuit 42 at the input of this rectifier in accordance with the amplitude of the A. F. C. potential, at a desired high rate and in the same sense as, or in the sense opposite to, that of the oscillator circuit. Mistuning of circuit 42 is toward one side or other of the intermediate frequency according as the A. F. C. potential, responsive to the small mistuning of the receiver in the "corrected" condition thereof, varies in the sense of positive or negative changes out of the reference potential condition; it will be understood that in either case the level of signal energy transferred through circuit 42 is decreased as the magnitude of the A. F. C. potential and the resulting amount of mistuning of circuit 42 is increased.

Whereas a great variety of arrangements may be used to cause the said mistuning of circuit 42, including purely electrical circuit arrangements for instance relying on the so-called Miller effect, it is believed that these circuits are sufficiently well known in the art, and for the sake of simplicity electromechanical mechanism is used including a motor of the galvanometer type indicated at 74. The galvanometer coil is included in the anode circuit of a D. C. amplifier tube 121, the grid of which is connected to the output line 12 of the A. F. C. discriminator 111—112. The spindle 141 of the motor 74 is grounded and carries the moving vane of a condenser 275 connected in shunt with the principal condenser of resonant circuit 42 through lead 175. The movement of the motor spindle may simultaneously control the oscillator frequency of the frequency changer device by means of a similar condenser 375.

The operation of the circuits in Fig. 4 will now be considered, reference being also had to the double graph in Fig. 5, wherein the right-hand portion shows the actual tuning frequency of the receiver as a function of the tuning frequency defined by the "physical" tuning means of the receiver, and the left-hand portion shows the potential of the channel responsive to the tuning-in of the carrier wave with respect to the associated operating threshold *s* indicated by the vertical dash-line as a function of the actual tuning frequency, the abscissae and ordinates being similar to those in Fig. 2.

Tube 92 is left excess-biased while no signal is being received, the A. F. C. device as well as the receiver portion 8 fed from the output of this tube being thereby inoperative, and the tuning frequency of the receiver being solely defined by the normal or principal tuning means. Just as in Fig. 3, conditions are not changed in this respect when static is received.

However when a signal is broadly tuned in, mistuning being less than some 2.5 kilocycles, high-frequency energy of substantial amplitude which may be slightly less than the level of energy at rectifier 25 may be applied to rectifier 23, and the resultant rise of the potential of line 26 is transferred through the "trigger device" and through filter 137 to the grid of tube 92, whereby to remove the cutoff bias from this tube so that the reproducer channel 8 may become effective as well as the A. F. C. device. By the way it will be observed that while the excess-bias of tube 92 is being lowered or removed as just indicated, a small A. F. C. potential may take place which on account of the thereby improved resonance conditions may increase somewhat the level of energy at rectifier 23 and decrease the level of energy at rectifier 25, thus bringing about a further increased potential of line 26 which in turn is fed back to the grid of tube 92 and which is cumulative with the action of the "trigger device." Normal operating conditions of tube 92 may thus be attained still more speedily.

It will be observed that at the instant of tuning-in of the carrier wave, the effective response

curve of the control channel including tube 201 and represented by the potential variation of line 26 with variations of the tuning frequency around the resonance frequency, may be indicated by the plain curve at the left of Fig. 5. During the small fraction of a second in which the actual tuning frequency of the receiver is brought into resonance with the received signal through the A. F. C. device, the effective response curve of this channel is however modified due to the mistuning of the resonant circuit 42 through the A. F. C. potential; it is arranged however that the corresponding decreased response of the control channel with respect to the associated operative threshold may reliably continue to exceed the said threshold, as long as the amount of mistuning, supposed above to be about 2.5 kilocycles, is not further increased.

Now suppose that the misalignment of the "physical" tuning means of the receiver is further increased, up to say, 3 kilocycles, as when the operator tunes through the exact resonance point and sufficiently past that point. On account of the resultant considerable (and progressive) mistuning of circuit 42 by the A. F. C. device and condenser 275, the effective response curve of the control channel including the said circuit may be that indicated by the dotted line at the left of Fig. 5. It will be appreciated that progressively the response may become insufficient to further exceed the operating threshold *s*, which may be the operating threshold of the "trigger device" in Fig. 4. The level of signal energy across rectifier 23 may thus become insufficient as compared with the energy level across rectifier 25, and the thus decreased potential of line 26 causes a still more substantially decreased potential of line 226 which may be effective with the desired abruptness and may speedily ensure that the initial excess-bias of tube 92 is restored. The A. F. C. potential may therefore disappear speedily, whereby the initial conditions as concerns the selectivity of the amplifier channel responsive to the tuning-in of the signal may be restored, and the said channel may quickly have insufficient response to the signal which was tuned in. It may be observed that until this condition is effective i. e. until the full amount of mistuning due to the physical tuning means becomes effective, the amount of mistuning of the receiver with respect to the signal that was tuned in will increase whereas the amount of mistuning of circuit 42 will simultaneously vanish; accordingly the delay filter 137 serves to maintain in the meanwhile tube 92 blocked. The potential across this filter may disappear after say 1/5th second, whereby the receiver may resume its initial condition.

