

Feb. 18, 1941.

G. GUANELLA ET AL

2,231,996

FREQUENCY VARIATION RESPONSE CIRCUIT

Filed June 5, 1937

2 Sheets-Sheet 1

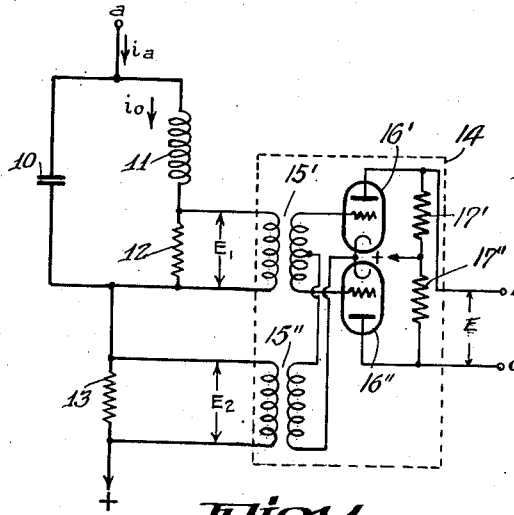


Fig. 1

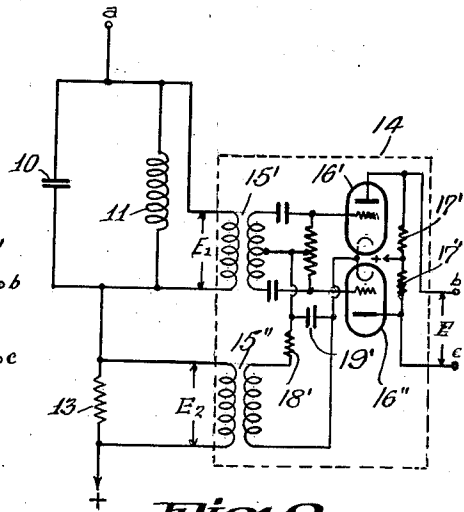


Fig. 2

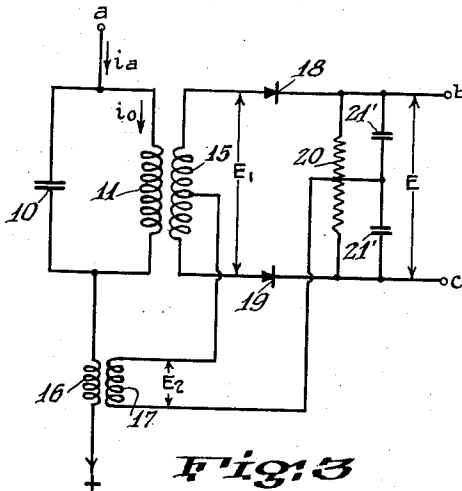


Fig. 3

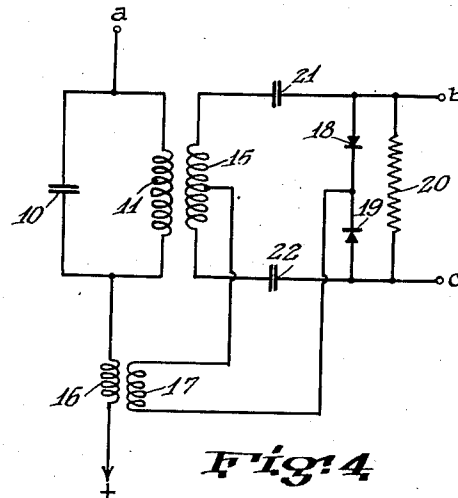


Fig. 4

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2 Sheets-Sheet 2

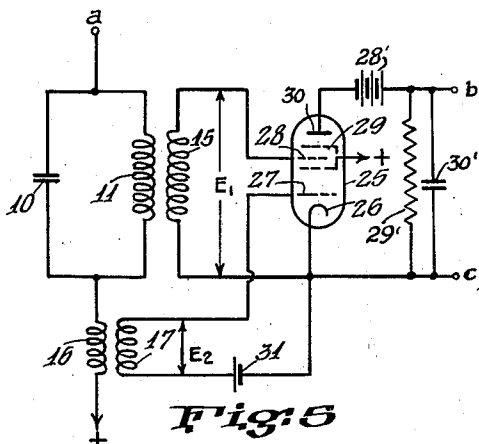


Fig. 5

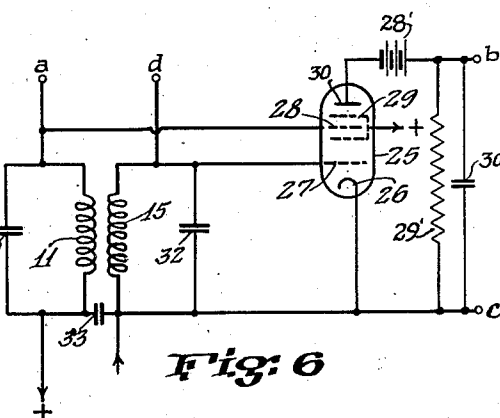


Fig. 6

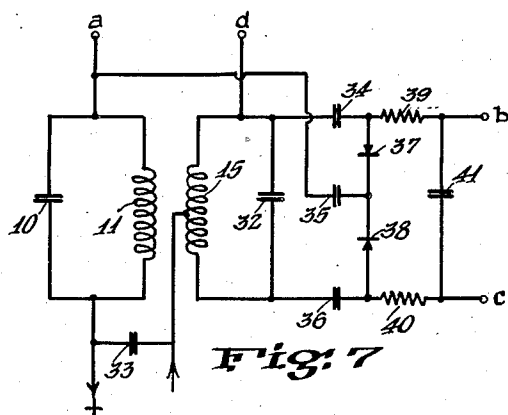


Fig. 7

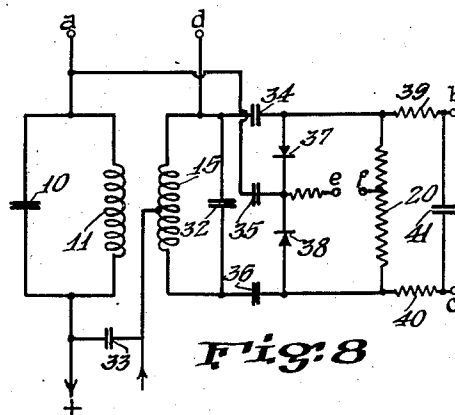


