

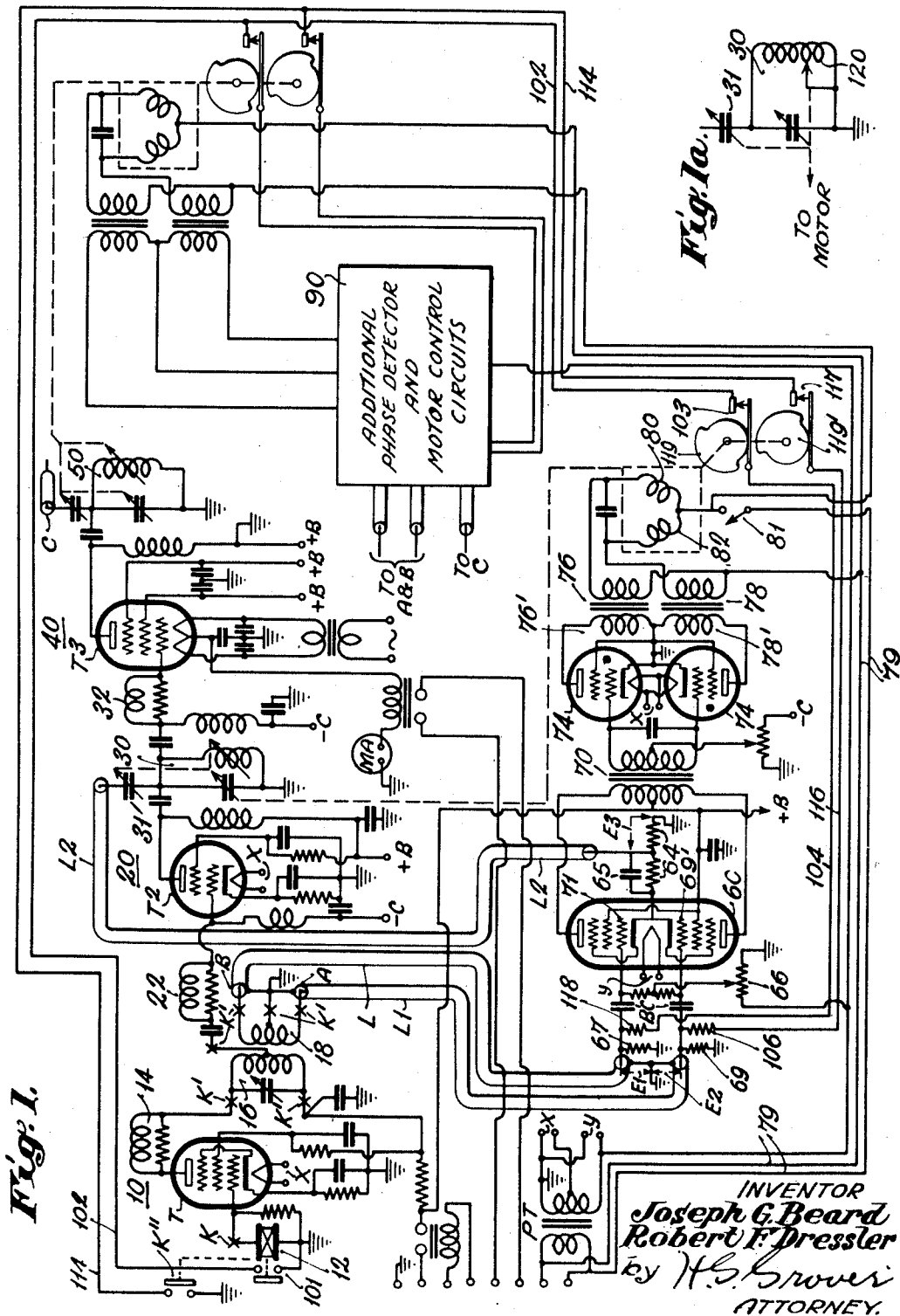
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CIRCUIT TUNER

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CIRCUIT TUNER

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1

In this application we disclose an improved method of and means for automatically tuning one or more radio stages such as, for example, wave generators, alternating current relays, amplifiers, frequency multipliers, etc. In the application for purposes of illustration and description our tuning method and means is shown applied to a transmitter of a particular type. The improvement may be used in other circuit arrangements equally well.

