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2,151,754

OSCILLATION GENERATOR

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FIG. 1

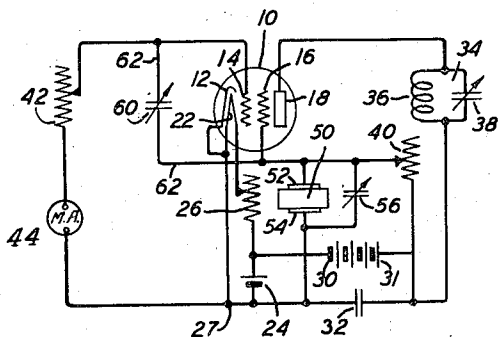


FIG. 2

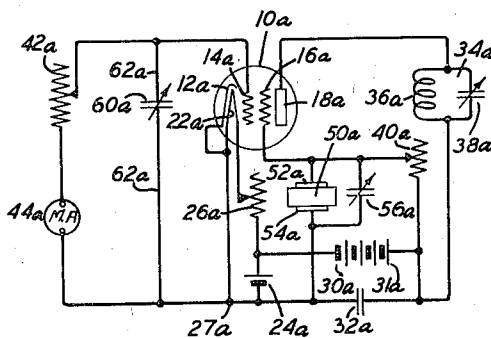


FIG. 3

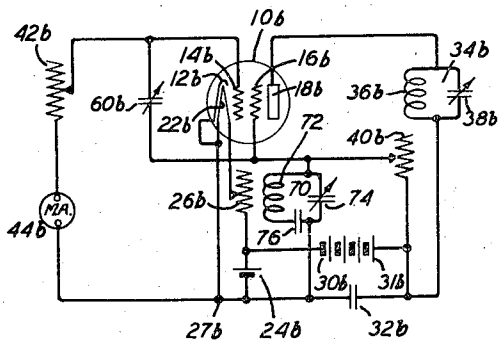


FIG. 4

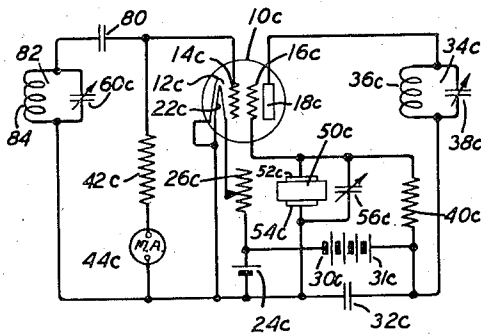
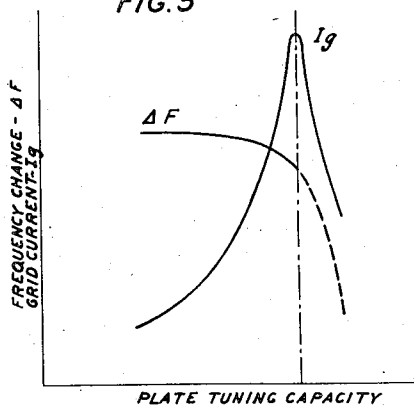


FIG. 5



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OSCILLATION GENERATOR

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21 Claims. (Cl. 250—36)

This invention relates to oscillation generators and particularly to constant frequency or stable frequency oscillation generators.

One of the objects of this invention is to provide a stable frequency oscillation generator which may have such a high degree of frequency stability that it may be used as a frequency standard, for example.

Another object of this invention is to render the frequency of an oscillation generator independent of voltage variations in the power supply circuit or circuits.

Another object of this invention is to render the frequency of an oscillation generator independent of small impedance variations in the circuit elements thereof.

Another object of this invention is to stabilize the frequency of an oscillation generator at a value of output circuit tuned plate impedance that has a minimum effect upon the frequency with small impedance variations therein.

In accordance with one form of this invention, an oscillation generator may be provided, the frequency of which may be determined or fixed by a suitable frequency determining system, for example, such as a piezoelectric quartz crystal, independently of impedance variations in other circuit elements and independently of power supply circuit voltage variations. The oscillation generator may have a very high order of frequency stability and, therefore, may be used as a frequency standard, for example. A frequency precision of better than a few parts in a million may be obtained, for example.