Fig. 8

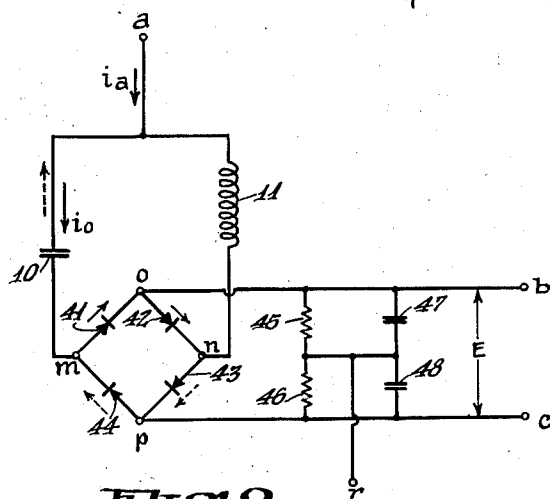


Fig. 9

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2,231,996

FREQUENCY VARIATION RESPONSE
CIRCUIT

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Application June 5, 1937, Serial No. 146,555
In Germany March 26, 1936

4 Claims. (Cl. 250—40)

The present invention relates to tuning circuits for radio receivers or the like and more particularly to a novel circuit arrangement for and a method of controlling the tuning of radio systems so as to increase the sharpness and accuracy of the tuning adjustment.