It is desirable that circuits following the stabilized generator in a transmitter be tuned to operate at a frequency in fixed relation to the generator frequency. Likewise, it is desirable that circuits operating in cascade operate at fixedly related frequencies.

An object of this invention is improved automatic circuit tuners for maintaining the tuning of one or more circuits such as cascaded circuits as desired. This is attained by comparing the phases of currents from the stabilized source and currents in the following stages and using any phase difference to automatically retune the following stages to eliminate the said phase difference.

In attaining this last object use is made of a current phase comparing and detecting circuit, and a further object of our invention is improved detection of relative phase variations of currents and use of the detected variations for tuning control purposes.

In an automatic tuning device for a transmitter, excited for example by a crystal controlled generator, which must cover a wide frequency range, it is often desirable to use different crystals and/or generating circuits to cover the entire range. In such systems, if the operating frequency is to be changed to a lower frequency by changing the crystal and/or generator circuits, some difficulty may be encountered due to the transmitter automatically tuning up to one of the harmonics of the desired frequency instead of tuning to the fundamental frequency.

An object of this invention is a tuning method and means free of this defect. This object is attained by means which causes the transmitter circuits always to be automatically retuned to the position of lowest frequency first, when the frequency of operation is changed by changing the crystal, and then to permit the automatic tuning arrangement to function from this position of lowest frequency as a starting point.

When our improved method and means is applied to a transmitter then the first point to which the transmitter is automatically tuned is

2

always the correct point, that is, the fundamental frequency. No other operation can take place because in starting at the low frequency end of the band and tuning upwards in frequency the transmitter tuning must hit the fundamental frequency and stop there before it ever has an opportunity to mistune to a harmonic frequency above the fundamental frequency. This special method and means is useful in any automatic tuning device which is sensitive to harmonics or other undesired frequencies.

The invention is as stated above, applicable to any arrangement involving radio stages which are to operate on the same frequency or at frequencies in fixed frequency relation. Moreover, it is understood that this improved method and means is applicable in any frequency range and in a band of any width. As a particular example, consider a transmitter whose range is 2 to 20 megacycles, equipped with some form of tuning control. Suppose the transmitter is tuned initially to 19 megacycles and let it be desired to change the tuning automatically to 6 megacycles. A different crystal for the generator will be required, one operating at 6 megacycles. This new crystal will then be arranged to replace the crystal used when operating at 19 megacycles.

Certain types of automatic transmitter tuning control systems cause the transmitter to tune and stop either at the fundamental frequency or at its harmonics indiscriminately, i. e., at 6, 12 or 18 megacycles, etc. Under the conditions assumed above, the automatic tuning system moves away from the original 19 megacycle towards the 6 megacycle position, and of course the transmitter tuning ordinarily first reaches the 18 megacycle position and stops there incorrectly, instead of continuing on down the frequency range to 6 megacycles.

In our improved method and means such operation is avoided by providing means whereby when the crystal is changed the transmitter is at once automatically tuned to its lowest limit, 2 megacycles, before the automatic tuning control is allowed to take over its continuous control function. The automatic tuning means then tunes the transmitter and it must always tune it in a direction of increasing frequency. Therefore it will reach 6 megacycles first and stop there as desired without having any opportunity to stop at a higher harmonic position.

In an embodiment, tuning of a circuit is accomplished by moving a tap on an inductance to thereby short circuit a variable number of turns thereof. Where a wide frequency range is used

the shorted part of the tuned circuit may resonate at the frequency of one of the crystals adapted for the upper end of this range. This would upset the operation of the phase detector and control circuit. An object of our invention is provision of means to automatically tune the circuits up to a selected higher frequency when for example the circuits have been tuned to the lowest frequency, as described in the two preceding paragraphs, and a crystal or similar frequency control unit operating at a frequency of the order of said selected frequency is plugged in.

A feature of our improved method and means is that it is not necessary to modify the radio frequency circuits of the transmitter to apply my improved automatic tuning method and means thereto.

A means for carrying out our method described hereinbefore has been illustrated in Fig. 1 of the drawings. Fig. 1a illustrates details of one of the tuned circuits of the transmitter.

