

May 22, 1945.

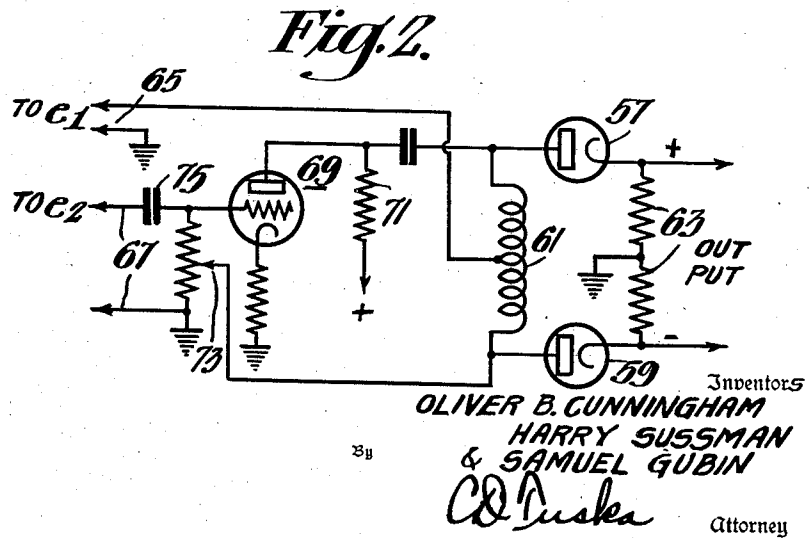
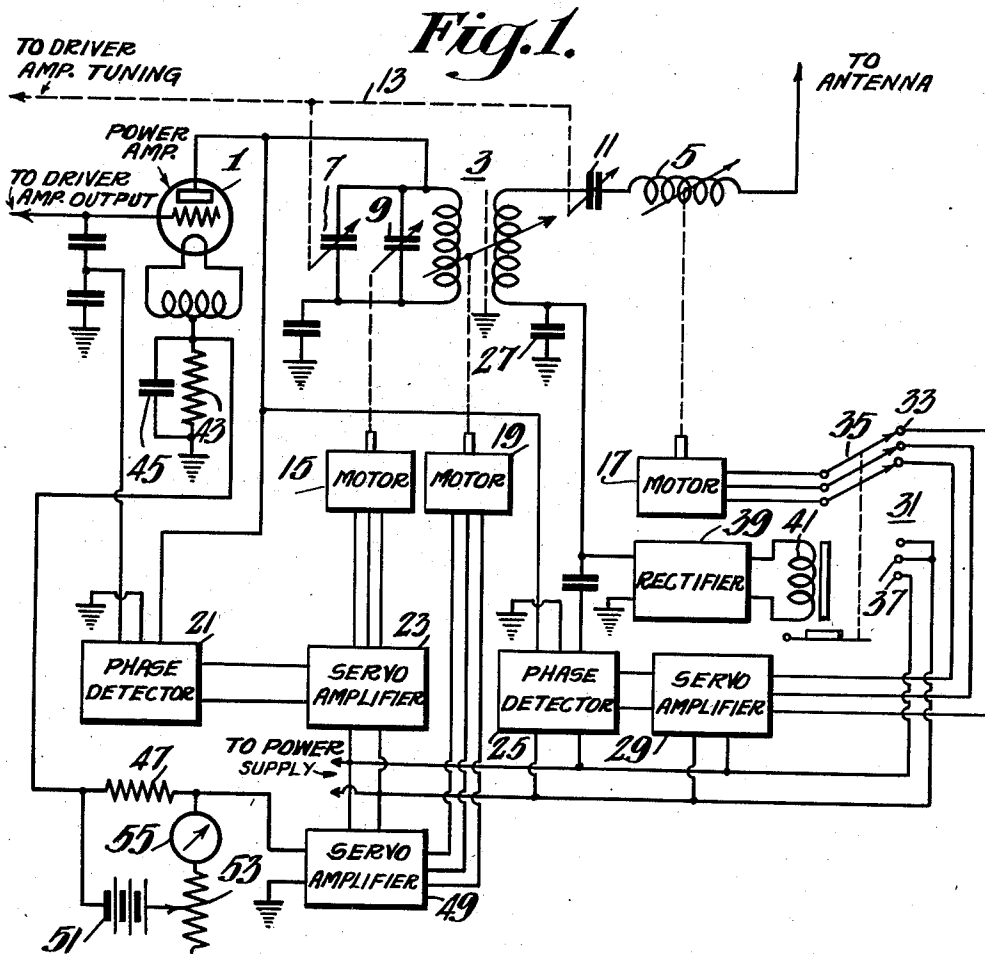
O. B. CUNNINGHAM ET AL

2,376,667

AUTOMATIC TUNING OF TRANSMITTERS

Filed March 29, 1943

2 Sheets-Sheet 1



May 22, 1945.