An object of the invention is the provision of an arrangement responsive to deviations of the tuning or natural frequency of a selective circuit or network in a radio receiver from the frequency of a radio signal impressed thereon for indicating and/or controlling the tuning of the receiver.

A more specific object of the invention is the provision of an arrangement responsive to deviations of the natural or tuning frequency of a selective circuit or network in a radio receiver from the frequency of an impressed radio signal wherein the direction of detuning of the circuit whether below or above the signalling frequency is indicated.

Another object is the provision of an error detector or tuning indicator for a radio receiver or the like operating in accordance with a null method or compensation principle wherein the indication and/or control at exact resonance is zero as compared with the adjustment to maximum signal in strength in the case of the known tuning indicators heretofore provided in radio receivers.

A further object of the invention is the provision of an error detector or discriminator arrangement embodied in a radio receiver adapted to supply a control potential varying in accordance with the degree of tuning of the receiver in respect to the frequency of an incoming radio signal and being of opposite sign dependent on whether the signal frequency is above or below the tuning frequency of the receiver whereby such control potential may serve to operate a tune adjusting device to automatically correct the tuning of the receiver to be in exact resonance with an incoming radio signal.

Further objects and features of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of this specification and wherein

Figure 1 illustrates diagrammatically a basic circuit constructed and operated according to the invention,

Figure 2 is a modified arrangement of a circuit shown in Figure 1,

Figures 3 and 4 illustrate practical circuit arrangements employing rectifying devices for practicing the invention,

Figure 5 illustrates the invention employing an electronic mixer valve for producing tune responsive potential variations,

Figures 6 and 7 illustrate circuits comprising a band pass filter or network used as a tune responsive means to produce indicating and/or control potentials according to the invention,

Figure 8 illustrates an arrangement similar to Figure 7 for producing both a volume and tune indication in a receiver, and

Figure 9 illustrates an alternative method of practicing the invention utilizing rectifying devices.

Like reference characters identify like parts throughout the different views of the drawings.

It is common practice in modern radio receivers to provide a station indicator to facilitate exact tuning but despite such provision correct tuning of a receiver especially one equipped with an anti-fading or volume control arrangement is by no means an easy matter to be accomplished by unskilled persons. One of the undesirable results of inexact tuning resides in a non-linear distortion of the demodulated or low frequency currents caused by an unsymmetrical position of the modulating side bands with respect to the central frequency of the pass band of the selector circuits normally used in radio receivers of present day construction. It is therefore desirable to provide an arrangement for indicating both the magnitude and direction of detuning of the receiver.

It has already been proposed to provide what may be termed semi-automatic tuning systems or systems for automatic fine adjustment of the tuning wherein accurate or fine tuning of a receiver to an incoming carrier signal is effected automatically after the receiver has been brought approximately in tune manually with the incoming signal frequency such as by operating an ordinary or mechanical dial or the like for roughly selecting the station which it is desired to receive.

In one type of semi-automatic tuning systems, especially adapted for superheterodyne receivers, two resonant circuits are provided at a suitable point in the intermediate frequency amplifier one of which circuits is sharply tuned a few kilocycles above and the other is sharply tuned by the same amount below the exact intermediate frequency for which the receiver is designed. By a superheterodyne receiver is meant a receiver in which incoming signal impulses of radio frequency are combined in a frequency changer with locally generated impulses of different radio frequency to produce impulses of an intermediate preferably supersonic frequency which are selected by tuned

circuits and demodulated. In an arrangement of the above type the current in one of the resonant circuits predominates over the current in the other resonant circuit depending on whether the incoming frequency combines with the local oscillating frequency to provide a beat or intermediate frequency above or below the predetermined intermediate frequency for which the receiver is designed. The currents in the two circuits are then rectified and differentially combined to produce a resultant direct current potential whose magnitude and sign will be a measure of the extent and direction of the detuning of the receiver. This potential may be applied to an indicating instrument thereby to indicate the extent and sense of detuning or it may serve to effect an automatic tuning adjustment by controlling a suitable tune adjuster device such as a thermionic valve suitably associated with the oscillating circuit of the local oscillator to determine the frequency thereof in a manner well known. In this manner the tuning of the receiver will be automatically regulated so as to correspond exactly with the predetermined intermediate frequency for which the receiver is designed, it being necessary for the operator or listener only to bring the tuning approximately to the point of resonance such as by means of a mechanical dial or the like.