The over-all frequency stability of an oscillator circuit is determined by the sum of all the frequency variations that may be caused by the changes in each circuit element thereof, such as in the coils, the condensers, the vacuum tubes or in any other circuit elements thereof or connections therebetween.

Power supply circuit voltage variations on the plate or on the grid of the space discharge device of an oscillation generator may, unless compensated, neutralized or balanced out, cause an appreciable change in the frequency of the oscillations generated. In accordance with one form of this invention, means in the form of a vacuum tube grid electrode used as a compensating grid or stabilizing grid, may be adapted to neutralize or compensate or balance out the effects of such voltage variations on the frequency thereby to obtain a stable frequency. More particularly, in one form of the invention, a part of the radio

frequency output oscillation currents may be fed back to another element as to an extra grid element by means of a reactance device, as a coupling condenser, and so adjusted in phase and magnitude as to balance out impedance phase changes caused by battery voltage variations thereby to eliminate the effect of such power supply circuit voltage variations upon the frequency of the oscillations generated.

Moreover, in accordance with this invention, the effect of battery voltage variations upon frequency may be compensated for by circuit elements, the adjustment of which is not strictly critical thereby rendering the frequency independent not only of battery voltage variations but also of impedance variations in the circuit elements that are utilized to balance out the battery voltage variations.

Such conditions as temperature changes, vibration, or aging may cause variations in the impedance characteristics of the various circuit elements of an oscillation generator and affect the frequency stability of the oscillation generator. This invention provides an oscillation generator, the circuit elements of which may be so proportioned that such impedance variations therein may have a minimum effect on the frequency stability of the oscillation generator.

In accordance with one form of this invention, the oscillation generator may include a multi-element space discharge device, such as a tetrode in the form of a screen grid or shield grid tube having a cathode, an anode or plate element and two grid elements therebetween; one, an inner grid disposed adjacent the cathode; the other a shield grid or screen grid disposed adjacent the plate. The frequency of the oscillator may be determined or fixed by a device having a sharp resonant or other frequency determining characteristic as a piezo-quartz crystal connected in the shield grid-cathode circuit. The tuned output circuit between the cathode and anode may include an adjustable anti-resonant circuit comprised of a tuning coil and condenser connected in parallel circuit relation. Polarizing voltage may be supplied from the same terminal of a battery to the plate and to the screen grid, the latter being polarized through a resistor. Another resistor may be connected in circuit with the inner grid and the cathode. The resistances of both resistors may be made of such values within critical ranges as to produce the optimum frequency stability. Reactance means in the form of a variable coupling condenser may be connected between the

two grids to feed back a part of the oscillation current so adjusted in both phase and magnitude as to balance out or neutralize or eliminate the effects of plate and screen grid voltage variations on the frequency, thereby to render the frequency of oscillations generated independent of supply circuit voltage variations. Suitable adjustments may be made in the resistors, the output circuit tuning condenser and in the coupling condenser to so proportion the circuit elements of the oscillation generator that the frequency of the oscillations generated is rendered independent of changes in the tube characteristics or in the tuning coil or tuning condenser characteristics such as may be caused by temperature changes.

For a clearer understanding of the nature of this invention and the additional features and objects thereof, reference is made to the following description taken in connection with the accompanying drawing, of which:

Figs. 1 to 4 are diagrams showing various modifications of the invention; and

Fig. 5 is a diagram showing typical curves useful in explaining a feature of the invention.

Fig. 1 shows a crystal-controlled oscillation generator circuit which includes a space discharge device in the form of a multi-grid four-electrode high vacuum oscillator tube or tetrode 10 having a cathode 12, a space current inner grid or control stabilizing and compensating grid 14 disposed adjacent and surrounding the cathode 12, and another control grid in the form of a shield or screen grid 16 disposed between the control grid 14 and an anode or plate element 18. The shield grid 16 may have a part surrounding the plate element 18 and electrically connected with the remaining part in a known manner. The cathode 12, the shield grid 16 and the anode 18 are so disposed with respect to each other as to generate oscillations when connected with suitable circuits. The grid 14 disposed between the shield grid 16 and the cathode 12 may, if desired, be so arranged with respect to the cathode 12 as to have a high μ or high amplification constant to control the degree of amplification of currents.