O. B. CUNNINGHAM ET AL

2,376,667

AUTOMATIC TUNING OF TRANSMITTERS

Filed March 29, 1943

2 Sheets-Sheet 2

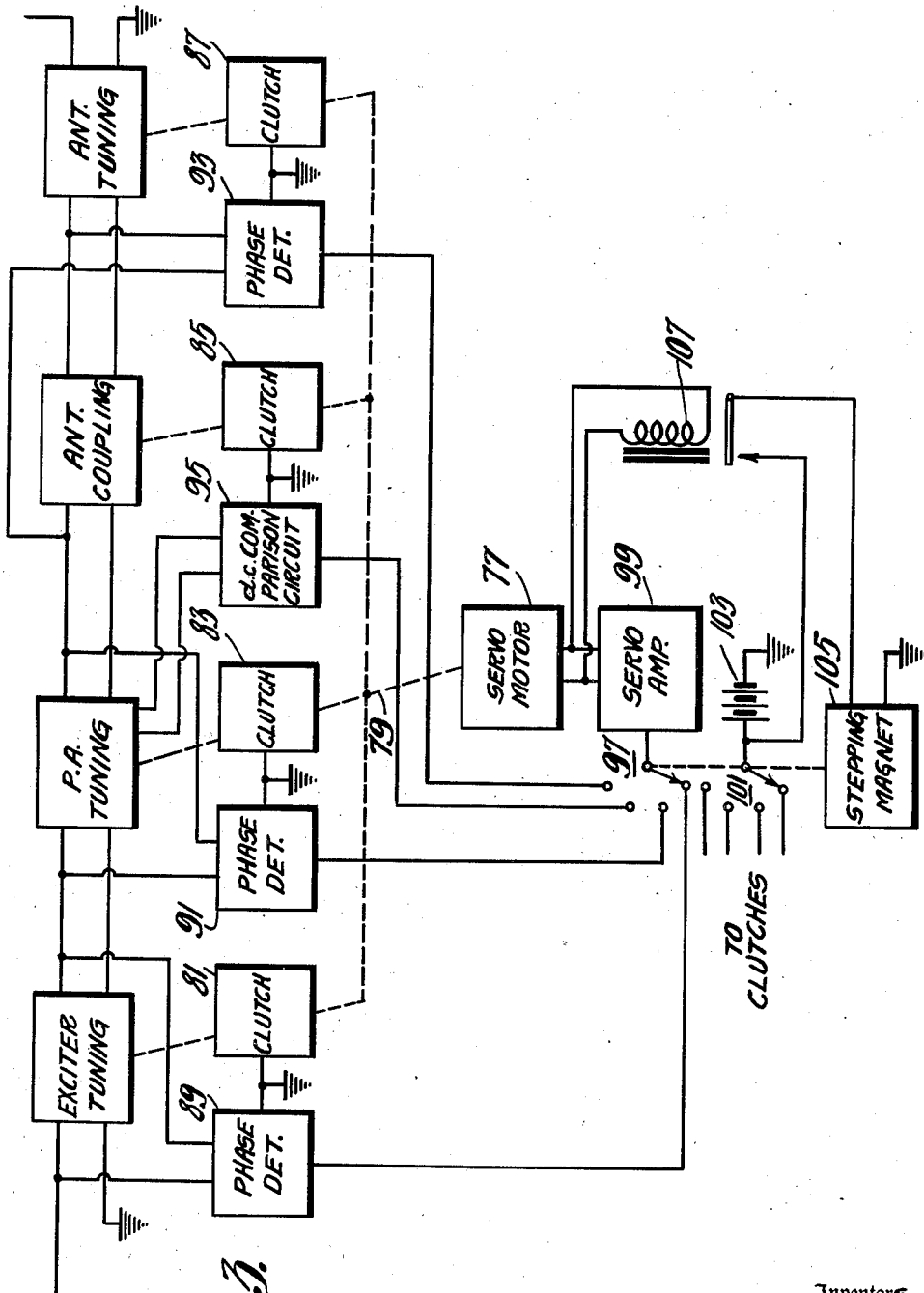


Fig. 3.

