April 23, 1963 W. W. McLEOD, JR 3,087,124

FEEDBACK SYSTEM FOR REED MODULATED MAGNETRONS

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FIG. 1

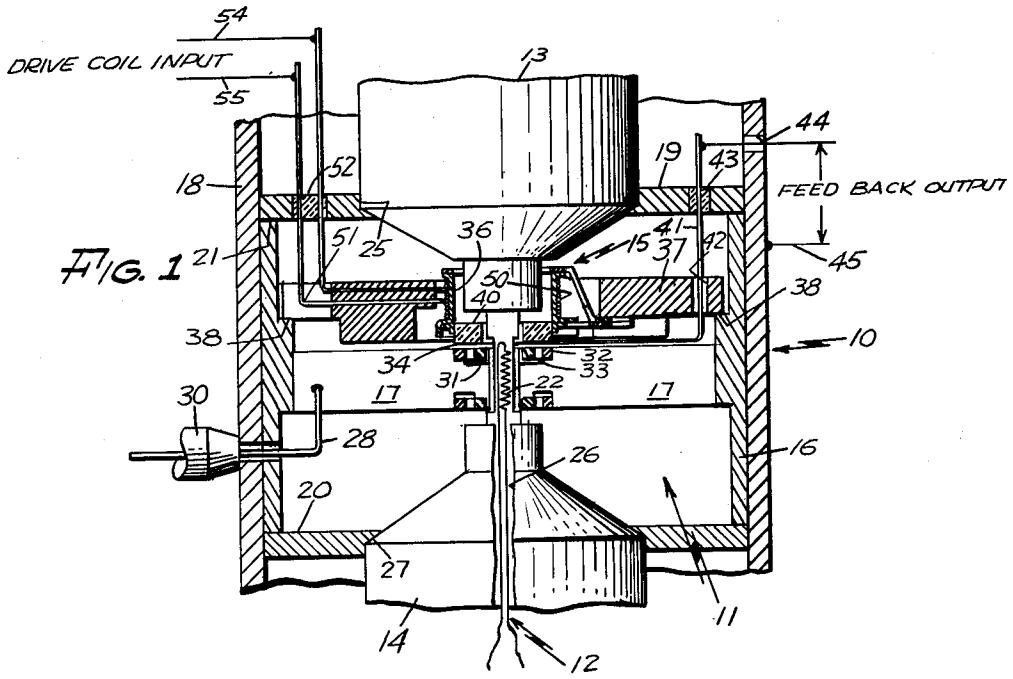


FIG. 2

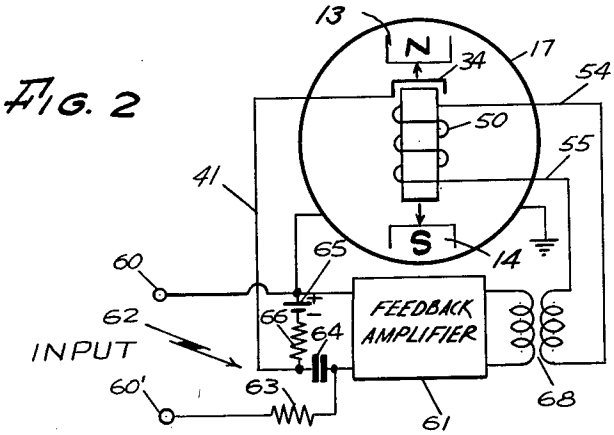
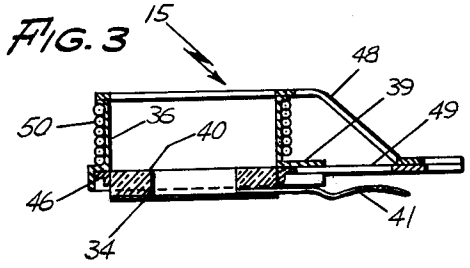


FIG. 3



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FEEDBACK SYSTEM FOR REED MODULATED MAGNETRONS

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This invention relates to electron discharge devices, and more particularly, to feedback means for stabilizing the frequency modulation characteristics of tunable election discharge devices of the frequency modulated megnetron type.

In an electron discharge device of the vibratory reed megnetron type, in which the frequency of the megnetron is a function of the capacity between the anode straps, the vibratory reed or tunable element usually supports a sensing coil and a drive coil adjacent to the anode and is movable with respect to the anode straps for tuning the device. As is known, the sensing or "pick-up" coil senses the motion of the vibratory reed or tunable element and produces a feedback voltage which is combined with a modulating input signal and amplified in a feedback amplifier. The output of this amplifier is connected to the drive coil to produce an electromagnetic field which interacts with the magnetic field of the magnetron to impart motion to the reed. In this manner, the drive coil operates to damp and control the motion of the reed to conform more accurately to the input frequency modulating signal. However, since the magnetron frequency is a function of the spacing between the reed or tunable element and the anode, a two coil system of this type does not directly compensate for variations in spacing between the reed and the anode. As a result, the feedback voltage so developed controls only the motion of the reed and not the capacity between the reed and the anode straps.