A disadvantage of this type of error detector or discriminator for tuning indication or automatic tune adjustment is due to the necessity of two exactly and sharply tuned resonant circuits provided somewhere within the intermediate frequency section of the receiver and to the fact that it is the difference between the natural frequency of the two resonant circuits and the fixed intermediate frequency of the receiver which determines the magnitude of the control potential. The two circuits in practice do not operate at their resonance points and are detuned relative to the intermediate frequency of the receiver, as by a few kilocycles and accordingly if they are directly coupled with an intermediate frequency stage from which they are to be controlled they will impose a considerable damping effect upon this stage resulting in a substantial impairment of the accuracy and sharpness of tuning. For this reason the circuits are usually energized through a separate coupling valve provided for this purpose which in turn involves increase of parts and bulk as well as cost of the receiver.

By the present invention the above drawbacks and other defects of fixed and slightly detuned resonant circuits acting as a discriminator or error detector are substantially eliminated by a novel arrangement and method utilizing the phase difference of the current in a resonant circuit at predetermined points of the circuit with variations of the frequency of the currents, to derive a potential which will depend upon the extent and direction of detuning of the circuit with respect to the impressed frequency. As is well known, the total impedance of a resonant circuit is equivalent to a pure ohmic resistance when the circuit is exactly in tune with the impressed frequency. For a slightly higher frequency the circuit presents a capacitive reactance and for a slightly lower frequency the circuit presents an inductive reactance. If the impressed frequency is in exact resonance with the tuning or natural frequency of the circuit the input current is exactly 90° out of phase or in phase quadrature with the oscillatory current developed within the circuit. In the case of detuning this phase displacement becomes greater or smaller than 90° .

In carrying out the invention both series or parallel tuned circuits or selective networks such as band selectors or any other complex circuit arrangement may be used to produce indicating and/or control potentials dependent on both the extent and amount of detuning of the circuit. Thus for example in a band pass type of filter the mutual phase position of the potentials at the input and the output ends is in one direction, say in a negative direction where the applied frequency is low, in the case of resonance the mutual phase relation becomes zero and then changes to the other direction (positive) when the applied frequency is too high. It is thus possible, in carrying out the invention, to use either simple or complex resonant circuits already existent in the receiver, preferably resonant circuits of the band selector type in order to obtain a desired extent of phase shift for a given amount of detuning for tuning control and/or indicating purposes. However, if desired special resonant or selector circuits may be provided for the tune indication or adjusting system fed from an incoming RF or IF signal in any suitable manner as is understood.

According to one embodiment and feature of the invention, a so-called watt meter type circuit or a modulating or mixer device is employed to produce a direct current potential from a pair of alternating currents varying in accordance with the degree of detuning or mutual phase relation of the currents and having a direction dependent on the sense of detuning of one current with respect to the other. In a watt meter or modulating type arrangement there is obtained a direct current component or potential proportional to the product of the amplitudes of the two currents or potentials impressed upon the device and to the cosine of the phase angle therebetween, thereby enabling the generation of a tuning error or discriminating potential for tuning indication and/or automatic control for the purpose of the invention.

A basic circuit arrangement of the type according to the invention is illustrated in Figure 1. In the latter there is shown a multiple tuned circuit comprising a condenser 10 shunted by an inductance 11 in series with a non-reactive impedance such as an ohmic resistance 12. This circuit may be connected anywhere in a radio system and may constitute for instance the output circuit of an amplifying valve in the IF stage of a superheterodyne receiver in which case the upper terminal *a* of the circuit may be connected to the anode of the valve while the lower terminal is connected to the positive pole of an anode potential source indicated by the plus sign in series with a further non-reactive impedance 13 provided in accordance with the present invention. The voltage drops E_1 and E_2 developed across the impedances 12 and 13 are applied to a watt meter type or modulator device 14 adapted to produce a combined direct output potential E at its output terminals *b* and *c* varying in accordance with the degree of detuning of the incoming frequency relative to the natural frequency of the circuit 10, 11, 12 and having a sense dependent on whether the detuning of the circuit is below or above the impressed signal frequency.

