

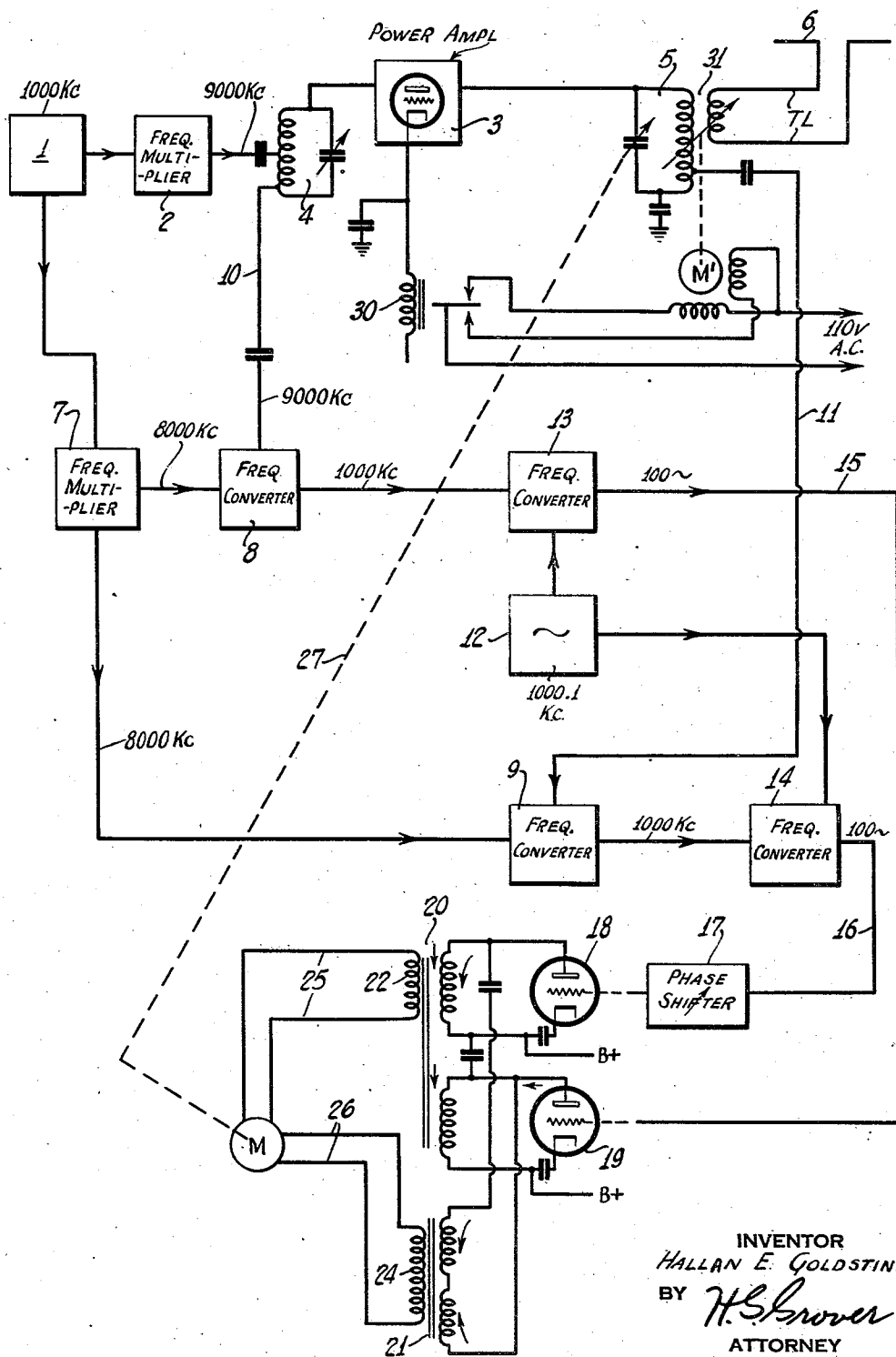
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AUTOMATIC CIRCUIT TUNING

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AUTOMATIC CIRCUIT TUNING

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The present invention, broadly stated, comprises an automatic tuning system for assuring the proper phase relation between the input and output voltages of an electron discharge device.