In the drawings, 10 represents the oscillation generator of a transmitter or transmitter exciter. The generator includes a tube T with its control grid connected to ground through piezoelectric crystal 12 and its anode connected to ground through a parasitic oscillation damping resistance and choke 14 and a circuit 16. The oscillation generator is of the conventional type having a tuned plate circuit and oscillates by virtue of the fact that circuit 16 is tuned to a frequency slightly above the frequency at which the crystal operates. The generator stage 10 has its output coupled by tank circuit 18 to the control electrode of tube T2 of an amplifier stage 20. A parasitic damping resistance and inductance 22 is included in this coupling circuit. The anode of tube T2 is connected with a tuned circuit 30 and coupled thereby through damping resistance and inductance 32 to an additional stage 40 with a tube T3 and a somewhat similar output circuit 50. The transmitter per se is not being claimed herein, and will not be described in detail. The usual tube electrode supply sources, biasing resistances and bypass condensers are provided as shown. The operation of the same in general will be apparent to those skilled in the art, and discussion of the novel features thereof and details of the operation, except as set forth hereinafter, is believed unnecessary.

The generator 10 excites the stages 20 and 40. The system is to cover a wide band of frequencies, and automatic tuning means for circuits 30 and 50 or at least some thereof is provided. The crystal 12 is of the plug-in type as indicated by the circuit contact K between the crystal and the grid of tube T. This is to permit use of different crystals for different frequencies. The crystal generator anode tank circuit 16 and the inductance 18 coupled thereto are also changeable as a unit as indicated by the contacts K' in the circuits. The center contact K' also serves as the ground contact for the crystal 12 and for the sake of clarity one electrode of crystal 12 is shown at ground potential.

The outstanding features of the automatic tuning system, including the improved phase detectors, used for tuning the circuit 30 and 50 or one thereof will now be described. For automatic tuning control the phase relation of the current induced from the output of the crystal oscillator 10 into circuit 18 and the amplified current in the circuit 30 or 50 is used. The circuits 16 and 18 are changed as a unit along with the crystal when the transmitter is to be changed

from one frequency to another. The crystal is changed when the frequency change is made and circuit connections are altered by the insertion and removal of the crystal, as will appear more in detail hereinafter.

The inductance 18 is coupled by lines L and L1 of the same electrical length and blocking condensers BC to the control grids 69' and 71 of two electron discharge systems 60, which may be in single or separate envelopes. The grid ends of the lines L and L1 are coupled to ground by impedances 67 and 69 and the radio frequency voltages E1 and E2 appearing across these impedances are fed differentially to the grids 69' and 71 of the tube systems 60.

The cathodes of these systems are maintained above ground radio frequency potential by an impedance arrangement 64 and the output of tuned circuit 30 of the stage 20 is supplied by a phasing condenser 31 and a line L2 to a point on the impedance 64 to feed the radio frequency current from the circuit 30 through bypass condenser 65 in phase to both cathodes of the discharge systems 60. There is a 90° phase change of the voltage fed through the condenser 31 over resistance 64 to the cathodes. This radio frequency voltage is designated as E3 herein.

A direct current bias circuit for the control grids 69' and 71 of tubes 60 is completed by means of a potentiometer resistance 66, a point on which runs through balancing resistances to the grids of tube systems 60. The anodes are supplied by direct current potential from a lead on the primary winding of the 60 cycle transformer 70. The resistance 66 serves also as a means for applying the 60 cycle alternating current from a power supply transformer PT having its secondary connected across resistance 66. The tubes then are excited in phase by the 60 cycle alternating current (the alternating current may also be used for filament heating) which furnishes the power for exciting the motor operating stage tubes 74. As long as the tubes 60 are balanced the alternating current bucks out in the transformer 70. The phase displacement between radio frequency voltages E3 and E1 and E3 and E2 changes the bias on one or the other of the grids 69' or 71 of tube 60 to let the same amplify the 60 cycle alternating current and strike one or the other of the tubes 74, depending on which tube 60 gets the radio frequency current of advanced phase. This in turn depends on the phase relation of the radio frequency in tank circuit 16 and in circuit 30 to be tuned.

The transformer 70 has its secondary winding coupled in pushpull relation to the control grids of a pair of gaseous tubes 74 of the Thyatron type. These tubes have their anodes coupled in pushpull relation by the secondary windings of two transformers 76 and 78, the primary windings of which are in series with two motor windings 80 and 82 when switch 81 is closed (as it is during operation). The primary winding of the transformer 76 and the motor winding 80 are also connected in series by lines 79 across the alternating power supply source. The primary winding of transformer 78 and the motor stator winding 82 are similarly connected across the alternating current power source. In the embodiment of our invention being described, the alternating current supplied to these windings 80 and 82 is of 60 cycles and 110 volts. Alternating currents of other frequencies and voltages may be used.