The control grid 14 is adapted to compensate or neutralize or balance out the effects of variations in the voltage of battery 30 upon the frequency thereby to render the frequency of oscillations generated independent of such battery voltage variations. The control grid 14 may also exert control on the space charge currents in the usual fashion and thereby assist in controlling the output power of oscillations generated.

The cathode 12 may be of the heater type, heated by a filament 22 energized by a suitable source such as a battery 24 which may be controlled by a suitable variable resistance 26. The cathode 12 and filament 22 may be grounded at 27 in a known manner.

The plate 18 of the space discharge device 10 may be positively polarized at a suitable potential by means of a suitable supply circuit source, as a battery 30 connected in the circuit between the cathode 12 and the plate or anode 18. A by-pass condenser 32 of suitable value may be connected across the supply sources 24 and 30 to by-pass alternating currents. The tuned output circuit or tuned plate supply circuit connected between the supply source 30 and the plate 18 includes a variable anti-resonant circuit 34 in the form of an inductance coil 36 connected

in parallel circuit relation with a tunable variable condenser 38.

The shield grid or screen grid 16 is polarized at a positive potential with respect to the cathode 12 by means of a circuit including an adjustable resistor 40 connected with the same common terminal 31 of the battery 30 as is connected with the plate 18 so as to have impressed thereon the same battery potential. An adjustable resistor 42 connects the control grid 14 with the cathode 12 and may include in circuit therewith a meter 44 to measure the current in such grid-cathode circuit.

A mechanical vibratile element in the form of piezo-quartz crystal 50 of suitable frequency characteristics may be disposed between suitable electrodes 52 and 54 in a suitable crystal holder and connected as in the circuit between the cathode 12 and the grid 16 to determine or fix the frequency of the oscillations generated in the output circuit in accordance with a selected frequency characteristic of the crystal 50. The element 50, for example, may be a zero or low temperature coefficient piezo-quartz crystal and may be disposed in a constant temperature oven in a known manner. A suitable variable condenser 56 may, if desired, be connected in parallel circuit relation with the crystal 50 to make slight frequency adjustments therein.

An adjustable reactance device in the form of a variable coupling condenser 60 may be connected by a circuit 62 with the grids 14 and 16 of the space discharge device 10 to feed back to the grid 14 part of the radio frequency output oscillation currents generated by the crystal controlled oscillator comprising the circuits including the cathode 12, the anode 18 and the grid 16. Such oscillation currents are fed back to the tube grid element 14 and may be so adjusted in both phase and magnitude by adjustment of the variable coupling condenser 60 as to neutralize or compensate or balance out the impedance phase changes caused by power supply voltage variations on the grid 16 and the plate 18 thereby to eliminate frequency changes in the oscillation generator caused by voltage variations in the power supply 30.

In this circuit, the two grids 14 and 16 may be looked upon as a combination functioning as a control system in which amplification or other control of the currents flowing may be variably secured by adjusting the relative amplitudes and/or phases of controlling voltages upon them. The control exerted may be adjusted or varied as mentioned in the preceding paragraph until its effect upon the tube 10, when the plate voltage changes, neutralizes the change in frequency which would occur due to such voltage change changing the internal impedances of the tube 10.

In a particular million cycle oscillation generator which was constructed in accordance with Fig. 1 and successfully operated, certain of the circuit elements hereinbefore mentioned had values as follows: The resistor 40 had a resistance value of 500,000 ohms. The resistor 42 had a resistance value of 50,000 ohms. The condenser 60 had a capacity value of 100 micromicrofarads (100 m. m. f.), and the condenser 56 had a capacity value up to 30 micro-microfarads (30 m. m. f.). It will be understood, however, that the selection of impedance values and their adjustments may be made in the following manner to suit the particular oscillator.

The various factors which may govern the frequency stability of the screen grid oscillator

shown in Fig. 1 are considered more particularly as follows: The same factors may apply also to the corresponding parts in the remaining figures and modifications.

