April 8, 1941. S. Y. WHITE 2,237,514

AUTOMATIC RESONANCE ADJUSTING MEANS

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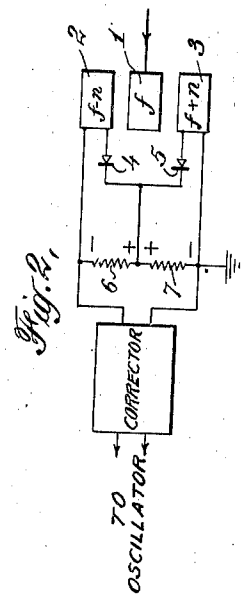


Fig. 2.

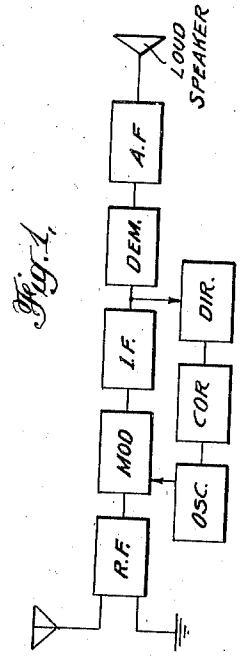


Fig. 1.

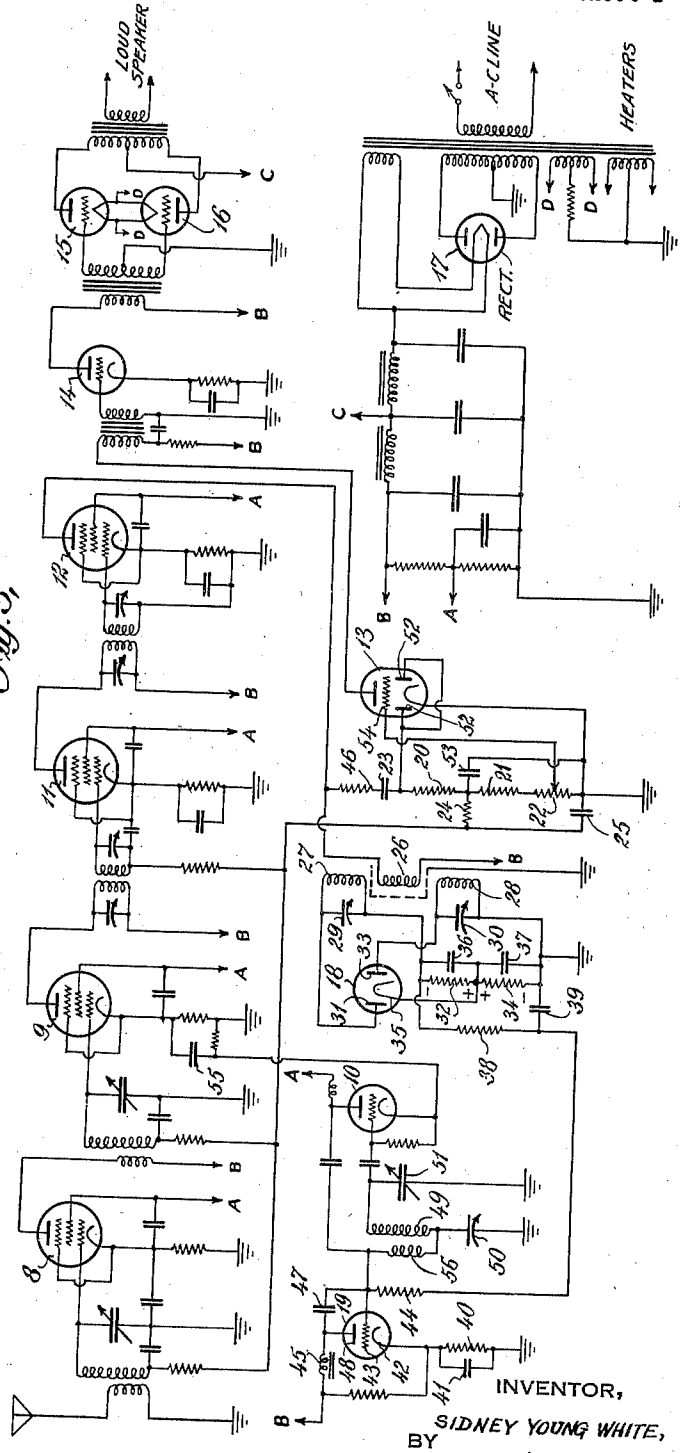


Fig. 3.

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Fig. 4.

