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AUTOMATIC FREQUENCY CONTROL CIRCUIT

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FIG. 1

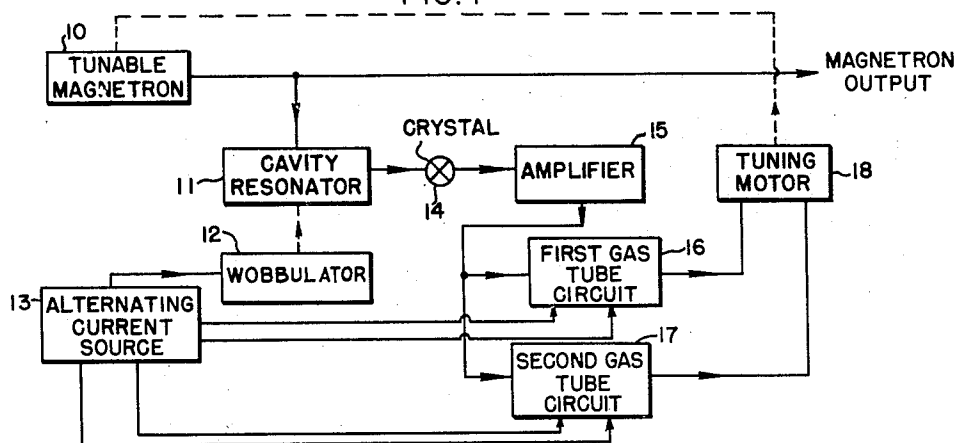


FIG. 3

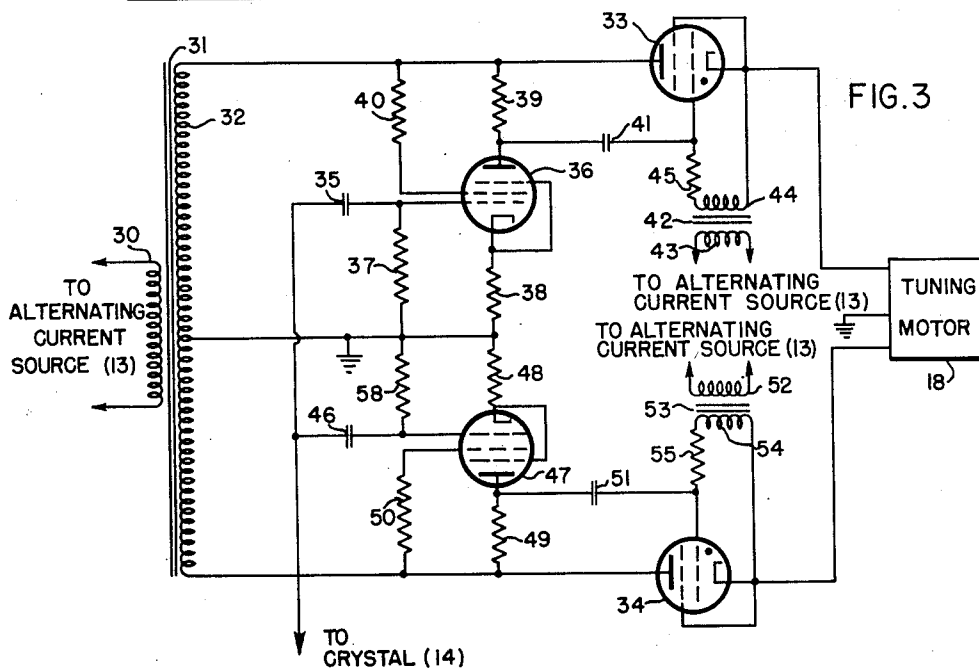
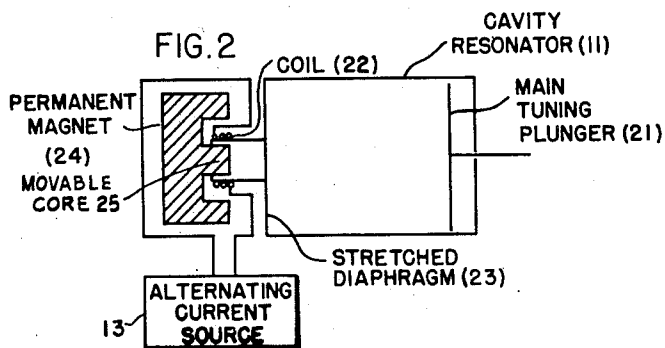


FIG. 2



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AUTOMATIC FREQUENCY CONTROL
CIRCUIT

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6 Claims. (Cl. 250—36)

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This invention relates in general to frequency control system for thermionic tubes having cavity resonators as resonant elements, and more particularly to systems wherein such control is automatic.