Referring now to the form of invention shown in Fig. 6, the A. F. C. device includes an amplifier 93 fed with intermediate frequency energy through the resonant transformer 6—7. The anode circuit comprises a resonant circuit 10 tuned to the intermediate frequency, coupled to the rectifiers 111 and 112 of the A. F. C. discriminator through the resonant mistuned circuits 101 and 102 respectively. These rectifiers are provided with load resistors 201 and 202, effectually connected in series and serving to derive potentials of relatively opposed polarities; the super-imposed potentials for A. F. C. control are derived through lead 12 and the disposition is substantially as shown in Fig. 1.

It is arranged that the A. F. C. device may have a limited range of effectiveness, with a view to leaving a sufficiently appreciable amount of mistuning when the "physical" tuning means of the receiver are mistuned by several kilocycles, so that the operation of the control device may be facilitated. The sensitivity as a whole of the A. F. C. device might be low to this end, at all times, but this is undesirable, and it may therefore be arranged that a reduction of the sensitivity takes place more particularly while the "physical" tuning means are actuated, as by causing such reduction in response to the operation of the tuning knob or other operating means of the principal tuning means, by mechanism well known per se. However I have preferred to ensure a sensitive operation of the A. F. C. device as long as the amount of mistuning of the "physical" tuning means is not excessive.

The A. F. C. control line to this end is associated with two limiting devices for limiting the amplitude of the A. F. C. potential derived through line 12 in the sense of positive and negative potential variations, including respectively a diode 81 associated with a resistor 80, and a diode 83 associated with a resistor 84. The series-connection of the diode 81 and resistor 80 is connected between the output line 12 of the A. F. C. discriminator and a point 82 of fixed potential, moderately positive with respect to the reference potential of line 12, i. e. the potential of that line in the absence of a carrier wave, and which as shown is at ground potential. As shown the potential of point 82 is tapped off from a potential divider connected across the terminals of the high-tension supply of the receiver, a desired intermediate point of which is grounded. The cathode of diode 81 is connected to line 12, and the "free" end of the resistor is connected to point 82, whereby the diode may normally be conducting and may have a very low internal resistance. The junction of diode 81 and of resistor 80 is connected to a point 85 of fixed potential, moderately negative with respect to the reference potential of the A. F. C. line, through the series-connection of diode 83 and resistor 84. The anode of diode 83 is connected to the junction of 80—81, the free end of resistor 84 being connected to a point 85 which may be tapped off from the potential divider just referred to. Diode 83 may accordingly be normally conducting and may have a very low internal resistance. The A. F. C. potential of the junction of diode 83 and resistor 84 is applied through line 212 to control the oscillator frequency of the receiver in well-known fashion.

The control channel for producing a potential serving to make effective the A. F. C. device in response to the broad selection of a carrier wave includes an amplifier tube 202, the normal control grid of which is fed with intermediate frequency energy from the resonant circuit 6 whereat the signal level is maintained substantially constant by means of the automatic gain control device 16. The anode circuit of tube 202 comprises a flatly resonant circuit 21 separately coupled to the rectifiers 231 and 251 through the intermediate-frequency circuit 22 and through the network 242—243 respectively; this network has a sufficiently pronounced double-humped resonance curve characteristic, and the disposition is similar to that of corresponding elements in Fig. 1.

The biased rectifier 251 produces potentials of positive polarity across its load resistor 1251, whereas rectifier 231 produces potentials of negative polarity across the associated load resistor

231, which is effectually connected in series with load resistor 251, the super-imposed potentials being derived through line 261. Whereas the potential of this line is normally slightly or moderately positive with respect to ground due to the biasing source of potentials of rectifier 251, the same is caused substantially to assume ground potential when the desired signal is exactly in resonance, the level of intermediate frequency being in substance the same across the rectifiers 231 and 251.