In an arrangement of the above type the oscillatory current i_0 is displaced by 90° with respect to the total current i_a flowing into the circuit if the impressed frequency is in exact resonance with the natural or tuning frequency of the circuit. If the voltages E_1 and E_2 set up across the resistances 12 and 13 by the currents i_0 and i_a , respectively, 75

are combined or mixed in the arrangement 14, a direct output potential E is obtained in the manner described which is zero in the case of resonance when the currents are in phase quadrature and which varies towards positive and negative values if the phase of the currents is less or more than 90° respectively, i. e., according to the degree of detuning of the circuit relative impressed signal frequency. Device 14 may be of any known type such as a watt meter type or balanced modulator comprising in the example shown a pair of input transformers 15' and 15'', the former serving to excite the grids of a pair of electron valves 16' and 16'' in opposite phase by connecting the ends of its secondary each to one of the grids, and the latter exciting the grids of valves 16' and 16'' in like phase by connecting its secondary between the common cathode of the valves and the center tap of the secondary of transformer 15'. The anodes of the valves are connected through load resistances 17' and 17'' to the positive terminal of an anode or B-supply source on the one hand and to the output terminals b, c on the other hand. There is obtained in this manner by mutual modulation or product formation of the impressed input potentials E_1, E_2 an output potential E at terminals b, c varying both in sign and magnitude in dependence upon variations of the mutual phase relation between the input potentials in either sense from a normal 90° phase relation as a result of deviations from resonance of the tuned circuit 10, 11, 12 relative to the impressed signal frequency.

Referring to Figure 2, there is shown an alternative arrangement similar to Figure 1 wherein the potential E_1 is derived from the drop across the inductance 11 of the resonant circuit. In this case the potentials E_1 and E_2 are in phase in the case of resonance and in order to obtain an output potential E varying in accordance with the phase relation of the currents and being zero in the case of resonance the device 14 must be of the type and operated according to a reactive power watt meter. Alternatively one of the potentials E_1 or E_2 may be phase shifted by 90° by means of any suitable phase shifting device of well known type in which case an ordinary watt meter or mixer arrangement may be employed. An arrangement of this type is shown in Figure 2 wherein the modulator 14 is of the reactive watt meter type differing from the arrangement according to Figure 1 by the provision of a quadrature phase shifting network in the secondary circuit of the transformer 15''. This network in the example shown comprises a resistance 18' and a condenser 19' in series. By proper design of the latter, the potential across condenser 19' will lag the current by 90° in such a manner that a tune responsive output potential is obtained at the terminals b, c which is zero or a minimum in the case of resonance and increases in a positive or negative direction in proportion to the degree of detuning of the resonant circuit in either sense relative to the impressed signal frequency.

In the accompanying Figure 3 there is shown a circuit arrangement for practicing the invention employing rectifying devices which may be metallic rectifiers, valve type rectifiers or the like. For this purpose the inductance 11 is provided with a secondary 15 and a further transformer is inserted in the lead from the resonant circuit to the high potential source comprising a primary 16 and a secondary 17. The potential E_1 is thus developed across the secondary 15 and the potential E_2 is developed across the secondary 17. The

secondary 15 is connected in series with a pair of rectifiers 18 and 19 to an ohmic or non-reactive impedance 20, while the center taps of the secondary 15 and the impedance 20 are connected through the secondary 17 in the manner shown. Preferably the portions of the impedance 20 are shunted by smoothing condensers 21' to improve the steadiness of the control potentials obtained at the output terminals b and c . Assuming that the circuit 10, 11 presents a high ohmic resistance as in the case of resonance, the secondary potentials E_1 and E_2 may be represented by the following theoretical equations well known to those versed in the art:

$$E_1 = j\omega M_1 i_o$$

$$E_2 = j\omega M_2 i_a$$

In these expressions, M_1 and M_2 represent the mutual inductances of the transformers and $\omega = 2\pi f$. Thus it is seen that the phase differences are retained in the potentials E_1 and E_2 . The resistance 20 is preferably given a high value.

