May 9, 1933. C. W. HANSELL 1,907,965

AUTOMATIC TUNING

Filed Nov. 1, 1927

Fig. 1

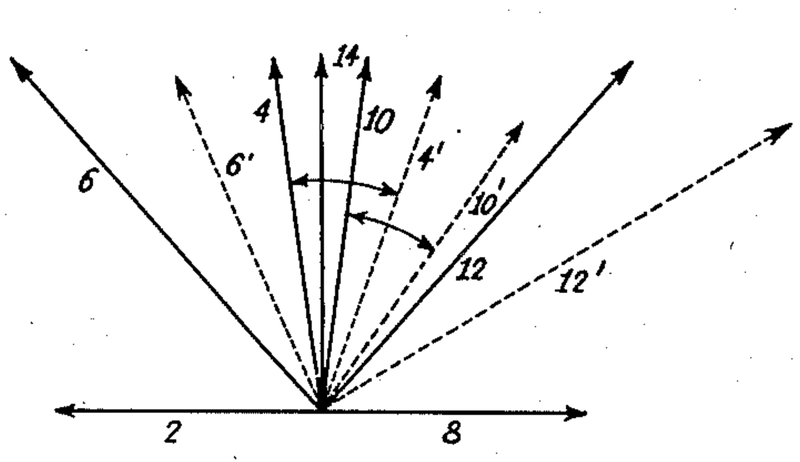


Fig. 3