Line 261 is connected to the normal control grid of the amplifier tube 202 through the normal grid leak thereof, tube 202 being accessorily utilized to perform the function of a D. C. amplifier. The cathode of tube 202 is at a desired positive potential, so that the control grid of the tube may normally be biased slightly or moderately negatively relative to the cathode, whereby the tube may efficiently amplify the signal energy impressed upon its input. The lower terminal of resonant circuit 21 in the anode circuit of tube 202 is connected to the positive terminal of the high-tension supply though a D. C. load resistor 87, which is by-passed from the high-frequency point of view. Between the junction of resistor 87 and the lower terminal of circuit 21 on one hand, and the negative terminal of the high-tension supply on the other hand, is connected a potential divider formed by a neon lamp 86 connected in series with a resistor 88, the free terminal of the resistor being connected to the negative potential. Since there is normally a comparatively substantial potential drop across the D. C. load resistor 87, the junction of the neon lamp and of resistor 87 is normally at a comparatively moderate potential with respect to the negative terminal of the high-tension supply, and the neon lamp may normally be extinguished, so that no current may flow through the associated resistor 88. The junction of the neon lamp 86 and resistor 88 may accordingly assume normally the potential of the negative terminal of the high-tension supply, and is connected to the control grid of amplifier tube 93 in the feed path of the A. F. C. device through a resistance-capacity filter 92 and through the normal input circuit 7 of tube 93. The cathode of tube 93 may be at the desired potential, adjusted in such a way that tube 93 is normally biased approximately to cutoff.

The lower terminal of the tuned circuit 10 in the anode circuit of amplifier tube 93 is connected to the high-tension supply through a D. C. load resistor 89. The junction of this resistor and of the lower terminal of circuit 10 on the other hand is connected to the negative terminal of the high-tension supply through a potential divider comprising the series-connected resistors 90, 91. The junction of these resistors is connected through a filter 92*a* to an auxiliary control grid of tube 202, of which a decreased potential brings about an increased anode current, the said auxiliary control grid being for instance the screen grid of a tetrode or a similar tube being used at 202, the attainment of such a tube characteristic with conventional tube constructions under suitable operating conditions and more particularly when using a not too low grid potential, being sufficiently well known in the art, the proper adjustment of the steady bias of this auxiliary grid being easily had by potentiometer 90—91. Tube 93 being normally excess-biased, there will be no potential drop across load resistor 89.

The operation of the system shown in Fig. 6 will now be considered, reference being also had to the double graph in Fig. 7, the right-hand portion of which shows the actual tuning frequency as a function of the tuning frequency defined by the "physical" tuning means (i. e. in the absence of the tuning corrector means), and the left-hand portion of which shows the amplitude of the control potential of line 261 or of the output of the D. C. amplifier 202 as a function of the actual tuning frequency.

Tube 93 is excess-biased in the absence of a carrier wave, and the A. F. C. device and the reproducer are inoperative. When high-frequency energy due to static is impressed upon the input of the receiver, energy will predominantly be impressed on rectifier 251, as compared with the energy impressed on rectifier 231, and the negative grid bias of tube 202 will be somewhat decreased, whereby the resultant, even more intense anode current of tube 202 causes a substantial potential drop across resistor 87 and leaves the neon lamp 86 extinguished, the amplifier 93 being accordingly left excess-biased.

However when the receiver is broadly tuned to the frequency of a carrier wave, the amount of mistuning being less than say, 2.5 kilocycles, the high-frequency energy applied to rectifier 231 will be but slightly lower than the energy applied to the biased rectifier 251, and the consequent decreased potential of line 261 will increase the negative bias of the normal control grid of tube 202 and will cause a decreased anode current and an increased potential of the tap 86—87; this may be represented by the full line at the lower left-hand portion of the graph in Fig. 7. The threshold value of the system, represented by the vertical dash-line marked *s*, at the left of Fig. 7, and representing in the construction of Fig. 6 the striking voltage of neon lamp 86, will be exceeded, whereby the neon lamp will be lightened and a current of substantially predetermined intensity may traverse resistor 88. The junction of 86—88 together with the associated grid potential of tube 93 may thus rise sufficiently to cause normal amplification of tube 93, hence normal operation of the A. F. C. system and normal reproduction of channel 8. It will be noted that both diodes 81 and 83 are conducting under these conditions; the potentials 82, 85, are to this end adjusted in such a way that potential 82 may reliably be more considerably positive or potential 85 more considerably negative than the potential of lead 12 as defined by the magnitude of the A. F. C. potential when the signal is broadly selected; the outgoing control line as applied to the A. F. C. impedance (not shown) is accordingly virtually connected directly to line 12.