This alternating current is induced into the

windings 76' and 78' and thereby sets up a voltage across the anode to cathode impedances of the tube systems in 74. If the two-tube systems are of high impedance (thyatron with negative or low positive voltage on grid) the transformers are unloaded (open circuited), and no current flows in the secondary windings of transformers 76 and 78 so the motor cannot turn. If the tubes are of low impedance the transformer secondaries are loaded, so current flows in the primaries and motor windings. However, since the current in one winding tends to turn the motor in one direction while the current in the other winding tends to turn the motor in the other direction the motor does turn. In practice the tube systems are alternatively conductive or both non-conductive.

The motor rotor is geared or linked to the tuning elements of tuned circuit 30, the phasing condenser 31 and the cam 119 to rotate the same like amounts, i. e., through an angle of 180° in the embodiment described.

The electron discharge devices 60 is a phase detector which compares the phase of the voltages in the tank circuit 16 with the phase of the voltage in tank circuit 30. If we give the voltage across the circuit 16 a first phase then by proper coupling of the winding 16 to winding 18 the voltage induced in winding 18 may be of said first phase and this voltage is fed by lines L and L1 differentially to the grids of tube 60. These opposed voltages are designated herein E1 and E2 respectively. For example, the voltage E1 at the end of line L is applied between the control grid 71 of one system and ground and a voltage E2 having a 180° phase relation to E1 at the end of the line L1 is applied between the control grid 69' of the other system and ground. At the same time a voltage is supplied in parallel by line L2 to the cathodes of the tubes from the circuit 30. The voltage in 30 is of a phase differing from the phase of said first voltage in the circuit 16 by 180°+90°, and therefore is in quadrature with respect to the voltage in circuit 18. Assume that the radio frequency voltage in tank circuit 16 is again of said first phase. This voltage is reversed in phase, i. e., displaced in phase 180° by the action of tube T2 and shifted in phase 90° by the phase shifter network including condenser 31 and resistance 64 at the other end of line L2. In the embodiment illustrated, the phasing network advances the phase of the voltage about 90° so that the voltages fed into line L2 are 90° displaced with respect to the voltage fed into lines L and L1 when circuit 18 is properly tuned, i. e., at resonance. To insure that this desired 90° displacement between voltage E3 and voltages E1 and E2 is maintained on the tube 60 electrodes the lines L, L1 and L2 are made of equivalent electrical length. Therefore when the stages 10 and 20 are properly tuned there will be a substantially exact phase quadrature relation between the voltages applied to the grids and cathodes of the respective discharge systems in the tube 60. Moreover, since they are properly tuned the voltage E3 applied to the cathode will be larger than voltages E1 and E2 which are equal, and there will be applied to the tubes equal radio frequency resultants so that their effects and the amplified alternating currents will cancel in the anode circuits. Moreover, since the 60 cycle current is fed by resistance 66 to the grids in phase the same is balanced in the primary winding of pushpull transformer 70 and cancels out or is at least ineffective to

strike the tube stages 74. The stage including tubes 74 is now ineffective to switch the current through one or the other of the windings 80 and 82 of the motor and the same will remain at rest in the position at which the circuit 30 is properly tuned.

Now assume that the circuit 30 is improperly tuned in one direction or the other. The phase quadrature relation between radio frequency voltages E1 and E2 and E3 is no longer present. Moreover, the voltage E3 will now be smaller than it is when the circuit 30 is properly tuned and the resultant radio frequency voltages on the grids 69' and 71 of the tubes in 60 are no longer equal and one of these tubes is more effective as an amplifier than the other, depending on whether the voltage E3 leads or lags the voltages E1 and/or E2. The grid of said one tube section is more positive than the grid of the other and amplifies the 60 cycle current more than the other tube and one or the other grids of the stage 74 is excited by the amplified alternating current power. The phase of the 60 cycle current in the secondary of 70 reverses as the devices in 60 are made alternatively operative by E1, E2, and E3. Then the voltages at the grids of 74 are in or out of phase with the 60 cycle voltage in the anode windings 76' and 78', depending on which side of 60 is operative to feed 60 cycle current through to tube 74. That side of the tube 74 excited by positive cycles of the anode and grid alternating current discharges to, in effect, lower (short) the anode to cathode impedance of this side, and a current flows through that winding of the motor coupled to this side of 74 during a half cycle of the alternating current applied to its grid. This causes the motor to drive the tuning reactance in one direction and the direction of tuning is related to the direction of shift of the voltage E3 so as to tune circuit 30 in the proper direction to set up the proper phase relation between the radio frequency voltages in circuits 30 and 16. The next positive cycle of the alternating current also has a similar effect but due to the inertia of the motor, the effect is integrated so that the motor turns slowly but continuously in the proper direction to retune the circuit 30 to resonance at the crystal frequency.