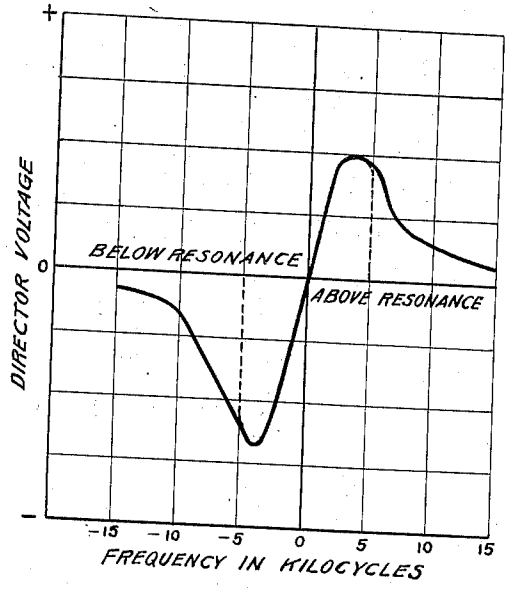


Fig. 5,

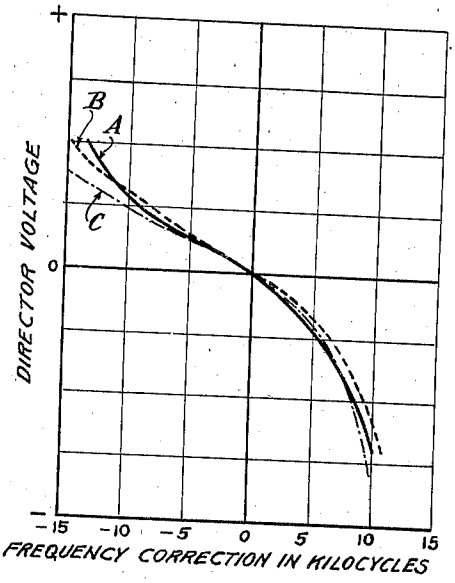


Fig. 6,

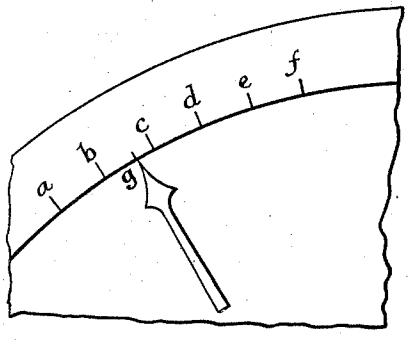
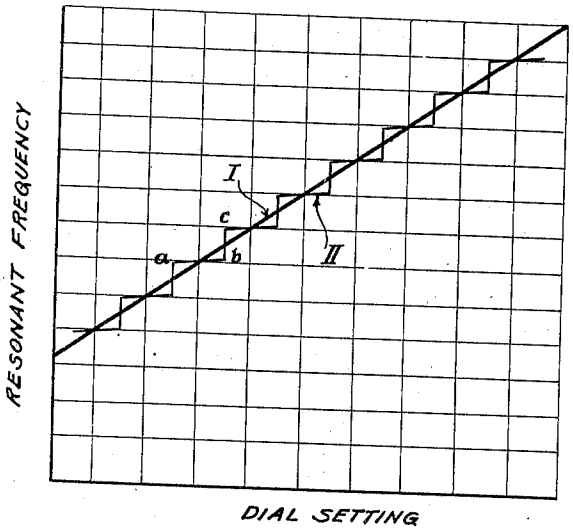


Fig. 7.



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UNITED STATES PATENT OFFICE

2,237,514

AUTOMATIC RESONANCE ADJUSTING MEANS

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Application July 1, 1935, Serial No. 29,244

11 Claims. (Cl. 250—20)

This invention relates to improvements in high-frequency signaling systems, and more particularly to systems employing modulated high-frequency signals for the transmission of intelligence. More specifically, this invention relates to improvements in radio broadcast receivers or other types of radio receivers adapted to respond to a particular desired signal.

An object of this invention is to provide means which will automatically tune a radio receiver to substantially exact resonance with a chosen incoming signal wave. An additional object is to provide means for maintaining the resonant frequency of a radio receiver substantially at a desired value, irrespective of the presence or absence of an incoming signal of corresponding frequency.

Still a further object of this invention is to provide means for automatically maintaining the resonant frequency of a radio receiver substantially at the frequency of a chosen component of a desired signal.

Another object of this invention is to provide a radio receiver which gives no response except when it is tuned to substantially exact resonance with an incoming signal having a predetermined minimum amplitude, the operation of the receiver in this respect being accomplished automatically.

Another object is to provide means by which single sideband transmission may be successfully utilized without the difficulties which would otherwise result from non-synchronous operation of the oscillator at the receiver.

Another object of the present invention is to provide a radio receiver which is simple in operation and which does not require precise manual adjustments for proper performance.

Still a further object of this invention is to provide a radio receiver which automatically gives substantially its best possible performance on any desired signal irrespective of careless manipulation on the part of the user.

An additional object of this invention is to provide simple, inexpensive and compact means for automatically adjusting the resonant frequency of a radio receiver substantially to a desired value.

An important problem in the design of radio receivers is to provide high fidelity of reproduction without sacrifice in ability to discriminate against stations on adjacent or closely spaced channels. One solution of this problem is to alter the shape of the selectivity characteristic from one with a pointed top and gradually sloping sides to one with a substantially flat top and steeply sloping sides. This improved selectivity characteristic results in a decrease in the attenuation of the higher modulation frequencies.

The steeper the sides of the selectivity characteristic, the more important it becomes that the receiver be accurately tuned to resonance with the incoming signal. Unless the carrier component of the signal corresponds in frequency with the mid-frequency of the selectivity characteristic, serious distortion is introduced, due to unsymmetrical attenuation of the sidebands. Thus, the more nearly the selectivity characteristic approaches the ideal flat-topped and steep-sided form, the greater the accuracy required in manually adjusting the station selector of the receiver, unless the automatic resonance-adjusting means of the present invention are provided.

Arrangements intended for maintaining a resonant system substantially in resonance with a given signal may be divided, for purposes of description, into two main parts: (1) means responsive to the sense and degree of deviation of the resonant frequency of the system from the frequency of the desired signal or some chosen frequency; and (2) means for altering the resonant frequency of the system in accordance with the response of the first means. These two parts are hereinafter referred to as the "director" and the "corrector," for convenience in describing various embodiments of the present invention.