Referring to Figure 4 there is shown a modification of a circuit described by Figure 3. According to Figure 4 the rectifiers 18 and 19 are connected in series and in opposition across the secondary 15 through a pair of condensers 21 and 22 and the secondary 17 is connected between the center point of the secondary 15 and the junction point of the rectifiers. As is understood, the function and operation of this circuit in combining or mixing the currents set up by the potentials E_1 and E_2 is substantially similar to Figure 3.

The circuit so far illustrated and described involves the comparison of the amplitudes of two alternating potentials or of the vectorial sum and difference of the two potentials derived from different points in an oscillatory circuit and rectified to obtain corresponding direct current potentials for tuning indication and/or control. A great advantage of arrangements of this type is the fact that even if the circuit or device energized by the final resultant control potential has a relatively small resistance any additional damping imposed upon the oscillatory circuit disappears as soon as the exact tuning is reached; that is, when the output potential is zero.

In place of a modulating or mixing arrangement utilizing dry rectifiers or the like, any other phase indicator circuit arrangement such as a thermionic valve or the like may be employed for the purpose of the invention. Thus, referring to Figure 5 of the drawings there is shown an electron mixer valve 25 having a cathode 26, a first grid 27, a second grid 28 surrounded by shield grid 29, and an anode 30. As is well known in valves of this and similar construction in which two control grids are provided, shielded from each other by a positively biased screen, the electron current may be controlled separately and independently at two or more points so as to produce a direct modulation or product combination of the impressed potentials in the output circuit of the tube. In the present example the secondary voltage E_1 supplied by the winding 15 is impressed upon the electron path between the cathode and the grid 28 while the potential E_2 produced by the secondary 17 is impressed upon the path between the cathode 26 and the grid 27. In this manner the two potentials are mixed and a steady output potential E produced varying in accordance with the degree of detuning or mutual phase relation of the impressed potential and having a sign which is either positive or negative in respect to a normal mean value. Item 28' is a source of space cur-

rent and items 29' and 30' a load resistance and by-pass condenser across the output terminals *b-c* adapted to develop output potential in substantially the same manner as shown in the remaining diagrams.

In the examples so far illustrated, simple tuned circuits have been shown but as pointed out the invention may be practiced in using any type of selective system or network. This is shown in Figure 6 where a so-called band pass circuit is provided comprising a primary circuit having an inductance 11 shunted by the capacity 10 and a secondary circuit having an inductance 15 shunted by a capacity 32. The inductances 11 and 15 are in mutual coupling arrangement thereby forming a band pass or filter circuit of well known type. The circuit may serve as a tuned coupling transformer in the anode circuit of an intermediate frequency amplifier or may be arranged at any other suitable point in a radio receiver. The lower points of the secondaries 11 and 15 are shown connected through a coupling condenser 33, while the upper terminal of the input circuit 10 and 11 is connected to the grid 28 and the grid 27 is controlled by the secondary circuit 15, 32. The phase of the output potentials of such a band pass filter varies substantially in regard to the phase of the input potential, the variation in the vicinity of the predetermined intermediate frequency being from zero to 180°. In the case of resonance the phase difference is equal to 90° and the two potentials may therefore be compared and utilized to produce a resultant control potential in substantially an analogous manner as described by the previous illustrations. In this arrangement the additional damping imposed by the output current is zero when the detuning is zero, an important feature if the band filter is used in a normal manner as a frequency selective circuit in the receiver.