The receiver is now speedily brought in substantially exact resonance with the carrier wave, due to the action of the correcting A. F. C. impedance, and the response across rectifier 231 is slightly increased whereas the response across rectifier 251 is slightly decreased; this causes a further decreased potential of line 261 and a further increased potential of junction 86—87; the bias of tube 93 may however be left substantially unchanged. On the other hand as soon as the excess-bias of tube 93 is removed, a substantial anode current flows through load resistor 89 and lowers the potential of the junctions 89—90 and 90—91; after a very brief delay due to filter 92*a*, the auxiliary control grid of tube 202 has its potential lowered and the anode current of tube 202 is slightly increased, causing

an increased potential drop across resistor **87**, hence a decreased potential effectively applied to the neon lamp, which may nearly compensate the decreased potential drop which tends to take place on account of the improved resonance condition considered above. As will be seen more particularly with reference to the left-hand portion of Fig. 7, despite the fact that the receiver is substantially exactly in tune with the carrier wave, the threshold value *s* indicated by the vertical dash-line is but slightly exceeded, and a comparatively low amount of mistuning with respect to exact resonance is sufficient to cause the neon lamp to be extinguished. However on account of the action of the A. F. C. device illustrated more particularly in the right-hand portion of the graph, this small mistuning corresponds to a comparatively large amount of mistuning of the "physical" tuning means. The actual amount of mistuning of the receiver may be as low as 50 cycles as long as the amount of misalignment of the physical tuning means is lower than some 2.5 kilocycles; this is shown by the slightly incurved and nearly horizontal response curve portion in the right-hand portion of the graph. However after the amount of misalignment of the physical tuning means is further increased, the corresponding increased magnitude of the A. F. C. potential causes the potential of line **12** to exceed, in the sense of positive or negative potential changes as the case will be, the potential either of point **82** or of point **85**. One or other of the diodes **81** and **83** may accordingly be effectually connected directly to point **82** or point **85**, as the case will be. Any further mistuning of the physical tuning means of the receiver cannot therefore be compensated in appreciable proportion by the A. F. C. device; this is represented by the considerably incurved portion of the response curve in the graph, this portion tending to become parallel to the response curve portions representing uncorrected tuning.

As the resulting actual mistuning of the receiver reaches a value of about 500 cycles, the correspondingly increased potential of line **261** and decreased potential of tap **86** causes the neon lamp to become extinguished and thus causes the suppression of the potential drop across resistor **88**; this latter potential variation is rather quickly transmitted through filter **92** to the grid of tube **93** to cause excess-bias. The reproducer channel will now be muted again, and the A. F. C. device will rather abruptly become ineffective, making the full mistuning of the physical tuning means effective, as shown by the vertical response curve portion in Fig. 7. The potential of control line **261** may now speedily resume its reference potential to define a comparatively low negative bias of the main control grid of tube **202**, thus causing a substantial anode current. On the other hand the decreased anode current of tube **93** taking place as this tube is again excess-biased, speedily causes a rise of the potential of tap **90—91**; however the corresponding increased potential of the auxiliary control grid of tube **202** tending to decrease the anode current is delayed by filter **92***a* during 1/5th of a second, say, so that a sufficiently low negative bias of the main control grid may be ensured as explained above, and the anode current may be left sufficient to maintain the neon lamp extinguished. The system is now ready for a fresh sequence of operations.

Having thus described certain typical embodiments of my invention, I declare that what I claim is:

1. In a radio receiving system, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for maintaining said automatic resonance adjusting means ineffective during the absence of a carrier; carrier-operated means for causing the effectiveness of said automatic adjusting means in response to the broad selection of a carrier by said tuning means; a second carrier-operated means for controlling the action of said automatic resonance adjusting means, applied to release said carrier and operated in response to the reception and departure from exact resonance of said carrier; means for leaving said second carrier-operated means ineffective during the absence of a carrier; and means for rendering said second carrier-operated means effective substantially concurrently with said automatic adjusting means.

2. In a radio receiving system, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; a reproducer channel for utilizing the modulation conveyed by said carrier; means for maintaining said automatic adjusting means and said reproducer channel ineffective during the absence of a carrier; carrier-operated means for causing the effectiveness of said automatic adjusting means in response to the broad selection by said tuning means of a carrier; further carrier-operated means for respectively controlling the action of said automatic resonance adjusting means to release said carrier, and for controlling the condition of reproduction of the modulation in said reproducer channel, said further carrier-operated means operating in response to the reception and departure from exact resonance of said carrier; means for leaving said further carrier-operated means ineffective during the absence of a carrier; and means for rendering said further carrier-operated means effective substantially concurrently with said automatic adjusting means.