For satisfactory operation in a radio receiver, arrangements of the type herein disclosed are designed to permit normal movement of the station selector; to operate independently of the intensity of the desired signal, within wide limits; to insure that initial adjustment will result in satisfactory performance over long periods of time; and to operate substantially independently of the degree of modulation of the signal.

The first requirement is met by employing a corrector which is mechanically independent of the manual station-selecting means. Thus the station selector may be operated in the usual manner without interference. The second requirement is met by so arranging the director that its operation is dependent only upon the frequency of the signal at the output of the resonant system.

The third requirement is met by employing an arrangement which is self-monitoring, and therefore able to compensate for small variations in the constants of the circuits and in the performance of the vacuum tubes used in the receiver. The last requirement is met by so choosing the

time required for the operation of the system that it will not respond to changes in the signal as rapid as are those due to modulation.

One general method of attaining the objects of th present invention involves the provision of a direct-current control voltage whose magnitude and polarity depend on the difference in degree and sense, respectively, between the frequency of a current corresponding to a desired signal and a predetermined frequency. In these arrangements, provision is made for varying the resonant frequency of one or more tuned circuits in accordance with the magnitude and polarity of the direct-current control voltage, the magnitude determining the amount of frequency change, and the polarity determining whether the frequency is increased or decreased.

In superheterodyne receivers, for example, the oscillation frequency of the oscillator is varied in accordance with changes in the frequency of the signal at the input to the demodulator, with the result that the latter frequency remains substantially constant in spite of variations in the constants of the oscillator circuit.

The invention will be better understood by reference to the accompanying drawings, in which:

Fig. 1 is a block diagram of a superheterodyne radio receiver incorporating one form of the present invention;

Fig. 2 is an expanded block diagram of a portion of Fig. 1;

Fig. 3 is a schematic diagram of a superheterodyne radio receiver incorporating the arrangements of Figs. 1 and 2;

Fig. 4 is a graph showing the characteristic of one portion of the circuit of Fig. 3;

Fig. 5 is a graph showing the characteristic of another portion of the circuit of Fig. 3;

Fig. 6 illustrates a portion of the dial of the receiver of Fig. 3; and

Fig. 7 is a graph showing the overall tuning characteristic of the receiver of Fig. 3.

Figure 1 is a block diagram of a conventional superheterodyne receiver to which has been added one form of the present invention. The director (marked DIR.) is actuated by the output of the intermediate-frequency amplifier (marked I. F.), and that in turn controls the corrector (marked COR.) which, in this embodiment, operates to vary the frequency of the local oscillator (marked OSC.). The intermediate-frequency amplifier of the receiver is thus maintained in substantial resonance with a chosen heterodyned signal. It will be understood that the automatic control may be arranged in such a way that it maintains the resonant frequency of the receiver substantially at a desired value irrespective of the presence of a signal at the antenna. For example, the receiver may be designed to respond only to signals whose carrier frequencies are exact multiples of 10 kilocycles.

A form of director which may be used with a superheterodyne receiver is shown in simplified form in Figure 2. Unit **1** represents a circuit which may be tuned to the intermediate-frequency signal which is supplied to it. Unit **2** represents a circuit which is responsive to a frequency slightly lower than the intermediate frequency, while unit **3** represents a circuit which is responsive to a frequency slightly higher than the intermediate frequency. The output currents of units **2** and **3** are rectified by means of rectifiers **4** and **5** and flow through resistors **6** and **7**, respectively. The total potential drop across resistors **6** and **7** depends for its polarity upon which unit produces the greater current, for its magnitude upon the difference between the currents delivered by the two units.

For example, if the signal has a frequency somewhat lower than the desired frequency, unit **2** will produce a flow of current through resistor **6**, with the polarity indicated. Unit **3**, however, will have only a relatively small response to the signal. The output voltage of the director will be negative relative to ground, and its magnitude will depend upon the difference in the signal and intermediate frequencies. The circuits of units **2** and **3** are sharply and adjustably tuned, the width of the control band of frequencies being readily adjustable. In a practical embodiment the circuits of units **2** and **3** may be arranged to couple with one of the windings of the last intermediate-frequency transformer in the receiver, thus eliminating the necessity for unit **1**.

For use in conjunction with a superheterodyne receiver, the corrector is a device which varies the frequency of the oscillator in accordance with changes in the magnitude and polarity of the direct-current voltage which is supplied by the director. The corrector operates without interfering with the normal performance of the oscillator, and is so arranged that its effect on the oscillator is substantially independent of the frequency to which the oscillator is tuned. The corrector is capable of varying the oscillation frequency over a band of a width at least equal to that of a channel. This range of variation is not critical in itself, but in combination with the characteristic of the director it determines the overall frequency range of the resonance-adjusting system.

The corrector is preferably arranged to alter the effective tuning capacitance of the oscillator resonant circuit. This is accomplished by the use of a vacuum tube having a capacitatively reactive load, the input circuit of the tube being arranged in effective shunt with the variable tuning capacitor of the oscillator resonant circuit. The amount of reflected capacitance is varied by altering the direct-current potential on the controll-grid of the tube. These devices operate electrically and require no appreciable power. A variable grid-bias voltage is supplied from the director. Uniform performance over a wide range of oscillation frequencies may be obtained by properly arranging the means for linking the input circuit of the tube to the resonant circuit of the oscillator. Advantage may be taken of the fact that the oscillator may be arranged with compound coupling to give a substantially constant output over the same band of frequencies, by employing part or all of the compound-coupling arrangements of the oscillator for simultaneously linking the corrector to the oscillator.