Inventors
OLIVER B. CUNNINGHAM
HARRY SUSSMAN
& SAMUEL GUBIN
CD Tucker
Attorney

UNITED STATES PATENT OFFICE

2,376,667

AUTOMATIC TUNING OF TRANSMITTERS

Oliver B. Cunningham, Haddonfield, Harry Sussman, Pensauken Township, Camden County, and Samuel Gubin, Merchantville, N. J., assignors to Radio Corporation of America, a corporation of Delaware

Application March 29, 1943, Serial No. 480,928

5 Claims. (Cl. 250-17)

This invention relates to automatic tuning of radio transmitters and more particularly to changing the frequency of operation of a multi-stage transmitter by means of a single control.

The usual radio transmitter comprises a master oscillator, one or more amplifiers, and a power amplifier. The output circuit of the power amplifier is coupled through resonant circuits to an antenna which is resonated at or near the frequency of operation of the transmitter. The tuned circuits preceding the final power amplifier stage may be arranged for single control tuning adjustment by means of mechanical ganging similar to that used in broadcast receivers. However, the power amplifier and antenna circuits cannot be controlled in this manner because of the wide variation in resistance and reactance of the antenna with variations in frequency. For this reason the adjustment of the frequency of operation of a transmitter is somewhat cumbersome, requiring the separate tuning of at least three different circuits: the exciter or oscillator and amplifier circuits, the power amplifier tank circuit and the antenna circuit. In addition to this the coupling between the antenna and the power amplifier must be readjusted for each change in the frequency.

It is the principal object of the present invention to provide an improved method of and means for tuning automatically the circuits following the master oscillator including the power amplifier output circuit and the antenna of a radio transmitter.

Other objects will become apparent to those skilled in the art upon consideration of the following description with reference to the accompanying drawings, of which Fig. 1 is a schematic circuit diagram of a preferred embodiment of the invention, Fig. 2 is a schematic circuit diagram of a phase detector employed in the circuit of Fig. 1, and Fig. 3 is a modified embodiment of the invention.

Referring to Fig. 1, a power amplifier stage 1 is coupled through a transformer 3 to an antenna circuit including an adjustable loading inductor 5. The primary of the transformer 3 is tuned by means of variable capacitors 7 and 9 connected in parallel. The secondary circuit is tuned by a variable capacitor 11 and the variable inductor 5. The capacitors 7 and 11 are mechanically ganged, as indicated by the dash line 13, to the tuning control of the driver amplifier and preceding stages of the transmitter. The capacitor 9 is mechanically connected to a reversible motor 15 and the inductor 5 is similarly connected to a

similar motor 17. The secondary of the transformer 3 is movable with respect to the primary to permit variation of the coupling and is mechanically connected to a reversible motor 19. A phase detector 21 is connected to the grid and anode circuits of the power amplifier 1. The output of the phase detector is connected to an amplifier 23. The amplifier 23 is arranged to control the energization of the motor 15 from a power supply, not shown.

A second phase detector 25 is connected to the anode circuit of the power amplifier 1 and to a capacitor 27 included in the ground circuit of the secondary of the transformer 3. An amplifier 29 similar to the amplifier 23 is connected to one group of fixed contacts 33 of a relay 31. The movable contacts 35 of the relay 31 are connected to the motor 17. A second group of fixed contacts 37 is connected to the power supply circuit. A rectifier 39 is connected across the capacitor 27 and to the energizing coil 41 of the relay 31.

A resistor 43, bypassed by a capacitor 45, is included in the cathode circuit of the amplifier 1. The resistor 43 is connected through a resistor 47 to the input circuit of an amplifier 49. The output circuit of the amplifier 49 is connected to the motor 19. A D.-C. source 51 is connected through a variable resistor 53 and a meter 55 across the resistor 47.

Referring to Fig. 2, each of the phase detectors 21 and 25 comprise a pair of diodes 57 and 59 connected between a center tapped inductor 61 and a center tapped resistor 63. The input circuit 67 is connected to a phase inverter 69. The output of the phase inverter 69 is applied across the inductor 61. In order to prevent variations in phase shift through the phase inverter with variations in frequency, the load resistor 71 is of very low resistance. This may provide a gain through the phase inverter of less than unity. The diode 59 is connected to the input circuit 67 through an adjustable voltage divider 73 to permit balancing of the output of the phase inverter. A capacitor 75 is provided between the input circuit 67 and the control grid of the phase inverter tube 69. The capacitor 75, in conjunction with the resistance of the voltage divider 73, provides substantially a 90 degree phase shift of the input to the circuit 67.