For some purposes in communication systems using ultra-high frequencies, the transmitting tubes used are magnetrons employing cavity resonators as resonant elements. Magnetrons of this type have the properties of drifting in frequency as the tube is warming up, and having their frequency changed, or "pulled," with a variation in loading. This frequency pulling is undesirable because it results in the receiver used in the communication system being improperly tuned with respect to the transmitter frequency a large portion of the time. A system commonly used to alleviate this difficulty is one in which the receiver is monitored as to tuning during the warm-up period of the magnetron, and the receiver bandwidth is made wide enough to effectively cover any frequency pulling that may occur afterwards. This system is undesirable in that the former procedure is cumbersome and the latter procedure is expensive in relation to equipment and space requirements.

Among the objects of the present invention, therefore, are:

1. To provide a magnetron capable of being tuned over a range of frequencies; and
2. To provide a control system for automatically keeping the frequency of the magnetron substantially constant.

In accordance with the present invention there is provided a multi-cavity magnetron oscillator with a tuning means embodied therein. A portion of the magnetron output is fed into a reference cavity resonator, which is of such a size and shape as to be resonant at the desired magnetron operating frequency. The resonant frequency of the cavity is periodically varied back and forth about this desired frequency. The cavity output is rectified and fed into a gas tube control circuit providing an output of one polarity if the cavity is tuned below this desired magnetron operating frequency and of the opposite polarity if the cavity is tune above. A D.-C. motor coupled to the gas tube circuit varies the tuning means within the magnetron in such a direction as to keep the magnetron operating at the resonant frequency of the cavity.

This invention will best be understood by reference to the drawings, in which:

Fig. 1 is a block diagram of one embodiment of the present invention;

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Fig. 2 is a functional diagram of the "wobbulator" cavity resonator arrangement used in the system of Fig. 1; and

Fig. 3 is a circuit diagram of one arrangement for controlling the tuning of the magnetron.

Referring now to a description of the invention and to Fig. 1 there is shown a tunable magnetron 10, a portion of the output of which is coupled to a cavity resonator 11. It is assumed that the operating frequency of the magnetron is such that cavity resonators must be used as the resonant elements thereof. Mechanically coupled to cavity 11 is a "wobbulator" 12, which is a device for transforming the alternating electric voltage from source 13 to an alternating periodic mechanical motion in a wall of cavity 11. In this specification, a "wobbulator" will be considered to be a device for performing the above operation.

The output of the cavity 11 is rectified by crystal 14, amplified by amplifier 15 and fed to a first and second gas tube circuit, 16 and 17 respectively, for control voltage forming purposes. Also coupled to control elements of the gas tubes in gas tube circuits 16 and 17 are alternating voltages, two each, from source 13.

The two gas tubes, acting as coincidence tubes, take the several voltages fed thereto and produce control voltages therein which are made to affect the duration of and length of time of rotation of D.-C. tuning motor 18. This motor is coupled to the magnetron tuning means, which varies the operating frequency of the magnetron. This tuning means may be a metallic slug, say, movable in and out of one of the magnetron cavities and so varying the resonant frequency thereof.

Fig. 2 is a functional diagram of the "wobbulator" and cavity resonator arrangement. Cavity 11 is shown with the main tuning plunger 21 situated in one end thereof. This may be a cylindrical cavity operating in the $TE_{0,1,1}$ mode, in which case the movement of the plunger 21 in a horizontal plane may alter the resonant frequency of the cavity appreciably. An alternating voltage from source 13 (see Fig. 1) is fed to a coil 22 wound about a movable core 25 that is rigidly coupled mechanically to one end 23 of cavity 11, this end 23 being a flexible diaphragm. Permanent magnet 24 is situated so that the field therefrom is fixed in position and envelops the moving coil 22.

Fig. 3 is a circuit diagram of the control circuit embodying the amplifier 15 and gas tube circuits 16 and 17. The voltage from alternating current source 13 is coupled to the primary winding 30

of transformer 31. One half of the secondary winding 32 of the transformer completes its circuit through tetrode gas tube 33 and tuning motor 18. The other half of the secondary winding 32 of the transformer completes its circuit through tetrode gas tube 34 and tuning motor 18. This center tap of this secondary winding is grounded. The connections to the tuning motor are such that current through the circuit of gas tube 33 will cause the tuning motor to turn in one direction, and current through gas tube 34 circuit will give a rotation in the other direction.