The direct-current voltage which is developed by the director and which is employed to operate the corrector may, if desired, also be utilized to control an electrical gate so arranged that the receiver gives no response except when the signal has an amplitude of at least a predetermined minimum value. In a preferred form, the electrical gate consists of an audio-frequency amplifier tube having a sharp plate-current cut-off characteristic, the control-grid bias of this tube being varied by the director. Substantially the same result may be obtained without additional apparatus by so arranging the resonance-adjusting system that it responds only to signals of a certain predetermined minimum amplitude.

Figure 3 is a schematic diagram of a super-

heterodyne radio receiver incorporating one form of the present invention. This receiver employs 12 vacuum tubes arranged as follows: a radio-frequency amplifying vacuum tube 8; a modulator vacuum tube 9; a local oscillator vacuum tube 10; a first intermediate-frequency amplifying vacuum tube 11; a second intermediate-frequency amplifying vacuum tube 12; a combined demodulator, first audio-frequency amplifying and automatic amplification control vacuum tube 13; a second audio-frequency amplifying vacuum tube 14; a push-pull output stage consisting of audio-frequency amplifying vacuum tubes 15 and 16; a rectifier vacuum tube 17; a director vacuum tube 18; and a corrector vacuum tube 19. With the exception of the novel arrangements now to be described, the receiver is of conventional design and operates in the usual manner.

A portion of the signal at the output of vacuum tube 12 is tapped off by means of resistor 46 and blocking capacitor 23 and is supplied to diode anodes 52 of vacuum tube 13. The diode anodes 52 of vacuum tube 13 are connected to ground through resistors 20 and 21 and potentiometer 22. Filter capacitor 53 is connected between the junction of resistors 20 and 21 and ground. The direct-current voltage which is developed across resistor 21 and potentiometer 22 is applied to the control-grids of vacuum tubes 8, 9 and 11 through a time-delay filter consisting of series resistor 24 and shunt capacitor 25. A desired portion of the audio-frequency voltage which appears across potentiometer 22 is tapped off and supplied to the control-grid 54 of vacuum tube 13.

Part of the signal at the output of vacuum tube 12 passes through primary winding 26 and induces voltages in secondary windings 27 and 28, which are tuned by means of adjustable capacitors 29 and 30 to frequencies slightly below and slightly above, respectively, the nominal intermediate frequency of the receiver. One terminal of winding 27 is connected to diode anode 31 of vacuum tube 18; the other terminal is connected to load resistor 32. Likewise, one terminal of winding 28 connects to diode anode 33 of vacuum tube 18; the other terminal connects to the grounded terminal of load resistor 34. Cathode 35 of vacuum tube 18 is connected to the junction of resistors 32 and 34. Resistors 32 and 34 are bypassed for high-frequency currents by capacitors 36 and 37, respectively. The direct-current voltage which is developed across resistors 32 and 34 in series is tapped off and filtered by means of series resistor 38 and shunt capacitor 39. The total voltage developed across resistors 32 and 34 is the algebraic sum of the voltages developed across the resistors individually, and for convenience the total voltage may be referred to as the director voltage.

A resistor 40, shunted by capacitor 41, is connected between the cathode 42 of vacuum tube 19 and ground. The voltage across resistor 40 together with the director voltage is impressed on grid 43 of vacuum tube 19 by means of high-resistance grid leak 44. The plate circuit of vacuum tube 19 includes inductor 45. A capacitor 47 is connected between grid 43 and plate 48 of vacuum tube 19. The grid circuit of vacuum tube 19 is coupled to the input circuit of oscillator vacuum tube 10 by means of a connection between grid 43 and one terminal of oscillator feedback coil 56, which is inductively coupled to oscillator grid coil 49. The grid circuit of vacuum tube 19 is also capacitively coupled to the grid circuit of oscillator vacuum tube 10 by means of adjustable padding capacitor 50, which is common to the grid circuits of both tubes.

In practice, the constants of the various circuits are so chosen that a desired relation exists between the frequency to which the oscillator is tuned and the amount of coupling between the oscillator and the corrector circuits. Actually, the capacitance which is reflected from the plate circuit of corrector vacuum tube 19 is effectually in shunt with oscillator tuning capacitor 51 so that changes in the amount of reflected capacitance produce corresponding changes in the oscillator frequency. In order, therefore, that a given change in the amount of reflected capacitance may produce a change in the oscillator frequency which is substantially independent of the frequency to which the oscillator is tuned, a combination of inductive and capacitive coupling is preferably employed between the oscillator and the corrector circuits, for example, as shown in Fig. 3, where coupling is secured through the combined action of inductors 49 and 55 and capacitor 50. By proper arrangement of the compound coupling elements, any non-uniformity in the performance of the corrector itself may also be compensated for. It will be understood, therefore, that the oscillator frequency correction may thus be arranged to maintain a definite and desired relation to the director voltage which is substantially independent of the frequency to which the oscillator is tuned. Oscillator vacuum tube 10 and modulator vacuum tube 9 have a coupling capacitor 55, but it will be understood that other suitable coupling means may be employed, such as for example inductive or electronic coupling.