3. In a radio receiving system, the combination of tuning means; automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; a reproducer channel for utilizing the modulation of said carrier; a carrier amplifier stage fed from a desired point in the receiver, having its output connected to the input of both said automatic adjusting means and said reproducer channel; means for minimizing the gain in said stage during the absence of a carrier; a first carrier-operated means, for making ineffective the action of the gain-minimizing means in response to the broad selection by said tuning means of a carrier; a second carrier-operated means for controlling the gain of said stage, applied to minimize the gain regardless of the operation of said first carrier-operated means, and operating in response to the reception and departure from exact resonance of said carrier; and means for rendering effective said second carrier-operated means substantially concurrently with said automatic resonance adjusting means.

4. In a radio receiver, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said

tuning means; means for making said automatic resonance adjusting means ineffective during the absence of a carrier; a first carrier-responsive means, for restoring the effectiveness of said automatic resonance adjusting means responsive to the broad selection of a carrier by said tuning means; a second carrier-responsive means, for causing said automatic resonance adjusting means to resume the ineffective condition regardless of the operation of said first carrier-responsive means, when the amount of automatic adjustment exceeds a desired value; said automatic resonance adjusting means including a discriminator unit provided with selective means providing progressively varying carrier response with departure from exact resonance; and said second carrier-responsive means including a connection to said selective means for causing resuming of the ineffective condition through energy of carrier frequency derived through said selective means.

5. In a radio receiver, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for making said automatic resonance adjusting means ineffective during the absence of a carrier; a carrier-operated means for restoring the effectiveness of said automatic adjusting means in response to the broad selection of a carrier; a second carrier-operated means for controlling the action of said automatic adjusting means, and applied to cause the resuming of the ineffective condition when the amount of automatic adjustment exceeds a desired value; said automatic resonance adjusting means including a discriminator unit for producing a unidirectional potential in response to the reception of the carrier, progressively varying in magnitude with departure from exact resonance and applied to detect and correct inaccurate tuning at least on one side of exact resonance; and said second carrier-operated means being provided with an operative coupling to said discriminator unit for utilizing said uni-directional potential to cause resuming of the ineffective condition as aforesaid.

6. In a radio receiver, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for making said automatic adjusting means ineffective during the absence of a carrier; a carrier-operated means, for restoring the effectiveness of said automatic adjusting means, in response to the broad selection of a carrier; a second carrier-operated means for controlling the action of said automatic adjusting means, and applied to cause the resuming of the ineffective condition when the amount of automatic adjustment exceeds a desired value; said automatic adjusting means including a discriminator unit provided with selective means providing two output points, the carrier response across one point and other increasing progressively with increasing departure from exact resonance on one side and other respectively from the resonance point; uni-directional potential providing means for said second carrier-operated means, respectively coupled to said two output points, for producing potentials in response to the reception of said carrier, increasing progressively in magnitude with departure from exact resonance; said second carrier-operated means being provided with means for utilizing both of said two potentials, to cause resuming of the ineffective condition when the magnitude of either potential exceeds a desired value.

7. A combination according to claim 6, characterized by the provision of means for additorily combining the effects of said two uni-directional potentials to produce a resultant potential progressively increasing in magnitude in the desired sense with departure from resonance on either side of the resonance point; said second carrier-operated means being operated by said resultant potential.

8. In a radio receiver, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for making said automatic resonance adjusting means ineffective during the absence of a carrier; carrier-operated means for restoring the effectiveness of said automatic resonance adjusting means in response to the broad selection of a carrier; further carrier-operated means for controlling the action of said automatic resonance adjusting means, applied to cause the resuming of the ineffective condition when the amount of automatic adjustment exceeds a desired value; said automatic resonance adjusting means including a discriminator unit provided with means for producing a uni-directional potential progressively varying in one sense and other with respect to a reference value with departure from exact resonance on one side and other of the resonance point, for detecting and correcting inaccurate tuning on both sides of exact resonance; wherein said further carrier-operated means are provided with two distinct connections to said uni-directional potential providing means of discriminator unit, for utilizing potential changes in one sense and other respectively; each of said connections including means establishing a threshold of operation whereby said automatic resonance adjusting means is caused to resume the ineffective condition, irrespective of the further operation of said first carrier-operated means, when the magnitude of said potential changes derived through either connection exceeds the associated value of threshold.