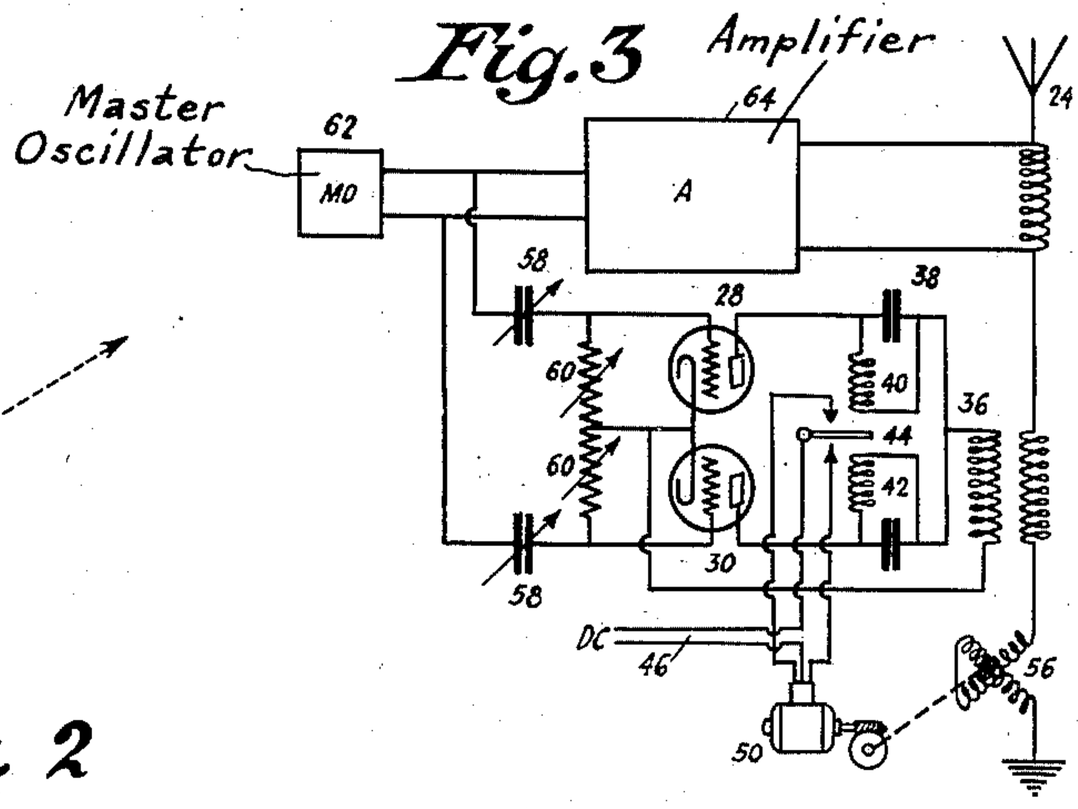


Fig. 2

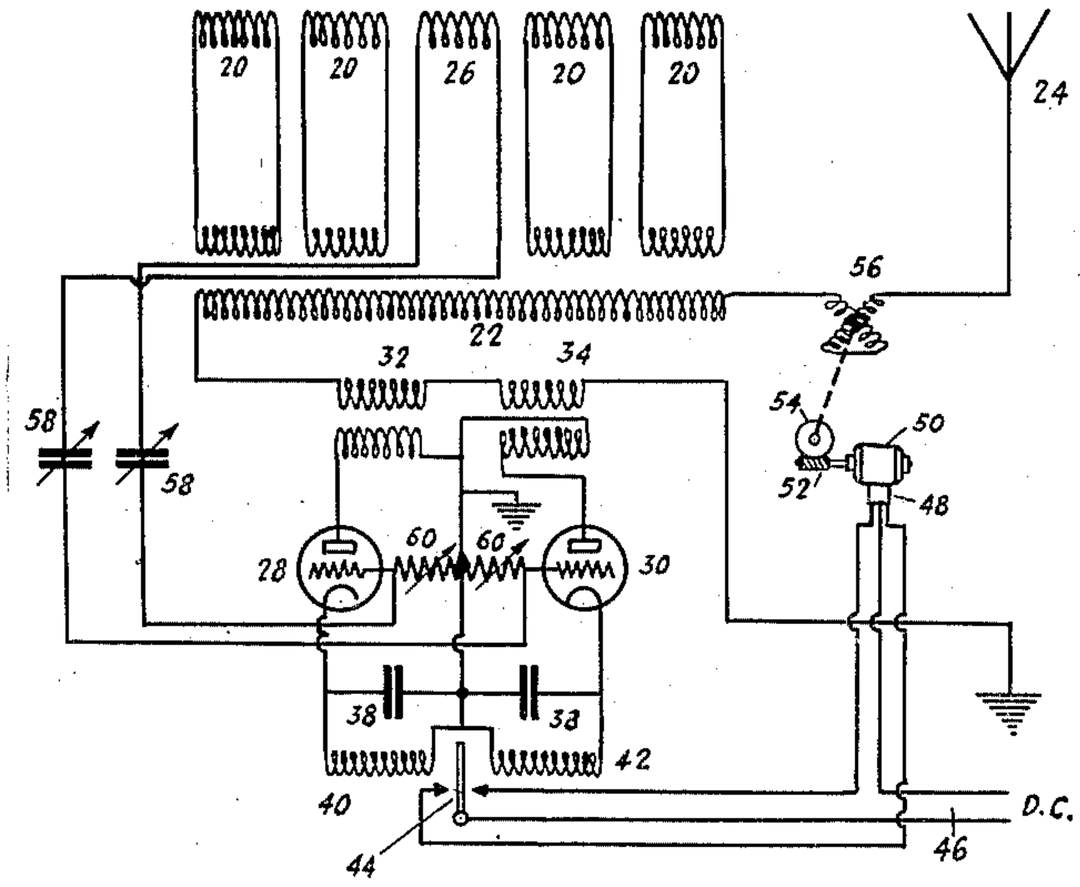
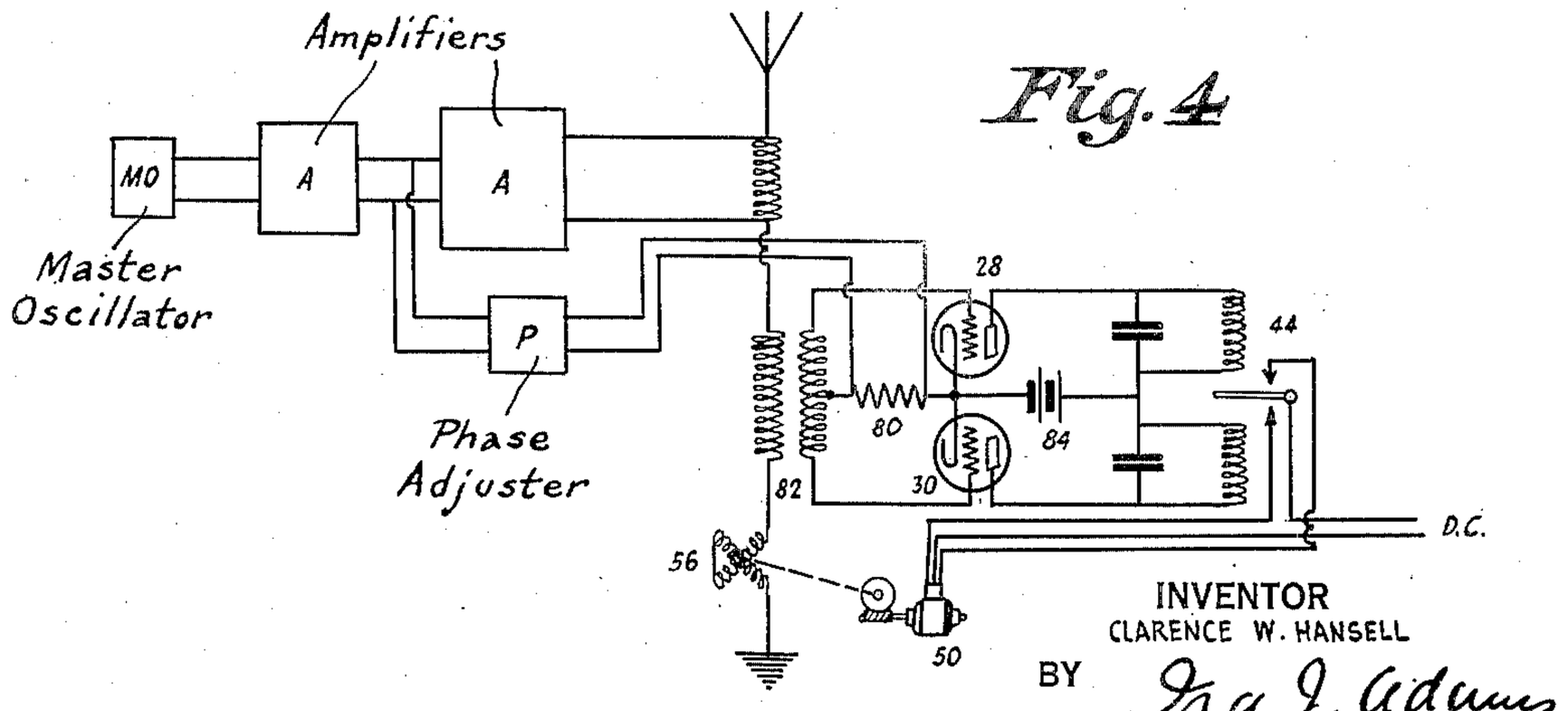