In operation, no director voltage is developed if no signal is present at the output of vacuum tube 12, or if the signal which is present at that point has exactly the correct frequency. If the frequency of the signal is slightly higher or slightly lower than the frequency to which the intermediate-frequency amplifier of the receiver is tuned, a director voltage is developed which corresponds in magnitude and polarity with the degree and sense, respectively, by which the signal differs from the intermediate frequency. This director voltage changes the reflected capacitance in the corrector vacuum tube, which in turn produces a corresponding change in the oscillator frequency. This change in the oscillator frequency produces a desired correction in the frequency of the signal in the output circuit of vacuum tube 12, and the system reaches equilibrium with the signal at substantially the intermediate frequency of the receiver. Since most of the amplification and selectivity of the receiver is obtained from the intermediate-frequency amplifier, the net result of the operation of the automatic resonance-adjusting arrangement is substantially the best performance of which the receiver is capable.

It will be understood that the system cannot bring the receiver to an equilibrium condition in which the signal has been converted to the exact frequency to which the intermediate-frequency amplifier of the receiver is tuned. This is because a slight deviation from the intermediate frequency is necessary in order to maintain the correction of the oscillator frequency. This situation is closely comparable with that encountered with the usual type of automatic high-frequency amplification control system, in which case the output from the demodulator rises slightly as the

signal input increases in order to maintain the necessary amplification control.

In the embodiment shown in Fig. 3, the following components or values of constants may be successfully employed, but it will be understood that this is not to be taken as in any way limiting my invention, since other types and values of components may be employed even in a circuit arrangement identical with that shown in Fig. 3.

Reference numeral	Type or value
Tubes:	
8, 9, 11, 12	6D6.
13	85.
14	76.
15 and 16	45.
17	80.
18	75.
10	76.
19	76.
Resistor:	
20	0.075 megohm.
21	0.50 megohm.
Potentiometer 22	0.50 megohm.
Capacitor 23	60 micromicrofarads.
Resistor 24	1.0 megohm.
Capacitor 25	0.02 microfarad.
Inductor 26	4.4 millihenries.
Inductors 27 and 28	1.0 millihenries.
Capacitors 29 and 30	30–170 micromicrofarads.
Resistors 32 and 34	1.5 megohms.
Capacitors 36 and 37	250 micromicrofarads.
Resistor 38	2.0 megohms.
Capacitor 39	0.05 microfarad.
Capacitor 41	0.1 microfarad.
Resistor 44	1.0 megohm.
Inductor 45	4.0 millihenries.
Resistor 46	0.05 megohm.
Capacitor 47	20 micromicrofarads.
Capacitor 50	1200 micromicrofarads (max.).
Capacitor 53	100 micromicrofarads.
Capacitor 55	0.01 microfarad.

Fig. 4 shows the characteristic of the director portion of the circuit of Fig. 3. The curve indicates that a positive director voltage is produced if the frequency of the signal at the input to the demodulator is higher than the nominal resonant frequency of the intermediate-frequency amplifier. If the signal frequency is lower than the intermediate frequency, a negative director voltage is produced. The solid curve indicates the performance of the director arrangement alone, and the dotted curves show how the performance of the director is affected by the selectivity characteristic of the intermediate-frequency amplifier. This figure shows that the director characteristic has a desired steep slope over practically all of the useful range of frequency variations bounded by the dotted curves.

The curves of Fig. 5 show how the amount of frequency correction which is applied to the oscillator of the receiver of Fig. 3 varies with changes in director voltage. Curve A indicates the performance of the corrector at an oscillator frequency of 920 kilocycles; curve B, at 1370 kilocycles; and curve C, at 1870 kilocycles. The close proximity of these curves is an indication of the uniformity of performance which may be obtained over a wide range of signal frequencies. A negative frequency correction is applied when the director voltage is positive, and a positive frequency correction results from the application of a negative director voltage.

Fig. 6 shows a portion of a dial such as might be used on the receiver of Fig. 3. If points *a*, *c* and *e* are the exact settings corresponding to precise resonance with the signals from three stations of equal signal strength, without the arrangements of the present invention the receiver would have to be accurately adjusted by hand to one of these three positions. If the indicator is carelessly set at the point *g*, reception will be very unsatisfactory from station *c*. With the arrangements of the present invention, however, the indicator may be set anywhere between the points *b* and *d* for proper reception of station *c*. Likewise, the indicator may be set anywhere between points *d* and *f* for proper reception of station *e*. Moreover, as the indicator passes point *d*, the receiver instantaneously shifts from the condition of being correctly tuned to station *c* to the condition of being correctly tuned to station *e*. A similar instantaneous shift is made if the indicator is moved in the opposite direction from station *e*, in this case station *c* being automatically properly tuned in.

In the graph of Fig. 7, curve I is the continuous tuning characteristic of a conventional receiver. Curve II is the tuning characteristic of a receiver incorporating the present invention. In each case, the resonant frequency of the receiver is plotted against dial settings. It will be noted that the curve II indicates that the receiver cannot be tuned between stations. The line *a*—*b* is nearly horizonal, which indicates that the frequency changes very slightly as the dial is moved through a whole division. The line *b*—*c*, however, is vertical, which shows that the frequency shifts instantaneously from that of one station to that of the next station as the dial passes through the line between two adjacent divisions.

In a radio receiver intended for the reception of signals whose carrier frequencies are spaced 10 kilocycles apart, the variation in the resonant frequency to be accomplished by the automatic resonance-adjusting arrangements has a theoretical maximum value of 10 kilocycles, since the selector cannot be more than 5 kilocycles from the correct setting without entering the region which corresponds with the next channel above or below that of the desired signal. If the actual range of automatic variation is substantially the same as this theoretical maximum value, the receiver automatically changes instantaneously from signal to signal as the selector is adjusted manually. This effect may be called "jump tuning" and makes the operation of the receiver very pleasing, greatly facilitating the choosing of a desired signal.