9. In a radio receiver, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for making said automatic resonance adjusting means ineffective during the absence of a carrier; a first carrier-operated means, for restoring the effectiveness of said automatic resonance adjusting means in response to the broad selection of a carrier; a second carrier-operated means, for causing said automatic resonance adjusting means to resume the ineffective condition when the amount of automatic adjustment exceeds a desired value; said automatic resonance adjusting means including a discriminator unit provided with means for producing a uni-directional potential progressively varying in one sense and other with respect to a reference value with departure from exact resonance on one side and other; wherein changes of one polarity of said potential are transferred to a first point without phase reversal, and changes of reverse polarity are transferred to a second point through means providing reversal of polarity; a potentiometer connected across said two points and including an element having predominant conductivity in one direction; one arm of said potentiometer being predominantly perme-

able to potential changes of one polarity and the second arm being substantially permeable to potential changes of the reverse polarity; and said second carrier-operated means being operatively connected to the tap of said potentiometer whereby a potential of predetermined polarity may be derived through said connection irrespective of the polarity of said uni-directional potential of discriminator unit, to cause the resuming of the ineffective condition when the magnitude of said potential exceeds a desired threshold value.

10. In a radio receiver, the combination of tuning means, automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for making said automatic resonance adjusting means ineffective during the absence of a carrier; a first carrier-operated means, for restoring the effectiveness of said automatic resonance adjusting means in response to the broad selection of a carrier; a second carrier-operated means, for causing the said automatic resonance adjusting means to resume the ineffective condition when the amount of automatic adjustment exceeds a desired value; said automatic resonance adjusting means including a discriminator unit provided with means for producing a uni-directional potential varying progressively in one sense and other with respect to a reference value with departure on one side and other from exact resonance; wherein there are provided means for impressing said potential across the input circuit of a direct-current amplifier tube having a load resistor in its output circuit; means for deriving two control potentials having relatively reversed polarity, from two points in the input and output circuits respectively of said amplifier tube, the magnitude of said two control potentials being approximately the same for a given amount of automatic resonance adjustment, and the potentials of said two points in the condition of exact resonance being approximately the same; a direct-current potentiometer connected across said two points and including in at least one arm an element having predominant conductivity in one direction, each arm of potentiometer being permeable to potential changes in a sense providing desired control effect; and an operative coupling including means providing a definite operating threshold, between the tap of said potentiometer and the said second carrier-operated means.

11. A combination according to claim 10, characterized in that both the anode and cathode of said amplifier tube are provided with load resistors; said tube having its control grid connected to the output of said discriminator unit; and in that the said two points for deriving control potentials are the cathode and a point tapped off from the anode circuit, respectively, further characterized in that one arm of said potentiometer comprises a diode having one electrode connected to the cathode of said tube, said tube and said diode being constructed as a unit.

12. In a radio receiving system, the combination of tuning means, an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for maintaining said automatic resonance adjusting system ineffective during the absence of a carrier; a first carrier-responsive device for restoring the effectiveness of said automatic adjusting system in response to the broad selection of a carrier; a second carrier-responsive device, for causing said automatic adjusting system to resume the ineffective condition, operated in accordance with departure from exact resonance, and operatively associated with means for maintaining said second carrier-responsive means ineffective during the absence of a carrier and with further means for restoring the effectiveness substantially concurrently with the restoration of the effectiveness of said automatic adjusting system, wherein said first carrier-responsive device comprises a channel, coupled to a desired point in the carrier-amplifying section of the receiving system, substantially distinct from said automatic adjusting system and connected in parallel with a receiving channel serving for reproduction; said channel including selective means providing substantially symmetrical relative response on both sides of exact resonance.

13. A combination according to claim 12, additionally characterized in that said first carrier-responsive device is provided with two uni-directional potential providing means fed through selective paths having unequal selectivity, said two potentials having broadly the same magnitude at exact resonance of a received carrier; and means for combining said two potentials whereby the output effect of said device is substantially predetermined irrespective of received carrier strength and responsive in substantially predetermined fashion to departure from exact resonance.

14. In a radio receiver, the combination of tuning means; automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means, and including a carrier amplifier stage; means for minimizing the gain in said stage during the absence of a carrier; a first carrier-responsive means, for making ineffective the action of said gain-minimizing means, in response to the broad selection of a carrier; a second carrier-responsive means, for minimizing the gain of said stage regardless of the operation of said first carrier-responsive means when the amount of mistuning exceeds a desired value; means for maintaining said second carrier-responsive means ineffective during the absence of a carrier; and means for rendering said second carrier-responsive means effective substantially concurrently with said automatic adjusting means; including a connection to said stage of the automatic adjustment means for deriving a direct-current potential from said stage substantially reaching the value required to make said second carrier-responsive means effective after the action of said gain-minimizing means has been made ineffective by said first carrier-responsive means.

