Nov. 22, 1949 V. H. VOGEL 2,489,064

AUTOMATIC RESONATING CONTROL SYSTEM

Filed May 7, 1948

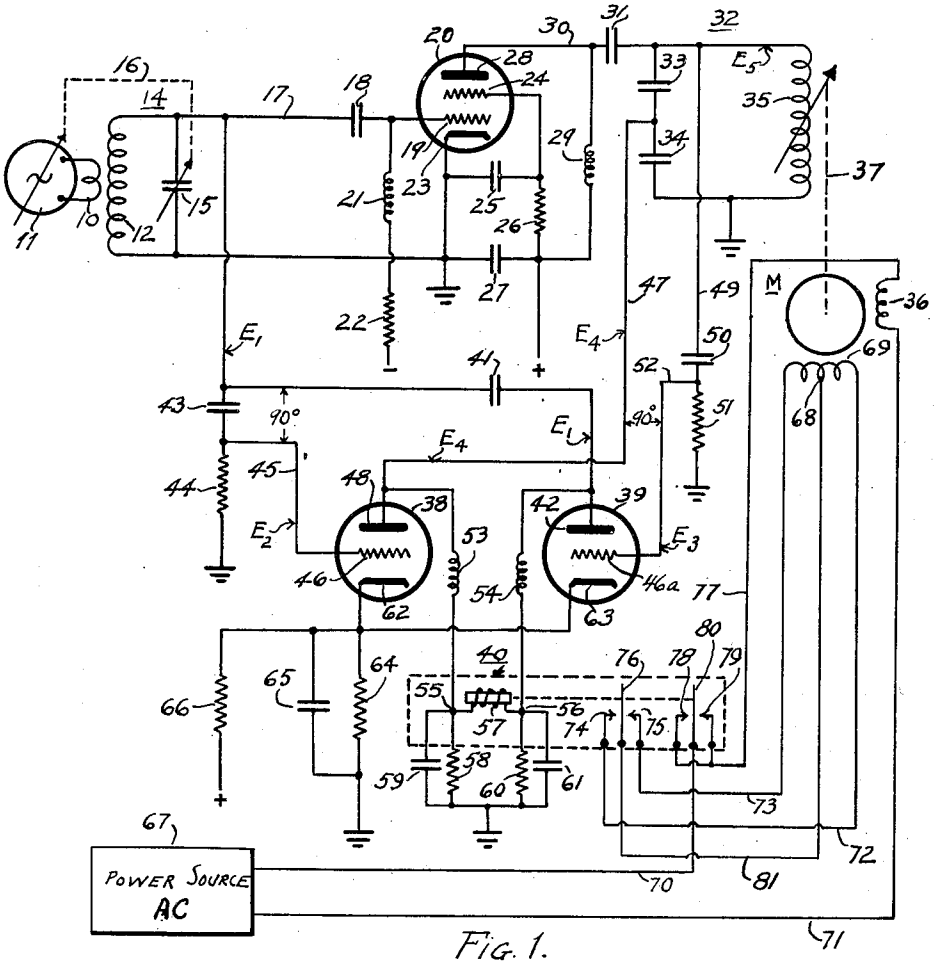


FIG. 1.

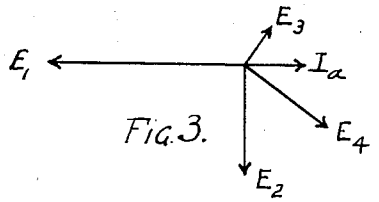


FIG. 3.

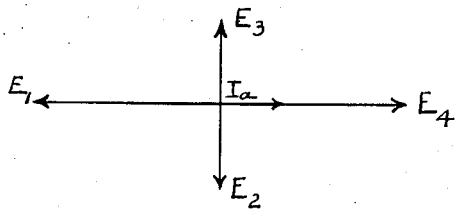


FIG. 2.

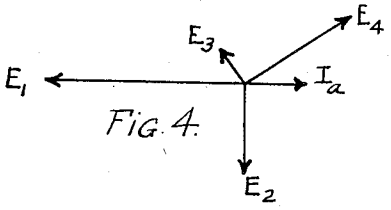


FIG. 4.