If some means for automatically regulating the high-frequency amplification of the receiver is employed, the signal at the input to the second demodulator remains of substantially constant amplitude and the operation of the resonance-adjusting arrangement is practically independent of the strength of incoming signals over a wide range. This substantial elimination of the effect of the strength of the incoming signal upon the automatic resonance-adjusting system greatly facilitates the attainment of the desired result, so that the receiver is brought into substantially exact resonance with an incoming signal as the selector approaches within approximately 5 kilocycles of the corresponding setting, and is maintained in substantially exact resonance as the selector is moved to and beyond the setting corresponding to the desired signal. The control holds the receiver in resonance with one signal until the adjacent signal is encountered.

In practice it is costly to provide an automatic resonance-adjusting system which by itself operates within a sharply defined range of frequencies. Therefore, the arrangements of the present invention are so designed that the selectivity characteristic of the radio receiver is utilized to limit the range of frequencies over which the resonance-adjusting system operates. Because the system of the present invention is self-monitor-

ing as to frequency correction, only a small amount of control is necessary to secure correct tuning. The system is so arranged that the control is originated by that signal whose frequency is closest to that corresponding with the setting of the selector, even though another signal in a nearby channel is of substantially greater strength. Thus, in the case of broadcast signals for example, the frequency corresponding to the setting of the selector will not be in error by more than five kilocycles and even a very much smaller frequency difference produces a voltage in the director. Whatever the difference may be, it tends to be immediately reduced to a smaller difference until the system is in substantial resonance. The result is attained by taking advantage of the selectivity characteristic of a portion of the receiver itself, and the system therefore operates satisfactorily without the provision of elaborate and costly additional filters or other devices for providing the necessary limitation on the range of frequencies over which the system is operative.

For use in conjunction with a superheterodyne receiver, the director may be a reactive bridge arranged to produce a direct-current control voltage whose magnitude and polarity depend on the difference in degree and sense, respectively, between the frequency of the signal at the output of the intermediate-frequency amplifier and the nominal intermediate frequency. No control voltage is produced if the receiver is correctly tuned or if no signal is present.

For the most satisfactory performance, the automatic resonance-adjusting system may be so arranged that the amount of correction which is made in the frequency of the oscillator is substantially proportional to the amount of deviation from the nominal resonant frequency. In a preferred arrangement, the director is so arranged that its direct-current output voltage is roughly proportional to the degree of frequency deviation at the input to the demodulator, and the corrector is so arranged that the corrections which are made in the frequency of the oscillator are roughly proportional to the direct-current control voltages which are supplied to it. It is, of course, within the scope of the present invention to use relationships other than approximately direct proportionality between the direct-current control voltage and the frequency deviation and frequency correction, respectively, and, if desired, to so arrange the system that these relationships complement each other to produce a substantially proportional over-all relationship between the frequency deviation and the frequency correction.

Various arrangements have been devised to facilitate accurate tuning. Some of the these devices are merely indicators to show by the deflection of a pointer or the width of a shadow when the receiver is tuned to exact resonance with the desired signal. Other methods automatically silence the receiver except when the selector is set very close to the correct point. These indicating and silencing arrangements help the user to correctly adjust the receiver, but they do not avoid the necessity for very careful manipulation of the station selector. The average user of a radio receiver lacks the skill and patience demanded by this difficult manual operation. Thus such a receiver is rarely tuned with sufficient accuracy to secure the best performance of which it is capable. The addition of my automatic resonance-adjusting means, therefore, not only completely eliminates the necessity for accurately adjusting the receiver and the requirement for any form of resonance indicator, but also definitely insures maximum fidelity and eliminates the many types of disturbing noise which result from inaccurate tuning.

Mechanical detent arrangements, intended to arrest the motion of the station selector at the correct positions for a relatively small number of previously chosen stations, have been proposed. These mechanical devices, however, have the serious disadvantages of introducing a drag on the station selector and of requiring careful initial adjustment for each of the chosen stations on each individual receiver. Furthermore, any drift in the receiver constants, such, for example, as may be caused by temperature changes, affects the accuracy of these initial settings. Arrangements of this type have been employed in radio receivers, but none of them successfully solved the problem of a simple and inexpensive means to automatically correctly tune the receiver to any one of the many signal frequencies without requiring close attention on the part of the operator. The present invention, however, provides means applicable to radio receivers which attain this very desirable result, without unduly increasing the complication or cost of construction. Furthermore, the arrangements herein disclosed operate electrically and employ no moving parts to produce noise and to require adjustment.

Various electrical and mechanical devices are sometimes used in conjunction with radio receivers to obtain remote tuning or automatic tuning in accordance with a predetermined schedule. In other cases, the receiver is equipped with arrangements to give push-button tuning without the necessity for close attention by the user. All of these arrangements depend for their proper operation upon the permanence of the initial adjustments of the receiver and of the tuning devices, and they are readily rendered incapable of satisfactory operation by a slight shift in these adjustments. The application of the arrangements of the present invention to remotely tuned or automatically tuned receivers removes this inherent difficulty in such receivers, and makes their performance entirely satisfactory in this respect.