In Figure 7 there is shown another circuit employing a band pass filter and a pair of ordinary rectifiers 37 and 38 as modulating devices. The latter are connected in opposition across the secondary of the band pass filter through the condensers 34 and 36. The junction point between the rectifiers is connected to the terminal *a* of the primary tuned circuit 10, 11 through a condenser 35 and the electrical center point of the secondary inductance 15 is connected to the lower terminal of the primary circuit 10, 11 through the condenser 33 which latter also serves as a blocking condenser if terminal *d* is connected to the grid of a secondary amplifier stage. In this manner the circuit for the modulating or watt meter arrangement is completed similarly as in the previous figures. The output terminals, *b, c* are connected to the rectifiers through smoothing resistors 39 and 40 with a decoupling condenser 41 being provided across the output terminals.

According to a further feature of the invention, a phase or tune responsive arrangement for indication or control of the tuning may be combined with an automatic volume indicator varying in accordance with the unmodulated or carrier component of a modulated signal for either indication or automatic control of the volume as known in automatic volume control or anti-fading systems. An arrangement of this type is schematically shown in Figure 8 which is otherwise substantially identical to Figure 7. In Figure 8 the operating potential for a station indicator or for automatic volume control is derived from terminals *e, f* connected between the junction point of the rectifiers 37, 38 and the center of the re-

sistance 20 across the output terminals while the potential for the tuning indication or adjustment is supplied from terminals *b, c* in a manner as described hereinabove.

A very satisfactory form of optical tuning indication is obtained if points *e* and *f* are directly connected and the voltage between points *f* and *c* is applied to one indicator and the voltage between points *f* and *b* is applied to another indicator arranged adjacent thereto. In an arrangement of this type the total deflection or indication of both indicators is a measure of the amplitude of an incoming carrier wave, while the difference between the two indications or deflections is a measure of the degree of detuning. If the indicators are such as to be responsive to high frequency such as in the case of glow discharge lamps no special rectifiers are required. Thus, referring to Figure 4 the latter may be modified by substituting two glow devices for the rectifiers shown and by connecting the leak resistance 20 directly between the junction of the rectifiers and the terminal *b* or between the junction of the rectifiers and the terminal *c*. In any one of the arrangements illustrated, one or more of the elements or circuits such as band pass filters or dry or valve rectifiers may be combined with already existing devices and parts provided in the receiver.

Referring to Figure 9 there is shown a further arrangement for practicing the invention comprising a Wheatstone bridge arrangement associated with the oscillatory input circuit. There is shown a bridge comprising rectifiers 41, 42, 43 and 44. The diagonal points *m, n* of the bridge are connected to the lower terminals of the condenser 19 and the inductance 11, respectively, while the remaining diagonal points *o* and *p* are connected to the output terminals *b* and *c* across which is placed a center tapped resistance comprising equal parts 45 and 46 shunted by condensers 47 and 48.

The operation of an arrangement of this type is as follows: The path for the oscillatory current during one-half cycle is through the rectifiers 41 and 42 as indicated by the full arrows and during the other half cycle through the rectifiers 44 and 43 indicated by the dashed arrows. The valve circuit in whose anode circuit the tuned circuit 10, 11 is assumed to be connected is completed via the bridge points *o* and *p* and the center tap *r* between the resistances 45 and 46. The rectifiers between *n* and *p* and *m* and *p* are simultaneously non-conducting during the first half cycle of the oscillating currents in which case no current can flow from the outside via the point *p* to the rectifier bridge. Simultaneously during the first half cycle the point *o* may be regarded as connected electrically with points *m* and *n* so that a total current flows to the bridge and the oscillatory circuit via this point during the first half cycle. The same applies as regards the point *p* during the second half cycle. Thus if the total current *i_a* is in phase with the oscillatory current *i_o* the positive half wave of the total current in each case will flow through *o* and during the negative half cycle through *p* in such a manner that the condensers 47, 48 are charged to the total direct potential *E*. If the oscillatory current is out of phase with the total current, the sense of *E* changes. In the case of 90° a resonance phase displacement between the oscillatory current and the total current the resultant of the total current through *b* and through *c* is equal to zero. This circuit arrangement offers the advantage of great simplicity for only one tuned circuit is re-

quired and this may be the same circuit as is used for ordinary frequency selection purposes in the stage in question of the intermediate frequency amplifier. This arrangement does result in a slight additional damping of the oscillatory circuit, but this defect is outweighed by its simplicity. It is to be recommended when small tuning indicating potentials are all that is necessary.