In addition, undesirable transformer coupling between the drive and the pick-up coils tends to cancel out the feedback voltage and limit the frequency response of the feedback system so that it is difficult, if not impossible, to control the motion of the reed at high frequencies. As a result, the frequency response of the tunable element or reed modulator is seriously limited in the region in which the feedback voltage is impaired. It is therefore desirable to provide a feedback system in which the capacity between the anode straps of a frequency modulated magnetron is varied in a linear manner in order to improve the frequency response of the reed modulator and, thereby, obtain linear frequency modulation.

In accordance with the reed modulated feedback system of this invention, a capacity plate is insulatedly supported by the vibratory reed or tunable element and positioned adjacent to the straps of a frequency modulated magnetron in order to form a capacity pick-off to develop a feedback voltage. This feedback voltage is fed to the input stage of a feedback amplifier connected to a drive coil supported by the vibratory reed element. The capacity plate is insulated from and biased with respect to the anode of the magnetron by means of a high impedance input circuit which introduces the frequency modulated input signal and the feedback voltage into the feedback amplifier. The time constant of this input circuit is made short relative to the input modulating frequency to permit the feedback voltage signal to be proportional to the rate of change of capacitance between the capacity plate and the anode straps. This feedback then provides frequency modulation which is proportional and linear with the input modulating signal. In addition, the voltage derived by the capacity pick-off plate will be a function of one over the reed to anode spacing, which is the same as the frequency modulating characteristics of the vibratory reed element. In this manner, the effective capacity between the straps of the magnetron is controlled by a capacity feedback system of this type and, thus, compensation is introduced for the non-linearity of the reed modulation element. With this arrangement, the rate of change of frequency of the magnetron is proportional to and linear with the input signal to the amplifier. In addition, the direct coupling between the drive and pick-up elements and the resulting limitation on frequency response is substantially eliminated.

The system of this invention constitutes an improvement over the system disclosed in U.S. Patent No. 2,750,565 of William R. Mercer et al., issued June 12, 1956.

Other and further advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

FIG. 1 is a fragmentary longitudinal sectional view taken through the center of the magnetron of the vibrating reed type showing the capacity plate and driving coil on the tunable reed element;

FIG. 2 is a simplified schematic of the magnetron feedback circuit of the subject invention in which the capacity feedback plate is connected in a manner to affect the input signal to the driving coil, hereinafter referred to as a "closed loop" circuit; and

FIG. 3 is an enlarged, fragmentary view of a portion of FIG. 1 showing the vibratory reed element and the capacity plate.

FIG. 1 illustrates a frequency modulated magnetron, generally indicated by reference numeral **10**, which utilizes a vibrating reed assembly upon which a driving coil and a capacity plate are mounted. Magnetron **10** comprises an anode structure **11**, a cathode structure **12** (only partially shown), magnetic means including pole pieces **13** and **14** for establishing a magnetic field in a direction perpendicular to the path of the electron flow between said cathode and anode structures, and a vibratory reed assembly or tunable element **15**.

As shown in FIG. 1, anode structure **11** includes a cylindrical body **16** made of highly conductive material, such as copper, and having a plurality of radially extending anode vanes **17**, as is well known in the magnetron art. Surrounding the cylindrical body **16** is a cover assembly **18** which functions as a magnetic return path for pole pieces **13** and **14**. Anode structure **11** is closed at the ends, for example, by end plates **19** and **20** hermetically sealed at the junction between said plates and cylindrical body **16**, as shown at **21**. The cathode structure **12** is coaxially arranged with respect to the anode structure and comprises a cathode heating filament **22** which passes through a recess in the pole piece **14** in the usual manner. The cathode may be supported and insulated from the anode structure in the manner shown by Becker in U.S. Patent No. 2,566,478, dated September 4, 1951.

One of the pole pieces **13** is hermetically sealed, as at **25**, into the end plate **19**. The other pole piece **14** is broken away at **26** and shows a centrally located bore which allows for entry of cathode assembly **12**. This pole piece may be hermetically sealed as at **27** into the end plate **20**. Pole pieces **13** and **14** are adapted to be fixed to the opposite ends of a magnet, such as bar magnets (not shown) for producing an appropriate magnetic field, as noted, in a direction normal to the path of electrons flowing from cathode to anode.