The rectified output of crystal 14 is coupled through condenser 35 to the control grid of amplifier tube 36 and developed across grid-leak resistor 37. The cathode of tube 36 is connected to ground through resistor 38, and the plate of the tube is connected to one end of the secondary winding 32 of the transformer through load resistor 39. The suppressor grid is connected to the cathode and the screen grid is returned to one end of the secondary winding 32 through screen dropping resistor 40.

The plate of this amplifier tube 36 is coupled through condenser 41 to the first grid of tetrode gas tube 33. The alternating voltage from source 13 is connected to the primary winding 43 of transformer 42, the secondary winding 44 of which is connected through resistor 45 between first grid and cathode of tube 33. The second grid of gas tube 33 is connected directly to the cathode.

The rectified output of the crystal 14 is also coupled through condenser 46 to the control grid of amplifier tube 47 and developed across grid-leak resistor 58. The cathode of tube 47 is connected to ground through resistor 48, and the plate of this tube is connected to the other end of the secondary winding 32 of the transformer through load resistor 49. The suppressor grid is connected to the cathode and the screen grid is returned to this same end of the secondary winding 32 through screen dropping resistor 50.

The plate of this amplifier tube 47 is coupled through condenser 51 to the first grid of tetrode gas tube 34. The alternating voltage from source 13 is connected to the primary winding 52 of transformer 53, the secondary winding 54 of which is connected through resistor 55 between first grid and cathode of tube 34. The second grid of gas tube 34 is connected directly to the cathode.

Referring now to the operation of the system and to Fig. 1, the general operation will first be discussed. A portion of the output from magnetron 10 is coupled into cavity resonator 11. This cavity is quiescently tuned to the desired operating frequency of the magnetron, and the resonant frequency is periodically varied or "wobulated" about this desired center frequency by the "wobulator" 12, which is synchronized by the voltage from the alternating current source 13.

The cavity 11 produces a large output when its resonant frequency passes through the operating frequency of the magnetron. This output is rectified by crystal 14 and fed to amplifier 15. One of the gas tube circuits, say circuit 16, now conducts and couples the energy from the amplifier 15 to the tuning motor 18. Gas tube circuits 16 and 17 are synchronized by the sine wave voltage from source 13 in such a manner that during the time the resonant frequency of the cavity 11 is below its quiescent resonant frequency, gas tube circuit 16, say, is held cut off by

the negative cycle of the sine wave impressed on its grid. When the cavity passes through the operating frequency of the magnetron, therefore, there will be a large output from cavity 11 and the output from amplifier 15 will be coupled to the tuning motor through gas tube 16. Similarly, when the "wobulator" 12 causes the resonant frequency of the cavity 11 to be above the quiescent resonant frequency, gas tube 17, say, is held cut off. In both cases the direction of rotation of the tuning motor is such that the tuning slug, say, which it controls moves so that the operating frequency of the magnetron is brought nearer to the quiescent resonant frequency of the cavity 11. Any type of mechanical tuning means may be used in conjunction with this system, the arrangement not being limited to the use of a tuning slug.

The "wobulator" which is illustrated schematically in Fig. 2 operates as follows. The cavity resonator 11, shown in the side view, may be cylindrical in shape and operating in the $TE_{0,1,1}$ mode. The main tuning plunger 21 is positioned so that the resonant frequency of the cavity is equal to the desired operating frequency of the magnetron. The whole of the opposite end of the cavity to that into which the tuning plunger is placed may consist of a flexible diaphragm 23. Rigidly mechanically coupled to this diaphragm is a movable core 25, around which is wound coil 22, through which passes alternating current from source 13. The alternating magnetic field produced by the current in coil 22 reacts with the fixed magnetic field from permanent magnet 24. The result is the oscillation, at the frequency of the alternating current from source 13, of the movable core 25 and so of the diaphragm 23. The resonant frequency of the cavity thus oscillates on a frequency axis about the quiescent cavity resonant frequency. In one arrangement, the frequency of the alternating current source was 60 cycles per second, and the diaphragm was constructed with a mechanical resonant frequency much greater than 60 cycles per second.

The circuit of Fig. 3 is one possible means to allow the output from the crystal to be transferred into an electronic control voltage for the tuning motor. It is seen that the secondary winding of transformer 31 may be thought of as a push-pull source of power for two separate circuits. One circuit embodies the upper half of the secondary winding 32, the gas tube 33 and the tuning motor 18, being completed through ground. The other circuit consists of the lower half of the secondary winding 32, the gas tube 34 and the tuning motor 18, being completed through ground.