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Patented Nov. 22, 1949 2,489,064

UNITED STATES PATENT OFFICE

2,489,064

AUTOMATIC RESONATING CONTROL SYSTEM

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Application May 7, 1948, Serial No. 25,552

7 Claims. (Cl. 250—40)

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This invention relates to automatic tuning systems, and more particularly to an electronically controlled system for tuning one tunable circuit in accordance with the tuning or resonance conditions of another circuit with which the first circuit cooperates.

There is disclosed in my copending application Serial No. 696,188, filed September 11, 1946, an arrangement for automatically resonating the amplifier input circuit and the antenna loading circuit of a radio transmitter. This is accomplished in my prior application, by employing a special resonance discriminator having a pair of screen grid tubes which are connected so that their plates are excited in parallel from the input of the final amplifier of the transmitter, and their control grids are excited in parallel from the output of the final amplifier and in accordance with the loading of the amplifier.

The present invention is in the nature of an improvement on the automatic resonating arrangement of my prior application in that it simplifies the resonance discriminator circuits and enables greater efficiency to be obtained.

A principal object of the invention is to provide an automatic resonating arrangement for a radio transmitter, employing a resonance discriminator in the form of a pair of grid-controlled tubes whose control grids are connected respectively to the input and output of the final amplifier of the transmitter, and whose anodes likewise are connected respectively to the input and output of the final amplifier. However, special reactance networks are connected individually to the control grids of the discriminator tubes to maintain a 90° phase shift relation between the grid and plate excitation of each tube.

A feature of the invention relates to a novel circuit arrangement, comprising a pair of grid-controlled electron tubes and associated circuits for comparing the phase relations existing between the input excitation circuit of a high frequency amplifier and the output load, for example the coupling between the output of the amplifier and an antenna circuit.

Another feature relates to the novel organization, arrangement and relative interconnection of parts which cooperate to provide an improved automatic resonating system for high frequency circuits.

Other features and advantages not particularly enumerated, will be apparent after a consideration of the following detailed descriptions and the appended claims.

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In the drawing,

Fig. 1 is a circuit diagram of an embodiment of the invention showing the inventive concept.

Fig. 2 is a vector diagram of the voltages at various places in the circuit shown in Fig. 1 when the tracking circuit is at resonance.

Fig. 3 is a vector diagram of the voltage shown in Fig. 2 when the tracking circuit contains capacitative reactance, and,

Fig. 4 is a vector diagram of the voltages shown in Fig. 2 when the tracking circuit contains inductive reactance.

Referring more particularly to Fig. 1, coil 10 of variable frequency oscillator 11 is coupled to input coil 12 of the radio frequency amplifier input circuit 14 which may be termed the tracked circuit. Coil 12 and adjustable condenser 15 associated therewith form the tuned input circuit 14 of the radio frequency amplifier. Dotted line 16 indicates the ganging of adjustable condenser 15 to the tuning element of the variable frequency oscillator 11. Oscillator 11 and tuned circuit 14 are designed and arranged so as to track over the desired predetermined frequency range.

The radio frequency oscillations are conveyed over conductor 17 through condenser 18 to the control grid 19 of tetrode tube 20. Control grid 19 is suitably biassed by connecting it to a source of negative potential through inductance coil 21 and resistor 22 in series. Cathode 23 is directly connected to ground, and the screen grid 24 is likewise grounded for radio frequency through condenser 25. Screen grid 24 is maintained at the proper positive bias voltage by connecting it through dropping resistor 26 to a suitable source of positive D. C. potential, which is by-passed to ground through radio frequency by-pass condenser 27. Anode 28 is connected to the source of positive D. C. potential through inductance 29. The amplified output of the tube 20 is applied over conductor 30 through condenser 31 and impressed upon the tuned output circuit 32 which may be termed the tracking circuit which is to be automatically resonated with circuit 14. Circuit 32 comprises the series connected capacitors 33 and 34 paralleled with adjustable inductance coil 35, whose inductance can be varied in any well-known way. The setting of the inductance coil 35 determines the resonant frequency or tuning of circuit 32, and this setting is effected by the reversible motor M coupled to the inductance adjusting element of coil 35, the coupling being indicated by dotted line 37. For example, motor 35 may be a shaded

pole induction motor with the usual armature or field coil 36 and the phasing winding 69, the phase excitation of winding 69 determining the direction of the motor rotation.