The operation of the phase shifters shown in Fig. 2 is as follows:

When the voltage applied to the input circuit 65 between the center taps of the elements 61 and 63 is positive at the same instant that the anode

of the diode 57 is positive, and that of the diode 59 is negative, the diode 57 will conduct during one-half of each cycle and the diode 59 will not conduct. This causes the upper end of the resistor 63 to become positive with respect to the lower end. Conversely when the voltage between the center taps or the voltage across the inductor 61 is reversed, the lower end of the resistor 63 becomes positive. When the two voltages are 90 degrees out of phase the voltage across the upper half of the resistor 63 is equal and opposite to that across the lower half so that the resultant output voltage is zero. The phase shifting network in the input circuit of the phase inverter 69 causes the device to provide zero output when the two input voltages are in phase or 180 degrees out of phase, and maximum output when the two voltages are 90 degrees out of phase, with a polarity depending upon which of the two input voltages leads the other.

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

The power amplifier circuit is tuned approximately to resonance by means of the capacitor 7 through the mechanical connections 13 to the tuning elements of the preceding stages. The antenna circuit is similarly brought to a rough approximation of its proper adjustment by means of the capacitor 11. The phase detector 21 responds to the voltage in the grid and anode circuits of the tube 1, providing direct current output related in its magnitude and in its polarity to deviation of the output voltage from a phase 180 degrees different from that of the input voltage. This D.-C. voltage controls the amplifier 23, which controls the power to the motor 15. Thus the motor is energized to run in the proper direction to make the anode voltage exactly 180 degrees out of phase with the grid voltage by adjustment of the capacitor 9. Under this condition the plate current and the plate voltage of the power amplifier are in phase, and the tank circuit is properly tuned.

The phase detector 25 compares the tank circuit voltage with the voltage across the capacitor 27. Since at the beginning of the adjustment cycle there may be insufficient voltage appearing at the capacitor 27, due to drastic mistuning of the antenna circuit, the motor 17 is normally connected through the contact 37 of the relay 31 to the power supply. This causes the motor 17 to run continuously, driving the inductor 5 to change the antenna circuit tuning until some voltage does appear across the capacitor 27. When this occurs the relay winding 41 is energized through the rectifier 39, transferring the connections of the motor 17 to the output circuit of the amplifier 29. The motor 17 is then operated under the control of the phase detector 25 to adjust the antenna circuit to resonance.

The coupling between the primary and secondary of the transformer 3 is adjusted by the motor 19 in response to the output of the amplifier 49. The voltage drop across the cathode resistor of the power amplifier 1 is proportional to the amplifier plate current. The D.-C. source 51 provides a current through the resistor 47, causing a voltage drop which opposes the voltage across the resistor 43. The drop in the resistor 47 is adjusted to a predetermined value corresponding to the rated plate current of the amplifier 1 by means of the variable resistor 53 and the meter 55. Thus when plate current of the amplifier is greater than the proper value, a positive voltage is applied to the input of the

amplifier 49, and when the plate current is less than the rated value, a negative voltage is applied to the amplifier 49.

For example, the tuning of the power amplifier plate circuit may be controlled by varying either the capacitance, as shown, or the inductance. Magnetic coupling to the antenna circuit is described in the illustrative embodiment of Fig. 1, but any coupling circuit with an adjustable mutual impedance may be used. Any known phase detector circuit may be substituted for that shown in Fig. 2, depending upon particular design requirements. In the above described system, the power amplifier is tuned approximately by gang connections to the exciter, and the antenna circuit control "searches" for rough tuning. It will be apparent to those skilled in the art that either of these methods may be applied to any of the tunable circuits, and that the rough tuning may be omitted providing the phase detectors are designed to operate over the necessary range. The rotation of the motor 19 is controlled in such a direction as to adjust the coupling of a transformer 3 to the correct value.

It is to be understood that the above described adjustments are made concurrently so that if there is any interaction, each is altered slightly to make the necessary correction until the proper phase and current relations are secured. The motors 15, 17 and 19 may be interconnected with the respective amplifiers 23, 29 and 49 in known manner to prevent "hunting," or overshooting and reversal.

For clarity in description independent motors and servo amplifiers have been illustrated. However a single motor may be used with clutch connections to the various tuning elements for sequential adjustment of several stages. Referring to Fig. 3, a single motor 77 is mechanically connected as indicated by the dash line 79 to a plurality of electro-magnetic clutches 81, 83, 85 and 87. The clutch 81 is connected to the exciter tuning control, the clutch 83 is connected to the power amplifier output circuit tuning control, the clutch 85 is connected to the antenna coupling control and the clutch 87 is connected to the antenna tuning control. Phase detectors 89, 91 and 93 are connected to the exciter power amplifier and antenna circuit respectively, and a D.-C. comparison circuit 95 is connected to the power amplifier, as in the arrangement of Fig. 1. The output circuits of the phase detectors 89, 91, 93 and the comparison circuit 95 are connected to a multiple circuit switch 97 in the input circuit of a servo amplifier 99. A second multiple circuit switch 101 is mechanically ganged with the switch 97 and connected to the clutches 81, 83, 85 and 87. A D.-C. source 103 is connected to the movable contact of the switch 101.