Fig. 4



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UNITED STATES PATENT OFFICE

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AUTOMATIC TUNING

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This invention relates to automatic tuning, and more particularly to automatic tuning of an antenna circuit to keep it in tune with the transmitter coupled thereto.

It often happens that a circuit and its source of energy drift relatively out of tune. In some cases the frequency of a transmitter may vary slightly, due to changes in temperature or of the applied input voltage or other factors, and the tuning of the antenna circuit should be varied to keep it in tune. In the case of an antenna circuit frequency drift may be caused by swaying of the antenna conductors in wind, with a resulting change in the capacitance of the antenna. In such case the transmitter may be considered to be a source of constant frequency, and the problem is to so vary a tuning reactance in the antenna circuit as to maintain constant frequency. Otherwise expressed, the circuit should follow the frequency variations of its source of energy even in the special case when the variation is zero.

Accordingly, it is an object of my invention to provide means for automatically varying the resonance frequency of a circuit to follow variations in the frequency of the energy supplied to it. To do this I take advantage of the phase displacement between the current in the circuit and the potential applied thereto which results from detuning by combining a portion of the supplied energy with a portion of the energy in the circuit at a desired phase displacement, preferably quadrature, when the tuning is correct, and simultaneously combining a similar portion of the supplied energy with a similar portion of the energy in the circuit at an approximately similar phase displacement in opposite sense. In this way the phase shift caused by incorrect tuning makes the phase displacements differ, for one is increased while the other is decreased. By then comparing the resulting energies their difference may be used to vary the tuning of the circuit in that direction which lessens the difference.