5 The screen resistor 40 which, in Fig. 1, is connected in series circuit relation with the screen grid 16 and the terminal 31 of the battery 30 may be adjusted as follows to such value of resistance as to provide the optimum frequency stability and power output of oscillations in the output circuit 34. More particularly, the resistance of resistor 40 may be adjusted for such value within a range of values, that the voltage supplied from the battery 30 to the screen grid 16 is so limited as to prevent excessive currents in the circuits of the screen grid 16 and plate 18, that the voltage on the screen 16 is sufficient to produce a desired radio frequency output power, that the frequency change due to variations in voltage on the screen 16 are of the same order as and linearly related to the frequency change due to voltage variations on the plate 18, and that small changes in the resistance, such as those caused by temperature change, do not affect the frequency. All of these features may be obtained within a range of resistance values to adapt the resistor 40 to influence or control the frequency stability of the oscillator as well as the radio frequency output power generated thereby. The value of the resistance 40 so selected, not being strictly critical, is such as to render the frequency of the oscillator independent of small impedance changes in the resistor 40 such as may be caused by temperature change or aging; and the value of the resistor 40, being such as to produce a linear frequency change with plate and screen voltage change, aids in stabilizing the frequency of the oscillator independently of voltage variations in the battery 30. The value of resistance in the resistor 40 may then be selected, as described, anywhere within such range of resistance values to obtain the desired frequency stability. Beyond this range, if in one direction, the resistor of the resistance 40 is made of too high value of resistance, the output power of the oscillator is reduced and if in the other direction, the resistor of the resistance 40 is made of too small a value of resistance, the frequency stability of the oscillator is reduced. Accordingly, the resistor value of the resistance 40 may be chosen within such range of resistance values to obtain the optimum frequency stability of oscillations and when so chosen, the effect of variations in the electrical impedance characteristics of the resistance 40, such as those caused by temperature change in or aging of the resistance 40, is minimized or eliminated whereby the frequency stability of the oscillator is rendered independent of such variations.

60 In the particular million cycle oscillator hereinbefore referred to as constructed in accordance with the circuit of Fig. 1, the resistor 40 had a resistance value of 0.5 megohm (500,000 ohms). A twenty per cent change in this resistance gave less than 0.1 cycle frequency change but when too low values of resistance were used, the frequency change with plate and screen voltage change was not linear and a small change in the screen resistance 40 changed the frequency considerably.

70 The grid leak resistance 42 of Fig. 1, which is connected in the circuit between the grid 14 and the cathode 12, may be adjusted to the proper impedance value to stabilize the frequency of oscillations generated. The proper value may be determined by test and so adjusted that small

changes in its value have the least effect upon the frequency of the oscillator. When so adjusted, the value not being strictly critical, the frequency of oscillations generated is independent of small impedance changes therein, such as may be caused by temperature change or aging of the resistance element 42. Moreover, when so adjusted to its proper value, the resistor 42 cooperating with other elements of the circuit and particularly in cooperation with the grid condenser 60 may reduce to practically zero any frequency change due to voltage fluctuations of the battery 30.

15 In the particular million cycle oscillator hereinbefore referred to as constructed in accordance with the circuit of Fig. 1 and successfully operated, the resistance 42 had a resistance value of 50,000 ohms to secure optimum stability of frequency. It will be understood, however, that the proper value is, of itself, not strictly critical and may be varied with such limits as to secure frequency stability.

20 The tuned plate impedance 34 may have such value as to stabilize the frequency of oscillations generated and also, at the same time, have a minimum effect upon the frequency when subjected to small impedance variations such as those which may be produced in the coil 36 and in the condenser 38 by temperature change or aging thereof. Reference is made to Fig. 5 to explain this feature of the invention.