A coupling device **28** connected to one of the anode vanes **17** serves to couple energy out of the magnetron and

is brought out through outlet pipe 30 which engages cylindrical body 16 of anode structure 11 and extends through the cover assembly 18.

The anode vanes 17 are each provided with a slot 31 for receiving a pair of concentric conducting straps 32 and 33 which contact alternate anode vanes. As is well known in the magnetron art, the aforesaid straps present a capacitance therebetween which partially determines the natural resonant frequency of the magnetron.

Referring now to FIGS. 1 and 3, a vibrating reed assembly 15 includes a capacity plate 34 which is moved with respect to anode vanes 17, that is with respect to straps 32 and 33, whereby the distributed capacitance may be altered so that the magnetron may be varied in frequency. The capacitance or capacity plate 34 takes the form of a metalized coating on an annular ceramic diaphragm 40 which is secured to the lower flanged portion of a hollow cylindrical core 36. The core 36 forming part of the tunable reed element 15 is secured, as by soldering, to a ring or flange portion 37 of the tunable element which, in turn, is secured at its periphery, to a supporting ledge 38 of cylindrical body 16 of anode structure 11.

The capacitive plate 34, as shown in FIG. 3, consists of a metalized surface on the ceramic insert 40 secured to reed-like flange 46 partially surrounded by an extension of core 36 and adjacent to core bracket 39. The end of core 36 opposite from core bracket 39, is braced by means of support 48 extending diagonally to the vibrator portion 49 of the reed-like flange 46. The ceramic support 40 insulates the capacitive plate 34 from the tuning assembly 15 and, in particular, from the core or metallic support 36 for a drive coil 50. Connected to the metallic capacitive plate is a wire output lead 41 which passes through an opening 42 in anode ring or flange 37 and out of the magnetron through a glass seal 43 in the end plate 19. The output lead 41 then passes through an opening 44 in cover assembly 18 and, together with a lead 45 connected to the anode assembly, provides a means for introducing the feedback voltage into the input circuitry of the feedback amplifier.

The drive coil 50, as shown in FIG. 3, preferably consists of approximately 20 turns of insulated wire which is wound upon the hollow core 36 and firmly attached thereto. The ends of drive coil 50 are led out of the magnetron through an aperture in the ring or flange portion 37 of the tunable element and through a glass seal 52 fused into the upper end plate 19. Output leads 54 and 55 are connected to the ends of coil 50 extending beyond the glass seal 52. The tunable reed assembly 15 and the driving coil 50 carried thereon are disposed relative to the pole pieces 13 and 14 so that the drive coil 50 is in the leakage field existing between said pole pieces. When an external modulating voltage is applied to leads 54 and 55, the electromagnetic field set up between the current flowing in driving coil 50 and the leakage magnetic field of the magnetron interact to produce motion of core 36 and is accompanying capacitive plate 34 with respect to the anode straps 32 and 33. In this manner, the distributed capacitance of the magnetron is varied and frequency modulation obtained. As the tuning element vibrates to and fro in response to the drive coil input, a capacitive pick-off voltage is generated on the capacitive plate 34 which is fed by way of lead 41 to the input terminals of a feedback amplifier 61.

Referring to FIG. 2, a square wave applied to the input terminals 60, 60' is coupled to feedback amplifier 61 by way of an input circuit 62. This circuit comprises a .5 megohm input resistor 63, and a .1 microfared coupling capacitor 54 which isolates the negative bias voltage from the input of amplifier 61. The insulated capacitive plate 34 is biased at a negative voltage of minus 400 volts with respect to the grounded anode structure 17 by means of a bias source 65 and .5 megohm bias resistor 66. The output of amplifier 61 is coupled through an output transformer 68 to the driving coil 50 shown in FIG. 1. The core about which the drive coil 50 is securely wound is adapted to move to and fro between the magnetic pole pieces 13 and 14 as shown by the arrows. The feedback voltage which is developed by the capacity plate 34 is fed to the input circuit of the amplifier, the time constant of which is made short relative to the square wave input modulating voltage at terminals 60, 60'. In this closed loop circuit, the feedback voltage and input signal become proportional to the rate of change of capacitance between the capacity plate 34 and the anode straps 32 and 33. This feedback circuit, therefore, provides a rate of change of frequency which is proportional to the input modulating signal. At the same time, the capacity plate provides that the feedback voltage is a function of one over the reed to anode spacing which is the same as the modulation characteristics of the vibrating tunable element. Thus, any variation of the reed modulation element due to non-linearity is compensated for by the amplified feedback and signal voltages. The voltage output from the capacitor plate will thus be constant while the motion of the core is in one direction, changes polarity when the coil reverses direction, and remains constant at the new polarity until the cycle reoccurs. If for any reason, the motion of the drive coil is not linear, the error or feedback voltage derived across the capacitive plate is fed to the amplifier input circuit, combined with the input signal voltage and reamplified in phase opposition so as to tend to cancel out the error originally generated by irregularities in the drive coil motion.