The control mechanism, in simplest form may comprise a differential relay which actuates a reversing motor which varies a tuning variometer. For combining the comparison energies, which may best be in the form of potential from the source and current from the circuit, and to provide an average current for actuating a differential relay, the combining means may conveniently be electron emission tubes, and in such case the apparatus comprises a pair of electron emission tubes, means coupling the source to a pair of like electrodes of the tubes, preferably the control electrodes, in series, means coupling the circuit to a pair of like electrodes of the tubes, preferably the anodes, in parallel, with a desired phase displacement, preferably 90°, and a differential relay in the anode circuits of the tubes for controlling the tuning of the circuit.

In the case of a high frequency alternator experience shows that the operation is more stable if the antenna is kept tuned to a frequency slightly higher than that generated by the alternator. In such case the control should maintain a desired relation between resonance frequency of a circuit and the frequency of energy supplied thereto, the relation being not necessarily unity. To attain this I adjust the phase of all of the energy supplied from either the source or the circuit. This makes apparent zero phase displacement occur when in actuality there is existent the desired phase displacement.

The invention is described more in detal in the following specification which is accompanied by drawing in which

Figure 1 is a vector diagram explanatory of my invention;

Figure 2 is a wiring diagram of my invention as applied to an alternator;

Figure 3 represents the invention applied to a vacuum tube transmitter; and

Figure 4 is a modification showing the transmitter and antenna energies combined on the control electrodes of the tubes.

Referring to Figure 1, vector 2 represents a portion of energy taken from the source, and vector 4 is a portion of energy taken from the circuit, these differing in phase by a desired amount. They combine to a resultant which may be represented by the vector 6. Similarly the vector 8 represents another portion of energy taken from the source,

which combines with a vector 10 representing another portion of energy taken from the circuit to effect a resultant vector 12, these vectors differing in phase from the aforementioned vectors by an equal amount but in opposite sense. Detuning of the circuit causes the phase relation between the current therein and the source to shift in one direction or the other, according as the circuit becomes capacitive or inductive. This shift affects the vectors 4 and 10 in the same direction, resulting in new positions 4′ and 10′, as a random instance. The resultant vectors, instead of being 6 and 12, which are equal, will become 6′ and 12′, which are unequal. In the special case in which the phase displacements between the vectors 2 and 4, and 8 and 10, are quadrature, the vectors 4 and 10 will merge to form a single vector 14.

Attention is now directed to Figure 2, in which the alternator coils of an Alexanderson alternator are represented by the numeral 20. These are coupled in series for potential addition with an alternator collector transformer 22 which feeds the antenna 24. In the alternator there is provided an extra coil 26, or one of the regular coils may be used, the potential cross which is in phase with the potential of the alternator. From this coil 26 a portion of the alternator energy is applied to the grids of the tubes 28 and 30 in series, or phase opposition.

In the antenna circuit there are provided radio frequency transformers 32 and 34, which are coupled to the anode circuits of the tubes by means of the transformer secondaries, the connections to one of which are reversed so that, in effect, a portion of the energy of the circuit is coupled to the tubes in parallel. The series connection of the grids causes their energization to be in phase opposition, that is, causes the vectors 2 and 8 in Figure 1 to lie in opposite directions. The parallel connection to the anodes causes the anode excitation to be cophasial, and because of the 90° phase displacement introduced by the radio frequency transformers 32 and 34, the antenna energization is in quadrature, as is represented by the vector 14 in Figure 1.

In the anode circuits there are connected in parallel the by-pass condensers 38 and the coils 40 and 42 of a differential relay, the armature 44 of which is adapted to close the circuit from a direct current supply 46 to either side of a relay 48 which reverses the reversing motor 50. This is arranged through a worm 52 and worm gear 54 to rotate a variometer 56 in order to vary the tuning of the antenna.

If it is desired to have the resonance frequency of the antenna circuit differ from that of the alternator it is only necessary to cause an appropriate anticipatory shift in the phase of either the alternator portion or the antenna portion of the comparison energy. To do this there are coupled variable condensers 58 and variable resistances 60 by the adjustment of the magnitude of which the phase of the alternator portion of energy may be suitably displaced.