The lines connecting the winding 18 and the circuit 30 to the tube stages 60 may be of any length but must be of equal electrical length to have similar effects on the voltages E1, E2, and E3. Additional stages such as tube 40 in circuit 50 may be tuned in a similar manner by similar means which compares the phase of the current in 50 with the phase of the current in circuit 16 as induced in circuit 18. This similar tuning means is shown in general at 90, and it is believed unnecessary to describe the same herein.

Now the automatic means for returning the tuner to low frequency position when a new range of frequencies is to be used will be described. The plug-in crystal 12 when in position holds open a contact 101 in a circuit which is completed through line 102 and a second contact 103 (shown adjacent the motor) and line 104 and one condenser BC to connect the control grid 71 of one of the discharge systems in 60 to ground through resistance 118. The contact 103 is at this time closed by cam 119. The control grids of the discharge systems in 60 are also supplied with 60 cycle alternating current applied from the power supply to the biasing resistance 66.

Now, where one of the grids, say 71, is con-

nected to ground as is done by closing the contact 101 when crystal 12 is removed (removes R. F. excitation on the phase detectors) the 60 cycle excitation on the grids of the tube stages 60 is unbalanced as described, and the 60 cycle current is amplified more in one side of tube 60 than in the other side. This results in an increase of the excitation on one of the tube stages 74 to excite one of the motor windings, say winding 80, coupled to the transformer winding 78', so that the motor runs in a direction to tune all of the circuits to the lowest frequency position. The cam 119 then opens contact 103 and the motor comes to rest. During this tuning operation it is assumed that contact K'' (near crystal) and/or cam operated contact 117 is open so that the grid of the other electron system of tube 60 is not grounded through contact K'', line 114, contact 117, line 116, resistance 106 and condenser BC. When the system is tuned as described above to the lowest frequency, contacts 117 are closed but contact K'' is open. This then is the means for automatically returning the system to the low frequency position when the frequency is to be changed in order to prevent the tuner from tuning to a harmonic frequency before the fundamental frequency is reached.

Now, if a crystal say operating at 2 or 4 or 6 megacycles, and a corresponding tank circuit 16 and 18 arrangement is plugged in, insertion of the crystal unit opens contact 101 to again balance the bias and apply radio frequency excitation to the grids of tubes 60 and the automatic tuning system again goes into operation. The phase shifter condenser 31 is also adjusted by the tuning motor and the arrangement is such that the 90° phase relation discussed above necessary at the phase detectors 60 when the system is properly tuned, is maintained throughout the tuner range.

The circuit 30 in one embodiment comprises a winding and a condenser in parallel with a tap on the winding 120 which is moved along the winding as the circuit is tuned. This arrangement is such that during tuning operations a variable unused portion of the inductance is short circuited, as shown in Fig. 1a. We have found that above a particular frequency, say above 15 megacycles, this shorted portion or unused section may resonate at the crystal frequency even though the circuit 30 is not actually tuned to the crystal frequency. This has various results, one of which is to make E3 large when it should be small and otherwise upset the operation of the automatic tuner. Thus if a crystal has been removed and the circuit 30 is tuned to the low frequency end of the range and a crystal operating at say 16 megacycles is put in, the shorted part of the circuit may resonate at the crystal frequency before the automatic tuner tunes circuit 30 properly. To prevent such operation, the crystal holders above 15 megacycles when placed in position close the contact K'' to connect line 114 to ground, thereby completing a circuit through line 114, contacts 117, which have been closed by the motor driven cam 119' and remain closed until the motor has tuned the circuit 30 up to 15 megacycles, line 116 and resistance 106 to which the grid 69' of the lower section of the discharge device 60 is connected. This grounding of the grid 69' unbalances the phase detectors as described above, but in an opposite sense, so that the motor is operated in a direction which increases the frequency at which the circuit 30 resonates until a resonant frequency of 15 megacycles is reached, at which point the cam shown

schematically at 119' opens the contacts 117 to disconnect the resistance 106 from ground and remove this drive circuit for the motor. The phase detector 60 is now made operative and the automatic tuner now takes over and operates in the usual manner.