25 In Fig. 5, characteristic curves are given showing the typical relation between plate tuning capacity and frequency of an oscillator and the corresponding variations in grid current. The curve indicated as ΔF represents a typical relation between the plate circuit tuning capacity and the frequency of oscillations generated. The curve indicated as I_g represents a typical relation between plate circuit tuning capacity and the current in the grid-cathode circuit of an oscillator generator. Applied to the particular oscillator circuits shown herein as, for example, that shown in Fig. 1, the curve indicated as ΔF in Fig. 5 may represent the relation between the plate circuit tuning capacity 38 of Fig. 1 and the frequency of oscillations generated; and the curve indicated as I_g in Fig. 5 may represent the relation between the plate circuit tuning capacity 38 of Fig. 1 and the current in the circuit connecting the grid 14 and the cathode 12 and including the meter 44 which might be used to measure such current. The maximum value of grid current (I_g) is used here in Fig. 5 as a reference point in tuning the oscillator.

55 As indicated in Fig. 5 by the broken line portion of the curve marked ΔF where an oscillator is so proportioned that it requires a value of plate tuning capacity greater than that corresponding to the maximum value of grid current I_g in order to stabilize the frequency of the circuit, then such value of plate tuning capacity is critical and relatively small changes in the output circuit plate tuning capacity cause relatively large changes in the frequency of oscillations generated as is evident from the nature of the broken line portion of the curve marked ΔF in Fig. 5.

60 In oscillation generators constructed in accordance with this invention, the region or range of output circuit plate tuning capacity to obtain frequency stability may extend over the stable range indicated by the solid line portion of the curve marked ΔF in Fig. 5 and is not limited for frequency stability to the region indicated by the broken line portion of the curve marked ΔF in 75

Fig. 5. Accordingly, the frequency of the oscillator circuit shown in Fig. 1, for example, may be stabilized by a value of tuning plate capacity 38, small variations in which have a minimum effect upon the frequency. This value of tuning capacity 38 may range from that corresponding to the maximum value of grid current I_g to a minimum required for oscillations as represented by the solid line portion of the frequency curve ΔF in Fig. 5. Over this range, the frequency change due to small capacity changes in the impedance 34 is a minimum, the value of capacity in the condenser 38 is not critical, and the frequency of the circuit shown in Fig. 1 may be stabilized when the condenser 38 is tuned for a maximum output voltage. Where frequency stability is of greater importance than maximum output voltage, the capacity of condenser 38 may be reduced to obtain maximum frequency stability with the sacrifice of some output power.

To obtain the optimum conditions of frequency stability, suitable adjustments, as described, may be made in the plate circuit reactance 34, in the grid circuit reactance 60, in the screen resistor 40 and in the grid resistor 42 and if utilized, also in the small condenser 56. These adjustments may be made by adjusting the resistance of screen resistor 40 to the value that gives the condition of optimum frequency stability in the output circuit 34, by adjusting the resistance of grid resistor 42 to the value that gives the condition of optimum frequency stability in the output circuit 34, by adjusting the plate circuit reactance 34 within the hereinbefore mentioned range of values as by varying the tuning condenser 38, and by adjusting the reactance between the grids 14 and 16, as by varying the condenser 60, to such value that the frequency in the output circuit 34 is rendered independent of power supply battery voltage variations on the shield grid 16 and on the plate 18.

More particularly, these adjustments may be made in accordance with the following general procedure to stabilize the frequency of oscillations generated. As applied to Fig. 1, set the variable grid condenser 60 of Fig. 1 at an estimated proper value to give constant frequency of oscillations. Then tune the plate circuit condenser 38 to maximum grid current as measured by the meter 44 shown in Fig. 1. Such current is represented by the curve I_g of Fig. 5. Next, reduce the capacity of condenser 38 of Fig. 1 to reduce the grid current to such minimum value as is allowable for a desired output voltage. Small impedance variations in the coil 36 and condenser 38 then have a minimum effect upon the frequency of oscillations. Then, to stabilize against voltage changes in the battery 30, change the value of such voltage and note the frequency change. If the frequency increases with increasing plate battery voltage, the capacity of the grid stabilizing condenser 60 should be decreased. If the frequency decreases with increasing plate battery voltage, the capacity of condenser 60 should be increased. In case the capacity of condenser 60 reaches a minimum and the frequency still increases with increasing voltage, the condenser may be connected between the grid 14 and cathode 12 as shown in Fig. 2 where the condenser 60a is connected between the grid 14a and the cathode 12a.