The remaining circuit elements according to the invention, serve to control the directional rotation of the motor in such a manner that output circuit 32 is kept tuned to the same frequency as the input circuit 14 controlled by the tuning of oscillator 11. These elements constitute what may be termed a resonance discriminator, and are built around the grid-controlled electron tubes 38 and 39 and the differential polarized relay 40. The motor responds to the differential current flowing through tubes 38 and 39, and tunes the circuit 32 to resonance, the direction of rotation being determined by the capacitative or inductive condition of circuit 32 caused by a change in the frequency of oscillator 11 which is reflected as a corresponding change in the resonance conditions of circuit 14.

Fig. 2 shows the vector representations of the voltages at various places in the circuit diagram of Fig. 1 when circuits 14 and 32 are in the resonant condition. Each vector is referred to I_a the anode current through radio frequency amplifier tube 20. E_1 represents the voltage applied to grid 19 of tube 20. Voltage E_1 is applied through coupling condenser 41 to anode 42 of grid-controlled tube 39. Conductor 17 is connected to ground through condenser 43 and resistor 44, and conductor 45 connected through condenser 43 and resistor 44, is connected to control grid 46 of the grid-controlled tube 38. The reactance of condenser 43 and the resistance of resistor 44 are so related that the voltage E_2 applied to the control grid 46 of tube 38 is substantially 90% out of phase with the voltage E_1 applied to anode 42 of tube 39.

In order for voltage E_2 to approach such a phase relationship with respect to the voltage E_1, the reactance of condenser 43 should be at least twenty times the resistance of resistor 44. Conductor 47 is connected between the condensers 33 and 34 to output circuit 32 and applies the output voltage E_4 to the anode 48 of tube 38. The values of condensers 33 and 34 are such that at resonance the value of voltage E_4 is substantially equal to the value of the voltage E_1. The two voltages are substantially 180° out of phase because of the phase reversal occurring in amplifier 20. The voltage E_4 is in phase with voltage E_5 appearing across inductance 35 but is of less value that E_5 because of the voltage dividing action of condensers 33 and 34. If desired, the voltage applied to anode 48 may be taken directly from inductance 35 by providing a tap on that inductance and conveying the voltage to anode 48 through a suitable blocking condenser.

Conductor 49 is connected between condenser 33 and adjustable inductance 35 and is grounded through condenser 50 and resistor 51. Conductor 52 connected between condenser 50 and resistor 51 applies the voltage E_3 to control grid 46a of tube 42. The network comprising condenser 50 and resistor 51 causes voltage E_3 to be substantially at 90° phase relationship with voltage E_4.

Inductances 53 and 54 connect anodes 48 and 42 of tubes 38 and 39 respectively to ends 55 and 56 of the coil 57 of differential polarized relay 40. End 55 of coil 57 is connected to ground through resistor 58 and by-pass condenser 59, and end 56 of that coil is connected to ground through resistor 60 and by-pass condenser 61. Cathodes 62 and 63 of tubes 38 and 39 respectively are connected together and to ground through bias resistor 64 and by-pass condenser 65 and are also biassed through limiting resistor 66 connected to a suitable source of positive biassing potential.

It is now clear that the voltages applied to the anodes of tubes 38 and 39 are substantially 180° out of phase, and that each of these voltages is 90° out of phase with the voltage applied to its control grid, and that the voltages applied to the control grids are 180° out of phase. It follows, therefore, that equal currents flow in anode resistors 58 and 60 at resonance, and that zero voltage drop exists across relay coil 57, thereby allowing the motor 36 to be open-circuited. In order that voltage E_3 appearing across resistor 51 be of such value that it is substantially equal, at resonance, to voltage E_2 appearing across resistor 44, the reactance of condenser 50 is made greater than voltage E_5/E_1 multiplied by twenty times the resistance of resistor 58.

Motor M is energized from a suitable source of A. C. power 67 but the application of the potential to the motor phase windings is controlled by the action of the differential polarized relay 40 which determines the direction and duration of rotation. One side of the motor armature circuit is directly connected to the source of power 67 by conductor 71. Conductors 72 and 73 connected to the phasing coil 69 are also connected to front and back contacts 74, 75, respectively associated with relay armature 76. Conductor 77 connected to the motor armature 36 is also connected to front and back contacts 78, 79, associated with the relay armature 80.