Arrangements have been disclosed previously which have been directed at the problem of correcting the tuning of a receiver to compensate for (1) changes in the frequency of the incoming signal and (2) changes, in the case of superheterodyne receivers, in the locally generated signal frequency due to variations in the constants of the oscillator circuit. In each of these arrangements it was assumed that the receiver was carefully tuned to resonance with a desired incoming signal, and it was the sole purpose of the resonance-correcting means to maintain this condition as closely as possible over a period of time. The present invention is distinguished from these earlier arrangements because it is specifically directed at the problem of providing a system which automatically produces substantial resonance with a desired signal once the receiver has been set by the user to a position closer to the desired signal than to any other signal. Thus while correcting for slight changes in the frequency of the incoming signal and, in the case of superheterodyne receivers, of the locally generated signal, the arrangements of the present invention are in addition effective to substantially compensate for the much larger changes in the

resonant frequency of a tuned system which result from inaccurate manual setting of the tuning control. Thus the present invention contemplates that the receiver to which it is applied may be rapidly set only approximately to any one of a plurality of incoming signals in succession, and it is capable of proper operation under such conditions.

The previous methods just discussed are not satisfactory for use in conjunction with broadcast receivers or with other types of receivers intended for the reception of a signal within a band of frequencies which consists of a plurality of channels of uniform width. In this service, the automatic resonance-adjusting system must operate in a substantially uniform manner over a wide band of signal frequencies. The previous methods lack the precise and definite performance which is imperative in systems intended for the reception of signals occupying closely spaced channels.

The present invention discloses arrangements which are capable of providing a substantially constant range of automatic control irrespective of the frequency to which the receiver is manually adjusted, thus producing eminently satisfactory results over the wide band of frequencies at present employed for broadcasting in the United States, and adequately meeting the requirements which are imposed on a resonance-correcting system by the 10-kilocycle channel width.

Although the arrangements of the present invention may be successfully applied to any type of radio receiver, I have chosen as an illustrative example a receiver of the superheterodyne type. In this case, the director is actuated by the signal at the input to the demodulator, and the corrector is arranged to alter the constants of the local oscillator circuit in such a way as to maintain the frequency of the signal at the input to the demodulator substantially fixed. Since most of the amplification and selection in this type of receiver takes place in the intermediate-frequency amplifier, it is unnecessary to regulate automatically the tuning of any of the variably tuned circuits in the receiver other than the oscillator circuit. This considerably simplifies the design of the corrector, and results in a very satisfactory receiver.

The automatic tuning arrangements of the present invention are not limited to use in radio receivers. They may be applied with equal success to other resonant systems which are maintained substantially in resonance with a given high-frequency signal, or at a chosen high frequency. Additional advantageous applications of arrangements within the scope of the present invention will suggest themselves to the man skilled in the art.

The arrangements of the present invention automatically maintain a resonant system in substantially exact resonance with a given high-frequency source. In some cases, this frequency may be produced by a generator in the receiver; in other cases, the carrier component of the signal from a transmitting station may be employed. The advantages of the present invention may therefore be realized in either of these general cases. Furthermore, the application of the present invention is not limited to any particular type of radio receiver. Its advantages may be realized in receivers in which the high-frequency amplification takes place at the frequency of the incoming signal as well as in receivers of the superheterodyne type, in which the greater part of the amplification before demodulation is accomplished at a relatively low constant intermediate frequency.

My invention provides a system which is signal seeking, and can be applied to short-wave systems, whereby the variations, if any, in the incoming signals will be compensated for and reliable communication maintained. The fact that I can compensate for oscillator-frequency drift, affords means for synchronizing the receiving system with distant transmitters, thereby maintaining reliable communication.

When in the claims I recite an alteration in the frequency of an oscillator or a resonant circuit, I use this term to indicate that the alteration is to be measured and expressed in the same unit as that in which the frequency is stated, and not as a percentage change. Thus an alteration of five kilocycles would be one percent of a frequency of five hundred kilocycles, but only one-third of one per cent of a frequency of fifteen hundred kilocycles. Similarly, when I recite a change in a direct-current potential or in a reactor or the adjustment of a reactor, I use the term to indicate that the change is to be expressed in the same unit as that in which the potential or the electrical value of the reactance is stated, and not as a percentage change. Likewise, when the terms compensation and inaccuracy are used in the claims, they are to be considered as referring to a given number of units of the whole, rather than to a percentage of the whole. Thus the ratio of these quantities has a definite numerical value which depends only upon the quantities involved, and is independent of the values of the quantities in which the inaccuracy occurs and to which the compensation is applied.

Having thus described my invention, what I claim is:

1. A radio receiver having manually controlled tuning means for selecting any one of a number of different carriers within a range of frequencies, a reactance, means actuated by any inaccuracy in the operation of said tuning means for varying said reactance, and means including combined inductive and capacitive couplings between said tuning means and said reactance for applying to said tuning means a portion of said reactance to substantially compensate for said inaccuracy, the magnitude of said portion being a function of the frequency of the selected carrier, whereby, the ratio of said compensation to said inaccuracy is rendered substantially constant regardless of the frequency of the selected carrier.

2. A radio receiver having an oscillator, tuning means for selecting any one of a number of different carriers within a range of frequencies, automatic electrical means including a corrector unit for substantially compensating for inaccuracy in the operation of said tuning means, and means including combined inductive and capacitive coupling between said corrector unit and said oscillator whereby the ratio of said compensation to said inaccuracy is rendered substantially constant regardless of the frequency of the selected carrier.

3. A high-frequency resonant system including a resonant circuit, a control for tuning said circuit to select any oscillation within a range of frequencies, an adjustable reactor, and means including combined inductive and capacitive couplings between said reactor and said circuit of such nature that a change in the adjustment of said reactor produces an alteration in the fre-

quency of said circuit which is substantially independent of the frequency of the selected oscillation.