15. In a radio receiver, the combination of tuning means; an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for maintaining said automatic resonance adjusting means ineffective during the absence of a carrier; a first carrier-responsive means, for restoring the effectiveness of said automatic adjusting system in response to the broad selection of a carrier; said carrier-responsive means being provided with an operative threshold of sufficiently low value to be exceeded comparatively easily by incident carrier energy when the carrier is still a substantial amount from exact resonance, whereby to restore the effectiveness; a second carrier-responsive means, substantially distinct from said

automatic adjusting system, for causing said automatic adjusting system to resume the ineffective condition when the amount of mistuning exceeds a desired low value, regardless of the further operation of said first carrier-responsive means; said second carrier-responsive means being operatively associated with a threshold of comparatively high value whereby the incident carrier energy drops comparatively easily and in response to comparatively small departure from exact resonance, below the value required to leave said automatic adjusting system effective; and means for making said second carrier-responsive means ineffective during the absence of a carrier and for rendering said second means effective substantially concurrently with said automatic adjusting system.

16. In a radio receiver, the combination of tuning means; an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means, and including a discriminator unit provided with selective means for detecting departure from exact resonance; means for making ineffective an element in said automatic resonance adjusting system, in the absence of a carrier, to disable normally said system; a first carrier-responsive means, for deriving a uni-directional potential in response to the broad selection of a carrier utilized to restore the effectiveness of the aforesaid element; a second carrier-responsive means, including a connection to said discriminator unit, for deriving a second uni-directional potential in accordance with the amount of automatic resonance adjustment, utilized to cause the resuming of the disabled condition of said element when said amount exceeds a desired value; wherein there are provided means for combining the control effects upon said element of said two uni-directional potentials whereby increased effectiveness of carrier reception of said first carrier-responsive means tends to neutralize the action of said means disabling the said element; and said second potential tends to enhance the action of said means disabling the aforesaid element.

17. In a radio receiver, the combination of tuning means; an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means and including a discriminator unit and a carrier-amplifier stage; means for minimizing the gain of said stage in the absence of a carrier; a first carrier-responsive means for deriving a unidirectional potential in response to the broad selection of a carrier, utilized to restore the gain of said stage; a second carrier-responsive potential having a substantially predetermined amplitude after said automatic adjusting system is rendered effective; a second carrier-responsive means including a connection to said discriminator unit and output of said stage, for deriving a second uni-directional potential in accordance with the amount of automatic resonance adjustment, utilized to cause the resuming of the condition of minimized gain when said amount exceeds a desired value; wherein there are provided means for algebraically superposing said two potentials; and an operative coupling with the aforesaid gain-minimizing means for utilizing the algebraic sum of said two potentials, said coupling including means providing a definite threshold of operation.

18. In a radio receiver, the combination of tuning means; an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for rendering ineffective an element in said automatic adjusting system in the absence of a carrier, to disable normally said system; a first carrier-responsive means, for deriving a unidirectional potential in response to the broad selection of a carrier, utilized through means providing a threshold of operation to restore the effectiveness of the aforesaid element when, and only when, said potential exceeds a desired comparatively low threshold; a second carrier-responsive means, made effective substantially concurrently with said automatic adjusting system, for deriving a second uni-directional potential, in accordance with departure from exact resonance, utilized to cause the resuming of the disabled condition when said amount of departure exceeds a desired value; wherein there is provided an operative coupling between said first carrier-responsive means and the output of said second carrier-responsive means for effectively altering the relation of the amplitude of said first carrier-responsive potential and associated operative threshold to raise said threshold to a comparatively more unstable value.

19. In a radio receiver, the combination of tuning means; an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means, and including a discriminator unit; means for rendering ineffective an element in said automatic adjusting system in the absence of a carrier, to disable normally said system; a first carrier-responsive means, for deriving a unidirectional potential in response to the broad selection of a carrier, utilized through means providing a threshold of operation, to restore the effectiveness of the aforesaid element only when said potential exceeds a desired comparatively low threshold value; a second carrier-responsive means, including a connection to said discriminator unit, for deriving a second uni-directional potential in accordance with the amount of automatic adjustment, utilized to cause the resuming of the disabled condition when said amount exceeds a desired value; wherein there is provided an operative coupling between said first carrier-responsive means and the output of said second carrier-responsive means for effectively altering the relation of the amplitude of said first potential and associated operative threshold to progressively urge said threshold toward an unstable condition.

20. In a radio receiver, the combination of tuning means; an automatic resonance adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means and including a discriminator unit and a carrier-amplifier stage; means for minimizing the gain of said stage in the absence of a carrier; a first carrier-responsive device for deriving a uni-directional potential in response to the broad selection of a carrier, for restoring the gain of said stage only when said potential exceeds a desired threshold value; said device including a selective circuit operatively associated with means for altering the resonant properties of said circuit whereby effectively to alter the adjustment of said first potential relative to said operative threshold value; a second

carrier-responsive means, provided with a coupling to said discriminator unit, for deriving a uni-directional potential applied to cause said stage to resume the condition of minimized gain when the amount of automatic adjustment exceeds a desired value; wherein there is provided an operative coupling between said second carrier-responsive potential and said resonance altering means, to make said threshold progressively unstable.