It is clear, that when output circuit 32 is at resonance, no voltage drop appears across relay coil 57 and consequently that coil exerts no force on relay contact 76 and 80 and the motor is in the open-circuited condition. It will be understood that relay 40 is of the neutral type, so that normally its armatures 76, 80, do not engage any of their respective contacts. The automatic resonating action will be explained when output circuit 32 is not at resonance with input circuit 14, first when it is capacitative with respect to circuit 14, and second when it is inductive with respect to circuit 14. As will be understood from the circuit arrangement and the voltage relationship shown in Figs. 3 and 4, the capacitative condition and the inductive condition cause opposite rotation of the motor and result in the tuning of the inductance 35 until circuit 32 is operating in the resonant condition causing restoration of the voltage relationships as shown in Fig. 1.

If the output circuit 32 is capacitative (Fig. 3) the voltages E_4 and E_5 lag the anode current I_a through amplifier tube 20, thereby causing a phase difference of more than 90° between the voltage E_1 applied to anode 42 of tube 39 and voltage E_3 applied to control grid 46a of tube 39. In a similar manner the phase difference between voltage E_2 applied to control grid 46 of tube 38 and voltage E_4 applied to anode 48 of tube 38 is less than 90°. This relationship causes the anode current flow through tube 39 to be less than the anode current flow through tube 38 which causes the voltage drop across resistor 60 to be less than that across resistor 58 which results in a corresponding current flow through relay coil 57 causing, for example, movement of contacts 76 and 80 into engagement with segments 74 and 78 respectively which completes the circuit of the motor windings. The circuit for winding 36 is completed from source of power

67 through conductor 71, winding 36, conductor 77, segment 78, contact 80 and conductor 70, back to the source of power 67. The phasing coil circuit is completed through conductor 81, contact 76, segment 74, conductor 72, phasing coil 69, tap 68, and back to conductor 81. This causes rotation of the motor in a direction such that inductance 35 is tuned in the proper direction to bring circuit 32 back to resonance at which time the current flow through relay coil 57 ceases and the motor coil circuits open, allowing the motor M to come to a stop.

If the output circuit 32 is inductive (Fig. 4) voltage E_3 and voltage E_5 lead the anode current I_a through amplifier 20, thereby causing a phase difference of less than 90° between the voltage E_1 applied to anode 42 of tube 39 and voltage E_3 applied to control grid 46a of tube 39. This voltage relationship causes the anode current flow through tube 39 to be greater than the anode current flow through tube 38 which causes the voltage drop across resistor 60 to be greater than that across resistor 58, resulting in a corresponding current flow through relay coil 57 causing, for example, movement of contacts 76 and 80 into engagement with segments 75 and 79 respectively, completing the phasing winding circuit accordingly. The circuit of coil 36 is completed as above described and the direction of the current flow therethrough is unchanged. The phasing coil circuit is completed through conductor 81, contact 76, segment 75, conductor 73, phasing coil 69, tap 68, and back to conductor 81. It is thus seen that the direction of rotation of the motor is reversed and is in the proper direction to tune circuit 32 toward resonance. When resonance is accomplished, the motor stops as above described.

When circuit 32 is not tuned to resonance, the value of the output voltage E_5 is reduced. Figs. 2, 3 and 4 show the reduction in voltages E_3 and E_4 applied to control grid 46a and anode 48 of tubes 39 and 38 respectively. Since this reduction of voltage is applied with equal consequence to each of the control tubes 38 and 39, it has no appreciable effect on the discriminator action if the amplification factor of tubes 38 and 39 are also about the same amplitude as the ratio of voltage E_4/E_2 which is also approximately equal to the ratio voltage E_1/E_3. The circuit arrangement here described insures that the difference of potential across resistors 58 and 60 and the direction of current flow through relay coil 57 is only determined by the phase relationship of the anode and control grid voltages applied to tubes 38 and 39. It is clear that the tuning of output circuit 32 is controlled by the voltage and current relation existing therein and that this invention provides the necessary automatic means to make the output circuit of the amplifier track with its input circuit. It is equally clear that the system of this invention may be used to effect remote tuning of a receiver, transmitter, or the like.