4. A high-frequency resonant system including a resonant circuit, a control for tuning said circuit to select any carrier within a range of frequencies having a ratio of maximum to minimum frequency not less than two, an adjustable reactor, and means including inductive and capacitive couplings linking said reactor to said circuit for producing an alteration in the frequency of said circuit in response to a change in said reactor, said means being of such nature that the ratio of said alteration to said change is substantially independent of the frequency of the selected carrier.

5. A high-frequency resonant system including a resonant circuit, a control for tuning said resonant circuit to select any carrier within a range of frequencies having a ratio of maximum to minimum frequency not less than two, a vacuum tube having an input circuit and an output circuit, a capacitively reactive load in said output circuit, means for applying a direct-current potential to a point in said input circuit, and means including inductive and capacitive couplings between said input circuit and said resonant circuit whereby a change in said direct-current potential produces a change in the frequency of said resonant circuit, said means being of such nature that the ratio of said change in frequency to said change in potential is substantially independent of the frequency of the selected carrier.

6. A high-frequency oscillator system including a vacuum tube and a resonant circuit, a control for tuning said circuit over a range of frequencies having a ratio of maximum to minimum frequency not less than two by which said system may be approximately adjusted to produce any chosen oscillation within said range, an adjustable reactor, and means including inductive and capacitive couplings linking said adjustable reactor to said resonant circuit whereby the frequency of oscillation of said oscillator system may be altered by a change in the adjustment of said reactor, said means being of such nature that the ratio of said alteration to said change is substantially independent of the frequency of said chosen oscillation.

7. A high-frequency resonant system including a resonant circuit, a control for tuning said resonant circuit to select any carrier within a range of frequencies having a ratio of maximum to minimum frequency not less than two; a vacuum tube having an input circuit and an output circuit; a capacitively reactive load in said output circuit; a rectifier having an output circuit; a resistor in said rectifier output circuit and a direct-current connection from a point on said resistor to a point in said input circuit; a capacitor common to said input circuit and said resonant circuit; and a coupling inductor in said input circuit, said coupling inductor being inductively related to an inductor in said resonant circuit; whereby a change in the direct-current voltage developed across said resistor produces an alteration in the frequency of said resonant circuit, said capacitor and said coupling inductor being so chosen and phased that the ratio of said alteration to said change is substantially independent of the frequency of the selected carrier.

8. A high-frequency oscillator system including a vacuum tube and a resonant circuit; means by which said system may be approximately adjusted to produce oscillations of any frequency within a range; a second vacuum tube having an input circuit and an output circuit; a capacitively reactive load in said output circuit; a rectifier having an output circuit; a resistor in said rectifier output circuit and a direct-current connection from a point on said resistor to a point in said input circuit; a capacitor common to said input circuit and said resonant circuit; and a coupling inductor in said input circuit, said coupling inductor being inductively related to an inductor in said resonant circuit; whereby the frequency of oscillation of said oscillator system is altered by changes in the direct-current voltage developed across said resistor, said capacitor and said coupling inductor being so chosen and phased that said alteration in frequency is substantially proportional to said change in voltage.

9. A radio receiver having in combination, an oscillator, means by which said receiver may be approximately adjusted to select any one of a number of carriers within a range of frequencies, a fixed-frequency amplifier, two resonant circuits tuned respectively not more than five kilocycles above and below the frequency of said amplifier, means for impressing the output of said amplifier upon said resonant circuits, a rectifier associated with each of said resonant circuits, a resistance network connected between said rectifiers, a vacuum tube having input electrodes and connections from said network to said electrodes whereby the rectified component of current delivered to said rectifiers by said resonant circuits produces a direct-current potential across said network which controls the input capacitance of said vacuum tube, and coupling means between said vacuum tube and said oscillator whereby a change in said input capacitance produces an alteration in the frequency generated by said oscillator, said coupling means being of such nature that said alteration in frequency is substantially proportional to said change in direct-current potential.

10. A radio receiver for the reception of high-frequency signals whose carriers are spaced in frequency by a constant difference of ten kilocycles, including tuning means which may be approximately adjusted to select any one of said carriers; automatic electrical means including a pair of resonant circuits, a pair of rectifiers, a resistance network and a vacuum tube whose input capacitance is controlled by applying to its control electrode a potential developed across said network by rectified current from said rectifiers resulting from resonant currents in said resonant circuits; and coupling means between said electrical means and said tuning means whereby changes in said input capacitance substantially compensate for inaccuracy in the setting of said tuning means, said coupling means being of such nature that the ratio of said compensation to said inaccuracy is substantially independent of the frequency of the selected carrier.

11. A radio receiver having in combination, an oscillator; means by which said receiver may be approximately adjusted to select any one of a number of carriers within a range of frequencies; a fixed-frequency amplifier; two resonant circuits tuned respectively substantially five kilocycles above and below the frequency of said amplifier, connections for impressing the output of said amplifier upon said resonant circuits, a rectifier associated with each of said resonant

circuits, a resistance network connected between said rectifiers, a vacuum tube having input electrodes, and connections from said network to said electrodes, whereby the rectified component of the current delivered to said rectifiers by said resonant circuits produces a direct-current potential across said network which controls the input capacitance of said vacuum tube; and coupling means between said vacuum tube and said oscillator whereby a change in said input capacitance produces an alteration in the frequency generated by said oscillator, said means being of such nature that the ratio of said change in input capacitance to said alteration in frequency is substantially independent of the frequency of the selected carrier.

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