21. A combination as defined in claim 20, wherein said discriminator unit is adapted to produce a uni-directional potential progressively varying in one sense and another with respect to a reference value with departure on one side and the other from exact resonance, applied to detect and correct inaccurate tuning on both sides of exact resonance; and said resonance altering means is adapted to produce mistuning of said selective circuit on one side and other from a reference frequency substantially corresponding a exact resonance; and wherein said resonance altering means is provided with an operative coupling to said discriminator unit and second carrier-responsive means, for utilizing the said uni-directional potential to cause progressive mistuning.

22. In a radio receiver, the combination of tuning means; automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means, and including a carrier amplifier channel and a discriminator unit; means for minimizing the gain in said channel during the absence of a carrier; a first carrier-responsive means, for rendering ineffective the action of said gain-minimizing means in response to the broad selection of a carrier; a second carrier-responsive means, including means for producing a second potential, responsive to the amount of automatic adjustment, derived through said channel and discriminator unit and utilized to cause said channel to resume a condition of minimized gain when the amount of departure from exact resonance in the supposed absence of said automatic adjusting means exceeds a desired value; characterized in that the control connection for utilizing said second potential is provided with auxiliary means providing a comparatively sharp rise of the control effect when said potential exceeds a threshold value, whereby to cause said resuming of the condition of minimized gain comparatively abruptly, and wherein furthermore said control connection includes a time-delaying network for maintaining said potential effective for a brief while after said channel is caused to resume said condition.

23. In a radio receiver, the combination of tuning means; automatic resonance adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means and including a carrier amplifier stage and a discriminator unit; means for minimizing the gain in said stage during the absence of a carrier; a first carrier-responsive means for producing a potential in response to the broad selection of a carrier; means for utilizing said potential to control the gain of said stage in a sense such as to make ineffective said gain minimizing means; a further carrier-responsive means for producing a second potential, responsive to the amount of automatic adjustment, derived through said stage and discriminator unit and utilized to control the gain of said stage in a sense such as to sustain the action of said gain minimizing means; wherein there are provided means for combining the control effects upon the aforesaid utilizing means in such a way as to produce a resultant control potential; and auxiliary means between said last-named potential-combining means and the aforesaid utilizing means for providing a comparatively sharp change of the control effect when said resultant potential exceeds a threshold value whereby control in said utilizing means may be comparatively abruptly; and wherein there is furthermore provided a time-delaying net-work between said potential-combining means and said utilizing means, for maintaining the effect of said resultant potential for a brief while after said stage is caused to resume the condition of minimized gain.

24. In a radio receiver, the combination of tuning means; an automatic adjusting system for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means; means for normally maintaining said automatic adjusting system ineffective; a carrier-responsive means effective at all times for producing a potential responsive to mistuning, said means including a selective circuit making said means responsive to comparatively small departure from exact resonance; means having a definite threshold of operation for utilizing said potential to make said automatic adjusting system effective, said threshold being sufficiently low to be exceeded in response to the broad selection of a carrier wave, whereupon said automatic adjusting system may bring the receiver frequency close to exact resonance; means for deriving an auxiliary potential of substantially predetermined amplitude in response to the condition of effectiveness of said automatic adjusting system; means for utilizing said auxiliary potential to counteract the influence of said first-named potential responsive to mistuning upon said means having a threshold of operation whereby to leave a comparatively small excess influence of said first-named potential despite the improved resonance condition as set forth so that said means having a threshold of operation may become responsive to small departure from exact resonance; and a time-delaying filter between said means for deriving said auxiliary potential and the means for utilizing said auxiliary potential.

25. In a radio receiver, the combination of tuning means; automatic adjusting means for bringing the receiver into substantially exact resonance with a carrier broadly selected by said tuning means including a discriminator for deriving a potential; means for normally maintaining said automatic adjusting system ineffective; a first carrier-responsive means, for restoring the effectiveness of said automatic adjusting means in response to the broad selection of a carrier; a second carrier-responsive means, for causing said automatic adjusting system to resume the ineffective condition when the amount of mistuning exceeds a desired comparatively very low value; said second means being normally maintained ineffective and being rendered effective substantially concurrently with said automatic adjusting means; characterized by the provision of means at the output of said discriminator unit for substantially limiting the effective magnitude of said potential of the discriminator, and further characterized in that said means includes a diode associated with a biasing threshold.

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