The invention is described hereinafter with particular reference to a radio transmitter. In high power radio transmitters, it is important for the plate tank circuit (oscillatory circuit) of the power amplifier to be correctly maintained in resonance. Often, there is provided a long transmission line which extends from the plate tank circuit of the power amplifier to the antenna for feeding energy to the antenna. If the impedance of the transmission line or antenna changes due to climatic conditions such as rain, snow, sleet, wind, etc., the loading on the transmitter will also change and this condition will reflect an impedance upon the transmitter which will change the tuning of the plate tank circuit of the power amplifier from its correct value. Such an undesired change in the tuning of the power amplifier is, in effect, a change in the phase of the output voltage with respect to the input voltage, and may cause a large increase in the plate current of the amplifier with consequent damage to the electron discharge device.

The present invention overcomes the foregoing difficulties by providing a system which automatically tunes the tank circuit of the power amplifier, or of any other desired vacuum tube stage, in order to maintain the phase of the plate voltage at the correct relation to the grid voltage. In this way I am able to prevent undesired energy losses in the plate circuit of the tube and maintain the operation of the system at high efficiency.

An important feature of the invention resides in an arrangement which utilizes the same standard oscillator furnishing the basic frequency for the transmitter for providing a lower frequency which serves, in a way described in more detail later, to energize a motor in order to restore the tuning to its correct value. This arrangement requires the use of a heterodyne oscillator and enables me to standardize all of the low frequency apparatus.

A description of the invention follows in conjunction with a drawing whose single figure illustrates an embodiment of the invention, applied to a high power radio transmitter.

Referring to the drawing, there is shown (diagrammatically only) a high power radio transmitter comprising a crystal oscillator 1, a frequency multiplier 2, a power amplifier 3 having an input tank circuit 4 and an output tank circuit 5, and a transmission line TL coupled to the tank

circuit 5 and feeding energy to a remote antenna 6. Only those parts of the transmitter have been shown which are essential to an understanding of the principles of the invention. For purposes of exposition only, let us assume that the crystal oscillator 1 generates stable oscillations of 1000 kilocycles, and that the frequency multiplier 2 multiplies the output of the oscillator to 9000 kilocycles. If the output tank circuit 5 is tuned to resonance (9000 kilocycles), then the plate current of amplifier 3 will be in phase with the voltage on the input grid of the amplifier, and the plate voltage will be 180° out-of-phase with the grid voltage on the same tube. In order to assure this phase relationship, there is provided an automatic tuning system which will now be described.

The crystal frequency of oscillator 1 is multiplied by frequency multiplier 7 to 8000 kilocycles and oscillations of this 8000 kilocycle frequency are supplied to frequency converters or mixers 8 and 9 which receive over leads 10 and 11, respectively, currents from the input and output tank circuits 4 and 5 of power amplifier 3. Since the currents in tanks 8 and 9 have a frequency of 9000 kilocycles, there will be produced in the outputs of these frequency converters currents of a frequency of 1000 kilocycles. A stable heterodyne oscillator 12, preferably a crystal-controlled type, provides currents which beat with the 1000 kilocycle output currents from converters 8 and 9 in additional frequency converters 13 and 14, respectively, to produce audio frequency outputs in leads 15 and 16 of 100 cycles each. One of these 100 cycle currents, here shown as appearing in lead 16, is fed to a phase shifter 17 and then to an audio amplifier 18. The other 100 cycle current in lead 15 is fed to an audio amplifier 19. In the outputs of these audio amplifiers 18 and 19 there are provided a pair of transformers 20 and 21. Transformer 20 is so arranged as to produce in its output coil 22 a voltage which is the vector sum of the voltages applied to the audio amplifiers, while transformer 21 is so arranged as to produce in its output coil 24 a voltage which is the vector difference of the voltages applied to the audio amplifiers. Coils 22 and 24 are coupled by means of leads 25 and 26, respectively, to different coils of a small two-phase reversible motor M whose rotatable armature is linked by a shaft, shown by dash lines 27, to a variable reactance (here shown as the condenser) in the output tank circuit 5. Motor M is used to tune the power amplifier tank circuit 5.