The alternating voltage on the control grid of the gas tube 33 is made to be 180° out of phase with the alternating voltage on the plate of this tube. This voltage is coupled to gas tube 34 in a similar out of phase manner.

The operation of this particular part of the invention will now be explained by means of an example. Let us suppose that during the time the "wobulator" causes the cavity resonant frequency to be below the quiescent cavity frequency the alternating voltage on the plate of tube 33 will be positive, and the voltage on the grid of tube 33 will be negative, with respect to the cathode. The tube is thus held in a cut off condition. Let it further be presumed that the magnetron is operating at a frequency which is below the cavity quiescent frequency and around the time when the resonant frequency of the cavity is

brought to the operating frequency of the magnetron, the cavity producing a relatively strong output, which is rectified by the crystal and fed to both amplifier tubes 36 and 47. This energy cannot pass through tube 47 because the plate is at a lower potential than the cathode, but the energy is amplified by tube 36 and coupled to the grid of gas tube 33. The grid voltage is now brought up to a sufficient value to turn this tube on, thus allowing current to flow through a winding of tuning motor 18. The direction of current flow is so chosen that the motor turns in a direction so as to move a slug, for instance, so that the operating frequency of the magnetron is increased. If this frequency had originally been greater than the cavity quiescent frequency, the signal from the crystal would have been amplified by tube 47, would have triggered gas tube 34, and so would have allowed current to flow through the tuning motor in a different direction, say, so that the rotation of the motor would be opposite to that which was obtained in the previous example.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A cavity resonator-type, tunable magnetron oscillator operating at a first resonant frequency, reference cavity resonator means having a quiescent resonant frequency, coupled to said magnetron and having at least a portion of one wall thereof of a flexible material, a coil wound about a movable core which is mechanically coupled to the flexible wall, a source of constant magnetic field in the neighborhood of said coil and capable of influencing the coil, a source of alternating current coupled to said coil, whereby the resonant frequency of said reference cavity resonator means is varied periodically, a rectifying means coupled to said reference cavity resonator, an electric motor, a first multi-element gas tube connected between said source of alternating current and said electric motor, a second multi-element gas tube connected between said source of alternating current and said electric motor in an oppositely phased manner than the connection through said first gas tube, means coupling said source of alternating current to a control element of said first gas tube in an opposite phase than the coupling to the plate thereof, means coupling said source of alternating current to a control element of said second gas tube in an opposite phase than the coupling to the plate thereof, means coupling said rectifying means to said control elements, and means mechanically coupling said electric motor to said tunable magnetron oscillator, whereby said first resonant frequency is held in the neighborhood of the quiescent resonant frequency of said reference cavity resonator.

2. An automatic frequency control circuit for stabilizing a tunable oscillator at a desired frequency, including: tunable resonator means coupled to said oscillator, the resonant frequency of

said resonator means being adapted to be varied on both sides of said frequency by a source of alternating current; first and second thermionic tube means coupled to the output of said resonator means in like phase; adjustment means, adapted to be activated by either of said thermionic tubes and coupled to said oscillator, for adjusting the frequency thereof; and transformer means, adapted to be activated by said alternating current source and coupled to the anodes and grids of said tube means to excite the anodes of said tube means in opposite phase, and to excite said grids in opposite phase with respect to the anodes of their respective tube means; whereby the output from said resonator means will cause one of said tube means to conduct, activate said adjustment means, and thereby bring said tunable oscillator back to said desired frequency.

3. The circuit of claim 2, wherein said adjustment means comprises tuning motor means, the direction of rotation of said motor means being determined by which of said first and second thermionic tube means is conducting at any given time.

4. The circuit of claim 2, further including rectifier means coupled between the output of said resonator means and the input to said first and second thermionic tube means.

5. The circuit of claim 4, further including amplifier means comprising third and fourth thermionic tube means the outputs of which are respectively coupled to said first and second thermionic tubes, the anodes of which are respectively coupled to said transformer means in the same phase as those of said first and second thermionic tube means, and the grids of which are both coupled in like phase to the output of said rectifier means.

6. A circuit for deriving control energy as a function of the difference between the resonant frequency of a tuned circuit and the frequency of a current exciting said circuit, comprising: periodic means for periodically varying one of said frequencies; first and second thermionic tube means, having their inputs coupled to the output of said tuned circuit in like phase; means for exciting the anodes of both said tube means in opposite phase by an alternating current equal to and synchronized with the frequency of said periodic means; means for exciting the grids of both said tube means by said alternating current, in opposite phase with respect to the anodes of their respective tube means; and a circuit activated by said tube means for deriving said control energy.

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