It should be understood that this invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. For example, the electrically insulated capacity plate may be used to regulate the frequency response of other than electron discharge devices. The non-linear response of, for example, a driving coil applied to a magnetic transducer, in an arrangement as shown in FIG. 3, may be compensated by the feedback voltage developed in this closed loop feedback system, or other non-linear electromechanical vibrating assemblies may attain similar advantages.

It is accordingly desired that this invention not be limited to the particular details of the embodiment disclosed herein except as defined by the appended claims.

What is claimed is:

1. A frequency modulation circuit comprising an electron discharge device including a cathode, an anode, means for producing a magnetic field and a tunable element positioned in said magnetic field, said tunable element including a conductive plate insulatedly supported thereon and adjacent to said anode in a manner adapted to vary the frequency of said electron discharge device in response to movement of said plate, means for varying the position of said plate including a driving element mounted on said tunable element, means for applying an input voltage to said driving coil, means for developing a feedback voltage in response to variations in electrical charge on said plate due to changes of capacitance between said plate and said anode, and means for combining said feedback voltage with said input voltage to apply a modulating voltage to said driving element.

2. A frequency modulation circuit comprising means for establishing a flow of electrons in a given direction, means for establishing a magnetic field in a direction substantially perpendicular to such direction of electron flow, and means mounted for movement within such magnetic field and adjacent such electron flow to both frequency-modulate such electron flow in accordance with such movement and provide a capacitive pick-off the amplitude of which varies in linear relationship with such movement, whereby the variable capacitance of said pick-off may be employed to control feedback circuitry the output of which is combined with drive signals applied to said frequency

modulating means to stabilize the operation of such last-mentioned means.

3. A frequency modulation circuit comprising means for establishing a flow of electrons in a given direction, means for establishing a magnetic field in a direction substantially perpendicular to such direction of electron flow, means mounted for movement within such magnetic field and adjacent such electron flow to both frequency-modulate such electron flow in accordance with such movement and provide a capacitive pick-off the amplitude of which varies in linear relationship with such movement, means for effecting movement of said frequency modulating means in accordance with a modulating signal, and means connected in feedback relationship between said capacitive pick-off means and said means for effecting movement.

4. A frequency modulation circuit, comprising an electron discharge device including a cathode, an anode, and means for establishing a magnetic field in a direction substantially perpendicular to the path of the electron flow between said cathode and said anode, a mechanical tuning means positioned in said magnetic field, and a conductive plate insulatedly supported by said tuning means within said device in capacitive relationship with said anode, said tuning means being mounted for movement relative to said anode to vary the distance between said conductive plate and said anode and thereby vary such capacitive relationship linearly with respect to such movement, whereby the movement of said conductive plate serves both to frequency-modulate the electron flow from said cathode to said anode and to provide a capacitive pick-off which varies linearly with such movement.

5. A frequency modulation circuit comprising an electron discharge device having a cathode, an anode and a magnetic circuit having a field portion substantially perpendicular to a flow of electrons between said cathode and said anode, a vibratory member mounted for movement within such magnetic field adjacent such electron flow, a drive coil mounted on said vibratory member, an input circuit for said drive coil for applying modulating signals thereto to cause corresponding movement of said coil and vibratory member as a result of interaction between the magnetic fields of said coil and said magnetic circuit, a conductive plate member mounted on and insulated from said vibratory member for movement toward and away from said anode in capacitive relationship therewith, and a feedback circuit connected between said insulated conductive plate member and said input circuit, whereby such movement of said conductive plate member serves both to frequency-modulate the electron flow from said cathode to said anode and to provide a variable capacitance control for such feedback circuit which varies linearly with the movement of said conductive plate member.

References Cited in the file of this patent

UNITED STATES PATENTS

2,114,036	Smith et al.	Apr. 12, 1938
2,269,041	Schussler	Jan. 6, 1942
2,444,435	Fisk	July 6, 1948
2,493,819	Harry	Jan. 10, 1950
2,615,156	Smith	Oct. 21, 1952
2,750,565	Mercer	June 12, 1956
2,784,345	Spencer	Mar. 5, 1957
2,802,178	Shafer	Aug. 6, 1957