The sum voltage in leads 25 is 90° out-of-phase

with respect to the difference voltage in leads 26. Motor M will run in either of two directions, depending upon the sense in which the output tank circuit is detuned. When the voltages applied to the motor are exactly 180° out-of-phase, there will be no torque developed on the motor due to the absence of a quadrature component, in which case there will be voltage on only one winding of the motor.

The phase shifter 17 serves to control the setting of the tuning of the output tank 5. If there is any undesired difference in phase between the input and output voltages derived from tanks 4 and 5, respectively, we can then compensate for this undesired difference by means of an adjustment in the phase shifter 17.

In the operation of the system, any departure from normal of the phase relation between the voltages in tanks 4 and 5, due to reflections caused by climatic conditions affecting the antenna, will produce a movement in the motor of such sense and magnitude as to restore the phase relation between the voltages in the input and output tank circuits 4 and 5 to normal.

The radio transmitter is also shown supplied with a coupling control feature comprising a plate current relay 30 in the cathode circuit of the power amplifier, and a reversible motor M' linked to the transformer 31. Relay 30 works between desired current maximum and current minimum limits. This motor M' varies the coupling between the antenna load and the output tank circuit 5 to assure constant power output from power amplifier 3. Without this coupling control feature, the power amplifier may always work into a resistive load because of the automatic tuning system but may not work into the optimum or proper load determined by various factors. Motor M' is interlocked in a manner not shown, to insure its operation only after motor M has functioned.

One advantage of the present invention lies in the ease with which the low frequency equipment can be standardized. This is in virtue of the heterodyne circuit which beats the high frequencies down to audio frequencies.

What is claimed is:

1. The method of maintaining a predetermined phase relation between the waves in a pair of cascaded tank circuits tuned to the same frequency which comprises deriving currents from each of said tank circuits, beating said currents with stable frequency oscillations to produce a pair of lower frequency currents of the same frequency combining said lower frequency currents to produce two phase displaced voltages one of which is equal to the vector sum and the other of which is equal to the vector difference of the voltages produced at said lower frequency, and utilizing said two phase displaced voltages to vary the tuning of one of said tank circuits in that direction which will maintain said predetermined phase relation.

2. The method of automatically maintaining a desired phase relation between the resonance frequency of a tuned circuit and the frequency of energy supplied thereto which includes separately mixing current derived from said tuned circuit and current from the energy supplied thereto with oscillations of a stable frequency to produce lower frequency currents, beating said lower frequency currents down to audio frequency currents of the same frequency, combining said audio frequency currents to produce two phase-quadrature displaced voltages one of which is

equal to the vector sum and the other of which is equal to the vector difference of the voltages of the currents at said audio frequency, and utilizing said two phase displaced voltages to vary the tuning of said tuned circuit in that direction which will maintain said desired phase relation.

3. In a system having an electron discharge device and grid input and plate output tuned circuits tuned to the same frequency, an arrangement for automatically maintaining a desired phase relation between the input and output voltages of said electron discharge device, comprising means for separately beating energy derived from said tuned circuits down to currents of the same audio frequency, an audio amplifier for amplifying each of said audio frequency currents, and means including a pair of audio transformers in the output circuits of said amplifiers for obtaining two phase displaced voltages one of which is equal to the vector sum and the other of which is equal to the vector difference of the voltages applied to said audio amplifiers, a two-phase-reversible motor coupled to said transformers, and a mechanical link between the rotatable element of said motor and a variable reactance in one of said tuned circuits for varying the tuning of said one tuned circuit in that direction which will maintain said desired phase relation.