The additional tuning apparatus 90 for additional circuits 50 includes means for tuning the circuits to the low frequency end of the range when a crystal is removed and up to 15 megacycles when a crystal operating above 15 megacycles is inserted. The operation of this means is as described hereinbefore and such operation will not be repeated.

15 What is claimed is:

1. In a signalling system comprising a source of oscillations the frequency of which is stabilized by a reactance and at least one tuned circuit coupled with said source to be excited by the oscillations therein, in combination, automatic apparatus including an oscillatory energy phase comparer and tuning apparatus in said one circuit controlled by said phase comparer for maintaining said one circuit tuned substantially to resonance at the frequency of said source, and apparatus including part of said first named apparatus conditioned by changing the stabilizing reactance of said source for automatically tuning said one circuit to its lowest resonant frequency.

2. In a signalling system comprising a source of oscillations including a circuit with a replaceable frequency controlling reactance, and at least one tuned circuit coupled with said source to be excited by the oscillations therein, in combination, automatic apparatus including an oscillatory energy phase comparer and tuning apparatus in said one circuit controlled by said phase comparer for maintaining said one tuned circuit tuned substantially to resonance at the frequency of said source, and apparatus including part of said first named apparatus conditioned by removal of said replaceable reactance from said first circuit for automatically tuning said one circuit to its lowest resonant frequency.

3. In a signalling system comprising a source of oscillations the frequency of which is controlled by a replaceable reactance, and at least one tuned circuit coupled in cascade with said source to be excited by the oscillations therein, in combination, a frequency control system including phase comparison detectors having circuits coupled to said source and to said tuned circuit and excited by oscillatory energy therein for maintaining said one circuit tuned substantially to resonance at the frequency of said source, and apparatus including said phase comparison detectors and other circuits for said phase comparison detectors, conditioned by removal of said replaceable reactance for automatically tuning said one circuit to its lowest resonant frequency.

4. In a signalling system comprising a source of oscillations the frequency of which is stabilized by a reactance and a plurality of tuned circuits in cascade coupled with said source to be excited in cascade by oscillations from the source, in combination, automatic apparatus including oscillatory energy phase comparers, and tuning apparatus in said tuned circuits controlled by said phase comparers for maintaining said tuned circuits tuned substantially to resonance at the frequency of said source, and apparatus including part of said first named apparatus conditioned by changing the stabilizing reactance of said source for automatically tuning said tuned circuits to their lowest resonant frequency.

5. In a signalling system comprising a source of oscillations the frequency of which depends on a plug-in crystal, and at least one tuned circuit coupled with said source, in combination, a phase comparison circuit coupled to said source and said tuned circuit for deriving control current, a tuning motor for said tuned circuit controlled as to direction of rotation by said control current for maintaining said one circuit tuned substantially to resonance at the frequency of said source, and a contact closed by removal of said crystal for modifying the phase comparison circuit to provide a control current for said motor which automatically tunes said one circuit to its lowest resonant frequency.

6. In a signalling system comprising a source of oscillations of changeable frequency and at least one other tuned circuit coupled with said source and excited by oscillations therefrom in combination, apparatus including a tuning reactance in said tuned circuit and voltage phase detectors coupled to the source and circuit and tuning control apparatus coupled to the detectors for operating the tuning reactance for automatically maintaining said circuit tuned substantially to resonance at the frequency of said source, and a normally inoperative circuit for said phase detectors made operative by changing the frequency of said source to a selected frequency for automatically tuning said one circuit to resonance at a frequency of the order of but below said selected frequency.

7. In a signalling system comprising a source of oscillations the frequency of which is controlled by a plug-in crystal and a plug-in tank circuit and at least one other tuned circuit coupled with the oscillator, in combination, a phase detector coupled to said tank circuit and said one other circuit for detecting changes in the phases of currents in said circuits, tuning apparatus in said tuned circuit and control apparatus therefor coupled to said phase detector for tuning said one circuit in accordance with the detected currents, and a circuit for said phase detector completed by removal of said crystal for changing the excitation of said phase detector.