In Figure 3 the transmitter is a vacuum tube oscillator comprising a master oscillator 62 for controlling the frequency in a power amplifier 64 the output from which is radiated by an antenna 24. The antenna circuit is coupled to the anodes of the tubes 28 and 30 by means of a single radio frequency transformer 36, but this is located in the common anode lead, so that the coupling, as before, is in parallel. In the anode circuits there are provided the coils 40 and 42 of a differential relay, by-passed by the condensers 38. The relay coils are arranged to differentially actuate an armature 44 which controls current from a direct current source 46 to a reversing motor 50 which adjusts the setting of a variometer 56.

The control electrode circuit is also similar to that shown in Figure 2 except that the portion of transmitter energy is tapped from the output of the master oscillator, instead of being obtained from a separate coil, as in the case of an alternator. This energy may equally well be obtained from one of the stages of the power amplifier.

In Figure 4 there is illustrated an alternative method for obtaining the desired phase relations between the antenna and transmitter portions of energy. The transmitter portion of energy is applied to the tube grids in parallel, instead of in series, across the resistance 80. The antenna energy is also applied to the grids, rather than to the anodes of the tubes, as in Figures 2 and 3, and in series, instead of in parallel. The coupling is through a radio frequency transformer 82, and such transformers usually have so high a leakage reactance that a phase change of almost 90° takes place.

In this respect it might be well to point out that the terms "quadrature", and "like phase displacement", referring to the vectors 4, 10 and 14, in Figure 1, are to be construed liberally. Thus, with the arrangement shown in Figure 4 the vectors 4 and 10 may coincide and be displaced from the vector 14, and yet the system is perfectly operative, the initial inequality being compensated by biasing the loading of the differential relay, or by adjustment of the phase of one of the energies.

Other differences illustrated by the modification shown in Figure 4 are that the phase adjusting means P is indicated more broadly, and may be a split phase goniometer, for example; that the comparison energy from the transmitter is taken from an intermediate power amplifier stage; and that the anode circuits of the tubes 28 and 30 are energized

from a direct current source 84. In this connection it should be noticed that also in the modifications shown in Figures 2 and 3 a B battery may be used to augment the relay currents.

I claim:

1. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, means for combining a portion of the energy in the circuit at a desired phase displacement when the desired frequency relation exists, means for combining a portion of the energy from the source with a portion of the energy in the circuit at a desired phase displacement in opposite sense, means to differentially compare the magnitudes of the resulting energies, an electromechanical relay responsive to the difference in energies, and an electromechanical device, responsive to the action of said relay for varying the tuning of the circuit in that direction which lessens the difference.

2. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to a like pair of electrodes of the tubes in one manner, means coupling the circuit to a like pair of electrodes of the tubes in another manner, respectively, with a desired phase displacement, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

3. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

4. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a desired phase displacement, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

5. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, an electromagnetic relay responsive to the difference in the anode currents and an electromechanical device, responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

6. An arrangement for automatically maintaining a desired relation between the resonance frequency of an antenna circuit and the frequency of energy supplied thereto comprising a transmitter, an antenna circuit supplied thereby, a pair of electron emission tubes, means coupling the transmitter to the control electrodes of the tubes in series, means coupling the antenna circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, an electromagnetic relay responsive to the difference in the anode currents and, an electromachanical device, responsive to the action of the relay for varying the tuning of the antenna circuit in that direction which lessens the difference.

7. An arrangement for automatically maintaining a desired relation between the resonance frequency of an antenna circuit and the frequency of energy supplied thereto comprising a transmitter, an antenna circuit supplied thereby, a pair of electron emission tubes, means coupling the transmitter to the control electrodes of the tubes in series, means coupling the antenna circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, a differential electromagnetic relay in the anode circuits of the tubes, a variable reactance in the antenna circuit, and electro-mechanical means responsive to the differential relay for varying the reactance in that direction which corrects the frequency relation.

8. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to a like pair of electrodes of the tubes in series, means cou-

pling the circuit to a like pair of electrodes of the tubes in parallel, respectively, with a desired phase displacement, phase adjusting means in one of the coupling circuits for adjusting the frequency relation, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

9. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a desired phase displacement, phase adjusting means in one of the coupling circuits for adjusting the frequency relation, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

10. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a desired phase displacement, phase adjusting means in the control electrode coupling circuit comprising series reactance and resistance for adjusting the frequency relation, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

11. An arrangement for automatically maintaining a desired relation between the resonance frequency of an antenna circuit and the frequency of energy supplied thereto comprising a transmitter, an antenna circuit supplied thereby, a pair of electron emission tubes, means coupling the transmitter to the control electrodes of the tubes in series, means coupling the antenna circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, a differential electromagnetic relay in the anode circuits of the tubes, a variable reactance in the antenna circuit, electro-mechanical means responsive to the differential relay for varying the reactance in that direction which corrects the frequency relation, and phase adjusting means in the control electrode coupling circuit comprising series reactance and resistance for adjusting the frequency relation.

12. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to a like pair of electrodes of the tubes in parallel, means coupling the circuit to a like pair of electrodes of the tubes in series, respectively, with a desired phase displacement, phase adjusting means in one of the coupling circuits for adjusting the frequency relation, an electromagnetic relay responsive to the difference in the anode currents and, an electromechanical device responsive to the action of the relay for varying the tuning of the circuit in that direction which lessens the difference.

13. The method of automatically maintaining a desired relation other than an equal relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto which includes combining a portion of the supplied energy with a portion of the energy in the circuit at a desired phase displacement when the desired frequency relation exists, simultaneously combining a portion of the supplied energy with a portion of the energy in the circuit at a desired phase displacement in opposite sense, whereby the phase shift caused by a change in the frequency makes the phase displacements differ, comparing the resulting energies, and using their difference to vary the tuning of the circuit in that direction which lessens the difference.

14. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, means for combining a portion of the energy in the circuit at a desired phase displacement when the desired frequency relation exists, means for combining a portion of the energy from the source with a portion o fthe energy in the circuit at a desired phase displacement in opposite sense, means to differentially compare the magnitudes of the resulting energies, and means responsive to their difference for varying the tuning of the circuit in that direction which lessens the difference.

15. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to a like pair of electrodes of the tubes in one manner, means coupling the circuit to a like pair of electrodes of the tubes in another manner, re-

spectively, with a desired phase displacement, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

16. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

17. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a desired phase displacement, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

18. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

19. An arrangement for automatically maintaining a desired relation between the resonance frequency of an antenna circuit and the frequency of energy supplied thereto comprising a transmitter, an antenna circuit supplied thereby, a pair of electron emission tubes, means coupling the transmitter to the control electrodes of the tubes in series, means coupling the antenna circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, and means responsive to the difference in the anode currents for varying the tuning of the antenna circuit in that direction which lessens the difference.

20. An arrangement for automatically maintaining a desired relation between the resonance frequency of an antenna circuit and the frequency of energy supplied thereto comprising a transmitter, an antenna circuit supplied thereby, a pair of electron emission tubes, means coupling the transmitter to the control electrodes of the tubes in series, means coupling the antenna circuit to the anodes of the tubes in parallel with a desired phase displacement in quadrature, and means responsive to the difference in the anode currents for varying the tuning of the antenna circuit in that direction which lessens the difference.

21. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to a like pair of electrodes of the tubes in series, means coupling the circuit to a like pair of electrodes of the tubes in parallel, respectively, with a desired phase displacement, phase adjusting means in one of the coupling circuits for adjusting the frequency relation, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

22. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a desired phase displacement, phase adjusting means in one of the coupling circuits for adjusting the frequency relation, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

23. An arrangement for automatically maintaining a desired relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto comprising a source of energy, a circuit supplied thereby, a pair of electron emission tubes, means coupling the source to the control electrodes of the tubes in series, means coupling the circuit to the anodes of the tubes in parallel with a desired phase displacement, phase adjusting means in the control electrode coupling circuit comprising series reactance and resistance for adjusting the frequency relation, and means responsive to the difference in the anode currents for varying the tuning of the circuit in that direction which lessens the difference.

24. An arrangement for automatically maintaining a desired relation between the resonance frequency of an antenna circuit

and the frequency of energy supplied thereto comprising a transmitter, an antenna circuit supplied thereby, a pair of electron emission tubes, means coupling the transmitter to the control electrodes of the tubes in series, means coupling the antenna circuit to the anodes of the tubes in parallel with a phase displacement in quadrature, a differential relay in the anode circuits of the tubes, a variable reactance in the antenna circuit, means responsive to the differential relay of varying the reactance in that direction which corrects the frequency relation, and phase adjusting means in the control electrode coupling circuit comprising series reactance and resistance for adjusting the frequency relation.

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