As the D.-C. source 103 is connected through the switch 101 to one of the magnetic clutches, for example, the clutch 81, the input circuit of the amplifier 99 is connected through the switch 97 to the corresponding control device, in this case the phase detector 89. The motor 77 will then operate in the same manner as the system of Fig. 1 to adjust the tuning of the exciter stage. Upon completion of the adjustment of the exciter tuning the switches 97 and 101 are moved to their next position, engaging the clutch 83 and connecting the phase detector 91 to the servo amplifier. This operation is continued down the line, each clutch being engaged in turn until all the adjustments are completed. The switches 97 and

101 may be operated manually, or automatically by means of a stepping magnet 105 constructed similarly to the stepping switch used in automatic telephone exchanges. In the system of Fig. 3, the magnet 105 is energized from the D.-C. source 103 through a relay 107. The actuating coil of the relay 107 is connected to the output of the servo amplifier 77. Thus as long as there is any output from the amplifier 99 the contacts of the relay 107 are held open and the magnet 105 is deenergized. When adjustment of any stage is completed, the output of the servo amplifier falls to zero and the relay 107 is deenergized, connecting the source 103 to the magnet 105 and actuating the switches 97 and 101 through one step to connect the next following stage of the transmitter. A limit switch may be operated by the stepping magnet 85 to deenergize the magnet after the adjustment of the last stage is completed.

We claim as our invention:

1. In combination with a radio transmitter including a power amplifier, driver amplifiers, a frequency determining oscillator and an antenna circuit, at least one variable reactance element in the plate circuit of said power amplifier, a motor arranged to vary the reactance of said element, a source of energy for said motor, control means connected between said source and said motor for controlling said motor in response to the difference in phase between the input and the output of said power amplifier, at least one variable reactance element and a further reactance element in said antenna circuit, a second motor arranged to vary said antenna circuit variable reactance element in response to the difference in phase between the output voltage of said power amplifier and the voltage appearing across said further antenna circuit reactance element, and a third motor arranged to vary the coupling between the output circuit of said power amplifier and said antenna circuit in response to the deviation of the plate current of said power amplifier from a predetermined value.

2. In a radio transmitter including an output tube, a power output circuit, an antenna circuit coupled to said output circuit, and mechanically operable means for varying the coupling between said circuits, a motor connected to said mechanically operable means, and plate current responsive means connected to said output tube for controlling the energization of said motor to increase said coupling in response to the deviation of the

plate current of said tube below a predetermined value, and to decrease said coupling in response to deviation of said plate current above said predetermined value.

3. In combination with a radio transmitter including a plurality of adjustable resonant circuit elements, independent means responsive to the tuning of each of said elements, an electric motor, independent clutch means connected between said motor and each of said adjustable elements, a control amplifier connected to energize said motor, multiple circuit multiple position switch means connected between the input circuit of said control amplifier and each of said tuning responsive means so as to connect, in each position, said input circuit to a respective one of said tuning responsive means, a second multiple circuit multiple position switch connected between a source of energy and each of said clutch means so as to connect, in each position, said source of energy to a respective one of said clutch means, and a mechanical connection between said switches, whereby upon actuation of said switches said resonant circuit elements are connected in sequence to said motor while said tuning responsive elements are connected in the same sequence to said control amplifier.

4. A radio transmitter comprising a plurality of cascaded stages, each including at least one tunable circuit element and means responsive to the tuning of said element, a control amplifier including an input circuit and an output circuit, a multiple position switch in said input circuit for sequentially and selectively connecting said tuning responsive means to said input circuit, a motor connected to said output circuit to be energized thereby in accordance with the input to said amplifier, selectively operable clutch means connected between said motor and each of said adjustable resonant elements, and multiple position switch means for selectively and sequentially engaging said clutches.

5. The invention as set forth in claim 3 including means for actuating said switches step by step from one position to another, a source of energy for said actuating means, and means responsive to output from said control amplifier to disconnect said actuating means from said source of energy, whereby said switches are actuated only upon deenergization of said motor.

OLIVER B. CUNNINGHAM.
HARRY SUSSMAN.
SAMUEL GUBIN.