8. In a signalling system comprising a source of oscillations the frequency of which is determined by a replaceable reactance, and at least one other tuned circuit coupled therewith in combination, means including a phase detector circuit for comparing the phases of the currents of said source and said one tuned circuit and automatically tuning said one circuit in accordance with the said phase relation of the two currents, additional apparatus conditioned by removing said replaceable reactance for automatically tuning said one circuit to its lowest resonant frequency, and other apparatus conditioned by replacement of said reactance for automatically tuning said resonant circuit to a selected frequency.

9. In a signalling system comprising a source of oscillations the frequency of which is controlled by a plugged in crystal, said source having a tank circuit, and at least one other tuned circuit coupled therewith in combination, a pair of tubes in a phase detector circuit, connections for applying oscillations in phase displaced relation to said tubes from said tank circuit and said tuned circuit, a pair of electron discharge devices having input electrodes coupled differentially to said tubes, a motor having two windings each in series with a source of current and an impedance, con-

nections effectively shunting said impedance respectively by the impedances of said two discharge devices, and a variable reactance in said other circuit varied by movement of the rotor of said motor.

10. In a signalling system comprising a frequency stabilized source of oscillations including a tuned tank circuit and cascaded stages including other tuned circuits coupled therewith with electron discharge tubes and circuits for comparing the phases or frequencies of currents in the tank and one of said tuned circuits and automatically tuning said one circuit when the same departs from resonance, said source including a reactance replaceable by a reactance of different frequency, and additional circuits for the said tubes conditioned by removal of said reactance for operating said automatic tuning means to tune said one circuit to resonance at its lowest frequency.

11. In a signalling system, a source of oscillations of substantially fixed frequency comprising a piezoelectric crystal in a holder adapted to be plugged in circuit connections and also including a tuned circuit wherein the oscillations are produced of a frequency determined by the tuning of the circuit and the dimensions of the crystal, a tube translating stage having electrodes coupled to said tuned circuit and having output electrodes coupled to a second adjustable tuned circuit tuned to the frequency of said first circuit, a balanced phase detector for comparing the phases and frequencies of the oscillations in said two circuits, automatic tuning means connected with said phase detector and operated thereby for maintaining said second circuit tuned to resonance at the frequency of said first circuit, and a bias circuit for unbalancing said phase detector which bias circuit is completed by removal of said plugged in elements from said circuits for tuning said second named circuit to resonance at its lowest frequency.

12. In a signalling system, a stabilized wave generator including a frequency fixing element and a tuned tank circuit, the element and tank circuit being adapted to plugging into the circuit connections, a relay tube having an input coupled to said tank circuit and having output electrodes coupled to a second circuit tunable to resonance at the frequency of said element and said first circuit, a phase detector coupled to both of said circuits to be excited by voltages therein in phase quadrature, means operated by a displacement in phase or frequency of the voltages in said two circuits for automatically tuning the second circuit to resonance at the frequency of said element and said first circuit, a bias circuit for said detector completed by removal of said plugged in element from the circuit connections for biasing said detector in a sense such that said tuning means operates automatically to tune said second circuit to resonance at its lowest frequency, and a second bias circuit completed by plugging in other elements operating at a higher frequency, for biasing said detector in a different sense such that said tuning means operates to automatically tune said second circuit to resonance at a selected frequency.

13. Signalling apparatus including a first circuit wherein wave energy is developed, a second circuit tuned to the frequency of said wave energy, two electron discharge systems each having a plurality of electrodes, connections for applying voltages of a first phase from said first circuit to

11

corresponding electrodes of said systems, connections including a variable phase shifting reactance for applying voltages displaced in phase about 90° with respect to said first voltage to corresponding electrodes of said systems, and tuning control means operated by currents in said systems for tuning said second circuit and said phase shifting reactance in accordance with changes in the phase relations of the currents in said first and second circuits.

14. In a signalling system, a stabilized wave generator including a crystal and a tuned tank circuit the crystal and tank circuit being adapted to plugging into the circuit connections, a relay tube having an input coupled to said tank circuit and having output electrodes coupled to a second circuit tunable to resonance at the frequency of said crystal and said first circuit, a phase detector coupled to both of said circuits to be excited by voltages therein in phase quadrature, a motor operated by the output of the phase detector in the presence of displacement in phase or frequency of the voltages in said two circuits for automatically tuning the second circuit to resonance at the frequency of said crystal and said first circuit, and a circuit for the electrodes of said detector completed by removal of said crystal from its circuit connections for automatically actuating said tuning means to tune said second circuit to resonance at its lowest frequency.