Where the present invention is employed for automatic fine tuning, the actual utilization of the tuning control potential to effect tuning variation may be effected in any well known way, e. g. in the case of superheterodyne receivers it may be used to vary the local oscillator frequency by varying the dynamic grid capacity of a thermionic valve connected in parallel with the normal tuning condenser in the circuit determining the local oscillating frequency. In such a case the other tuning circuits of the receiver, i. e. the intermediate frequency circuits and the high frequency preselection tuning circuits, if any, do not require any control. In some cases, for instance in the case of "straight" or TRF receivers automatic control of tuning circuits may be effected by means of a motor controlled by the tuning control potential. In such a case automatic tuning correction should be applied to all the resonant circuits of the receiver including the circuit from which the tuning control potential is obtained.

The automatic fine tuning methods of the invention are obviously not limited to their application to ordinary broadcast receivers; for example, they may be applied to television receivers, in which, as is well known, exact tuning to an incoming carrier wave is of great importance.

The invention is well suited for use in connection with short wave and ultra short wave superheterodyne receivers, for here great difficulty is commonly experienced with known receivers, in obtaining and maintaining accurate tuning.

It will be apparent from the above that the invention is not limited to the specific circuits and arrangements of parts shown and described herein for illustration, but that numerous variations and modifications may be made coming within the broad scope and spirit of the underlying novel idea and inventive concept as defined in the appended claims. The specification and drawings are accordingly to be regarded in an illustrative rather than a limiting sense.

We claim:

1. A frequency variation response circuit comprising a resonant network having a predetermined resonating frequency, means for feeding radio frequency signal energy to said network, means

for deriving a pair of signal potentials from such points of said network that the phase angle between the derived potentials will vary in either direction from a normal phase relation both according to the sense and in proportion to the amount of detuning of said network relative to the signal frequency, an electron tube having a cathode and an anode to produce an electron space current, a pair of control grids located in the path of said space current, a further grid located between said control grids, means for maintaining said further grid at a positive potential with respect to said cathode, means for impressing each of said signal potentials upon one of said control grids, an output circuit for said tube, and load means operatively associated with said output circuit to develop energy having an amplitude varying proportionately to the phase angle between said impressed potentials.

2. A frequency variation response circuit comprising a resonant network having a predetermined resonating frequency, means for feeding radio frequency signal energy to said network, means for deriving a pair of signal potentials from such points of said network that the relative phase angle between the derived potentials will vary in either direction from a normal 90° phase relation between the derived potentials according to the sense of and proportionately to the amount of detuning of said network relative to the signal frequency, an electron tube having a cathode and an anode to produce an electron space current, a pair of control grids located in the path of said space current, a further grid located between said control grids, means for maintaining said further grid at a positive potential with respect to said cathode, means for impressing each of said potentials upon one of said control grids, an output circuit for said tube, and load means operatively associated with said output circuit to derive energy having an amplitude varying proportionately to the phase angle between said impressed potentials.

3. A system as claimed in claim 2, wherein said network is a parallel tuned resonant circuit and said potentials are derived from the circulatory current flowing within said circuit and from the total input current to said circuit.

4. A system as claimed in claim 2, wherein said network is a band-pass filter comprising a primary and secondary tuned circuit inductively coupled with each other, said potentials being derived from points of said primary and secondary circuit carrying potentials at 90° phase difference when said network is in tune with the impressed signal frequency.

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