While there has been here described a preferred embodiment of this invention, it is understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An automatic resonating arrangement comprising a grid-controlled amplifier tube, a tunable input circuit for said amplifier tube, a tunable load circuit for said amplifier tube, a first grid-controlled electron tube, a second grid-controlled

electron tube, means to excite the grid of the first tube and the anode of the second tube in accordance with the input circuit energy, means to excite the grid of the second tube and the anode of the first tube in accordance with the load energy, an electrical network connected to the grid of the first tube for maintaining a substantially 90° phase relation between the excitations of the grid and anode of the first tube, another electrical network connected to the grid of the second tube for maintaining a substantially 90° phase relation between the grid and anode excitations of said second tube, a switching device, circuit connections for applying the differential anode currents of said tubes to control said switching device, means to tune the load circuit of said amplifier, and circuit connections between said tuning means and said switching device for automatically operating said tuning means under control of said switching device.

2. An automatic resonating arrangement according to claim 1 in which the first-mentioned network comprises a resistance-condenser combination connected between the said input circuit and the cathode return circuit of the first tube, and the second-mentioned network comprises a resistance-condenser combination connected between the load circuit and the cathode return circuit for the second tube.

3. An automatic resonating arrangement according to claim 1 in which the second-mentioned electrical network includes a resistor and condenser connected in series between the said input circuit and the cathode return circuit of the first tube said condenser having a reactance at least twenty times the resistance of said resistor, and the second-mentioned network includes a condenser and resistor connected in series between the said load circuit and the cathode return of the second tube, the reactance of the condenser of the second network being at least twenty times the resistance of the resistor of the second network.

4. An automatic resonating arrangement comprising a high frequency input circuit having a tuning element and a high frequency load circuit having a tuning element, an electron tube amplifier interconnecting said input and load circuits, a resonance discriminator, said discriminator consisting of a first grid-controlled electron tube, a second grid-controlled electron tube, a resistor and condenser connected in series between the input circuit and ground, another condenser and resistor connected in series between the load circuit and ground, a connection from the junction between the first condenser and first resistor to the grid of the said first tube, a connection from the junction point of the second resistor and the second condenser to the grid of the second tube, means to excite the anode of the second tube by the input energy, means to excite the anode of the first tube by the load energy, a differential polarized relay connected in common to the output circuits of said tubes, a motor for controlling the tuning of said load circuit, and circuit arrangements controlled by said relay for causing said motor automatically to adjust the tuning element of said load circuit to resonate said load circuit with said input circuit.

5. An automatic resonating arrangement according to claim 4 in which the first-mentioned condenser and resistor are proportioned to maintain an approximately 90° phase relation between the excitation of the grid and anode of the first tube, and the second-mentioned re-

sistor and condenser are proportioned to maintain approximately a 90° phase relation between the excitation of the grid and anode of the second tube.

6. An automatic resonating arrangement, comprising an amplifier, a tunable input circuit for said amplifier, a tunable output circuit for said amplifier, first and second grid-controlled electron tubes for controlling the tuning of said output circuit, circuit connections for exciting the grid of the said first tube by voltages derived from the said input circuit, circuit connections for exciting the grid of said second tube by voltages derived from the said output circuit, circuit connections for exciting the anode of said first tube by voltages derived from the said output circuit, circuit connections for exciting the anode of the said second tube by voltages derived from said input circuit, an adjustable element for tuning said output circuit, a switch device for controlling said tuning element, and circuit connections between the anodes of said first and second tubes and said switch device for operating said switch device in accordance with the differential current from said anodes.

7. An automatic resonating arrangement, comprising an amplifier, a tunable input circuit for said amplifier, a tunable load circuit for said amplifier, first and second grid-controlled electron tubes for controlling the tuning of said load circuit, circuit connections for exciting the grid of the first tube and the anode of the second tube by voltages derived from said input circuit, circuit connections for exciting the grid of the second tube and the anode of the first tube by voltages derived from said output circuit, means for maintaing approximately a 90° phase relation between the excitation of the grid and anode of the first tube, means for maintaining approximately 90° phase relation between the excitation of the grid and anode of the second tube, adjustable means to tune said load circuit, a switch device for controlling said tuning means, and circuit connections between the anode of said first and second tubes and said switching device to control the operation of said switching device in accordance with the differential anode currents of said first and second tubes.

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The following references are of record in the file of this patent:

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