15. In a signalling system, a source of oscillations of substantially fixed frequency comprising a piezo electric crystal in a holder adapted to be plugged in circuit connections and also including a tuned circuit wherein the oscillations are produced of a frequency determined by the tuning of the circuit and the dimensions of the crystal, a tube translating stage having electrodes coupled to said tuned circuit and having output electrodes coupled to a second adjustably tuned circuit tuned substantially to the frequency of said first circuit, a phase detector for comparing the phases and frequencies of the oscillations in said two circuits, automatic tuning means connected with said phase detector and operated thereby for maintaining said second circuit tuned to resonance at the frequency of said first circuit, and a biasing circuit for said phase detector conditioned by removal of said crystal from said circuits for unbalancing said phase detector and tuning said second named circuit to resonance at its lowest frequency.

16. In a signalling system, a stabilized wave generator including a crystal and a tuned tank circuit the crystal and tank circuit being adapted to plugging into the circuit connections, a relay tube having an input coupled to said tank circuit and having output electrodes coupled to a second circuit tunable to resonance at the frequency of said crystal and said first circuit, a phase detector coupled to both of said circuits to be excited by voltages therein in phase quadrature, means operated by a displacement in phase or frequency of the voltages in said two circuits for automatically tuning the second circuit to resonance at the frequency of said crystal and said first circuit, apparatus set in motion by removal of said crystal from its circuit connections for automatically actuating said tuning means to tune said second circuit to resonance at its lowest frequency, and apparatus set in motion by insertion of a second crystal operating at a higher frequency in said circuit connections for operating said automatic tuning mechanism to automati-

12

cally tune said second frequency to resonance at a selected high frequency.

17. In a signal system comprising a source of oscillations including a replaceable frequency controlling reactance, and at least one tuned circuit coupled with said source, in combination, automatic means for maintaining said one circuit tuned substantially to resonance at the frequency of said source, means conditioned by removal of said replaceable reactance for automatically tuning said one circuit to its lowest resonant frequency and means, conditioned by again including in said source of oscillations a frequency controlling reactance, for setting said first mentioned automatic means into operation.

18. In a signal system comprising a source of oscillations including a replaceable frequency controlling reactance, and at least one tuned circuit coupled with said source, in combination, automatic means for maintaining said one circuit tuned substantially to resonance at the frequency of said source, means conditioned by removal of said replaceable reactance for automatically tuning said one circuit to its lowest resonant frequency, and means, conditioned by including in said source of oscillations a frequency controlling reactance arranged to operate said source of oscillations at a frequency above a selected frequency, for tuning said one circuit toward said selected frequency.

19. In a signal system comprising a source of oscillations including a replaceable frequency controlling reactance, and at least one tuned circuit coupled with said source, in combination, automatic means for maintaining said one circuit tuned substantially to resonance at the frequency of said source, means conditioned by removal of said replaceable reactance for automatically tuning said one circuit to its lowest resonant frequency, means, conditioned by replacing said reactance by a frequency controlling reactance arranged to operate said source of oscillations at a frequency above a selected frequency, for tuning said one circuit to a higher frequency, and means for setting said automatic tuning means in operation when said higher frequency is reached.

20. In a signalling system comprising a source of oscillations the frequency of which is determined by a replaceable reactance and at least one other tuned circuit coupled therewith in combination, means including a phase detector circuit for comparing the phases of the currents of said source and said one tuned circuit and automatically tuning said one circuit in accordance with the phase relation of the two currents, additional apparatus coupled with said detector and conditioned by removing said replaceable reactance for automatically tuning said one circuit to its lowest resonant frequency, and other apparatus coupled with said detector and conditioned by replacement of said reactance for automatically tuning said resonant circuit to a selected frequency.

21. In a signalling system the frequency of which is determined by the value of a reactive element therein, and at least one other tuned circuit coupled therewith in combination, means including a phase detector with its circuit balanced, when the said tuned circuit is tuned to the frequency of said source, for comparing the phases of the currents of said source and said one tuned circuit and automatically tuning said one circuit in accordance with the phase relation of the two currents, and additional apparatus put in operation when the value of said reactive element is

changed for automatically tuning said one circuit to its lowest resonant frequency, said additional apparatus including said phase detector and a circuit for changing the balance thereof when the value of said reactive element is changed.

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