4. In a radio transmitter having a power amplifier, grid input and plate output tuned circuits therefore, and a load coupled to said output tuned circuit, an arrangement for maintaining the output tuned circuit at its resonance frequency despite changes in loading comprising connections extending directly from said input and output circuits to separate frequency converters, means for supplying said converters with stable oscillations to produce in the output circuits of said converters currents of the same but of a lower frequency than those in said tuned circuits, means for combining currents derived from said lower frequency to produce two phase displaced voltages one of which is equal to the vector sum and the other of which is equal to the vector difference of the voltages of said currents, and an electromechanical device responsive to said phase displaced voltages for varying the tuning of said amplifier output tuned circuit in that direction which will maintain it in resonance.

5. In a radio transmitter having a stable oscillator furnishing energy to a power amplifier, input and output tuned circuits for said amplifier, a load including an antenna coupled to said output tuned circuit, an arrangement for maintaining the output tuned circuit at its resonance frequency despite changes in loading comprising connections extending directly from said input and output circuits to separate frequency converters, means for supplying said converters with oscillations derived from said oscillator for producing in the output circuits of said converters currents of the same but of a lower frequency than those in said tuned circuits, additional converters for separately mixing the currents of said lower frequency with additional oscillations of a stable frequency to produce two currents of the same audio frequency, a phase shifter for one of said last two currents for compensating for any undesired difference in phase between the voltages derived from said input and output tuned circuits, and means including an electromechanical device responsive to a change in the phase between said last two currents for varying the tuning of said output tuned circuit in that direction which will maintain it in resonance.

6. In a radio transmitter having a stable oscillator furnishing energy to a power amplifier, input and output tuned circuits for said amplifier, a load including an antenna coupled to said output tuned circuit, an arrangement for maintaining the output tuned circuit at its resonance frequency despite changes in loading comprising connections extending directly from said input and output circuits to separate frequency converters, means for supplying said converters with oscillations derived from said oscillator for producing in the output circuits of said converters currents of the same but of a lower frequency than those in said tuned circuits, additional converters for separately mixing the currents of said lower frequency with additional oscillations of a stable frequency to produce two currents of the same audio frequency, a phase shifter for one of said last two currents, means for combining the audio frequency currents to produce two phase displaced voltages in quadrature one of which is equal to the vector sum and the other of which is equal to the vector difference of the voltages of said audio currents, and an electromechanical device responsive to said phase displaced voltages for varying the tuning of said amplifier output tuned circuit in that direction which will maintain it in resonance.

7. A system in accordance with claim 5, including a frequency multiplier for said transmitter and a frequency multiplier between said stable oscillator and said first converters.

8. The combination with an electron discharge device having grid input and plate output tuned

circuits tuned to the same frequency, of an arrangement for automatically maintaining a desired phase relation between the input and output voltages of said device, comprising means for comparing voltages representative of said input and output voltages and for obtaining two phase displaced voltages one of which is equal to the vector sum and the other of which is equal to the vector difference of said representative voltages, a two-phase reversible motor responsive to said two phase displaced voltages, and a mechanical link between the rotatable element of said motor and a variable reactance in one of said tuned circuits for varying the tuning of said one tuned circuit in that direction which will maintain said desired phase relation.

9. The combination with a vacuum tube amplifier having input and output tuned circuits, one of which is tunable over a range of frequencies, of an arrangement for automatically maintaining a 180° phase relation between the input and output voltages of said vacuum tube amplifier, comprising a reversible motor having its rotatable armature linked to said one tuned circuit for tuning the same in such direction as to restore said 180° phase relation, a pair of field coils for said motor, and means for comparing voltages representative of said input and output voltages and for applying the resultants to said field coils to produce rotation of said motor whenever there is a departure of said voltages from the 180° relation.

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