After stabilizing the frequency against voltage changes of the battery 30 as indicated in the preceding paragraph, the desired value of frequency may, if the crystal 50 is not of itself the exact value desired, be obtained by adjusting the

capacity value of the condenser 56 which may be connected across the crystal 50. If this adjustment by the condenser 56 results in an appreciable frequency change, a final stabilizing adjustment may be made by readjusting the condenser 60 to stabilize the frequency against voltage changes as explained in the preceding paragraph, since the value of the capacity in the condenser 56 may influence the capacity value of the condenser 60 required to balance out the effect of battery voltage on the frequency of oscillations. Accordingly, the capacity value of the condenser 56 is preferably limited with respect to the capacity value of the condenser 60. These adjustments, once made, may be left at the proper values. The frequency of the oscillator, then being wholly determined by the crystal system 50 which may be temperature controlled for precision purposes, is independent of rather wide variations in the electrical characteristics of all the remaining elements of the circuit such as may be caused by temperature changes or aging of such elements as the tube 10, the coil 36, the condenser 38, the resistances 40 and 42 or the condenser 60 and such as may be caused by voltage variations in the filament battery 24 and in the plate battery 30.

The system operates in the following manner to eliminate the effect of supply circuit voltage variations upon the frequency of the oscillator. The by-pass condenser 32 which is connected across the battery 30 and also across the battery 24 by-passes alternating currents and may serve to reduce to at least some extent the influence of voltage variations in the battery 30 itself upon the plate 18 and the screen grid 16 connected therewith. However, variations of power supply voltage on either the plate 18 or screen grid 16 alone may result in frequency change in the oscillations generated. To compensate for a large percentage of such frequency change due to such voltage change, the screen grid 16 may be fed through the resistor 40 of suitable value as hereinbefore described, from the terminal 31 of the plate supply source 30 so that any change in voltage on the plate 18 will automatically result in a change in voltage in the same direction and of the same order on the screen grid 16, the one thereby tending to compensate for the other somewhat with respect to the over-all or net frequency change since the frequency changes are of the same order when a suitable value of resistance 40 is used and are in opposite directions when the voltage changes on the plate 18 and on the screen 16 are in the same direction. The resistance of resistor 40 may be adjusted as hereinbefore described to such value, that the frequency change due to battery voltage variations on the screen 16 is of the same order as that due to the voltage variations on the plate 18; and also to such value that small changes in resistance thereof have no effect on the frequency to compensate not only for the effect of battery voltage variations on the frequency but also to render the frequency independent of small impedance variations therein.

When the voltage variations on the screen 16 as controlled by the value of the resistance of resistor 40 do not sufficiently compensate the voltage variations on the plate 18 to render the frequency of oscillations sufficiently independent of voltage variations of the battery 30, the control grid 14 may be used as a compensating grid and by means of the proper value of grid impedance associated therewith, the frequency change that

would otherwise occur due to fluctuations of voltage of the battery 30 may be reduced to practically zero. In the modification shown in Fig. 1, the grid arrangement includes the grid resistance 42 and the grid condenser 60. The resistance 42 is connected from the grid 14 to the cathode 12 which may be grounded at 27 and has such value of resistance that small changes therein have the least or no effect on the frequency. The grid condenser 60 is connected in Fig. 1 to feed back to the grid 14 part of the alternating current voltage on the screen 16. By setting the condenser 60 at the proper value, compensation for the effects of voltage changes in the battery 30 on the frequency may be obtained. More particularly, to balance out the impedance phase changes caused by such battery voltage variations on the plate 18 and on the screen grid 16, a part of the output circuit oscillation current may be fed back through the circuit 62 to the control grid 14 and so adjusted in phase and magnitude by adjustment of the variable condenser 60 as to render the frequency of oscillations generated in the output circuit 34 independent of power voltage variations on the plate 18 and the screen grid 16. In this circuit, the two grids 14 and 16 may be regarded as a combination functioning as a control system in which the control of the currents flowing may be variably secured by adjusting the relative amplitudes and/or phases of the controlling voltages upon the grids 14 and 16. The control exerted may be adjusted or varied by the condenser 60 until its effect upon the tube 10 neutralizes the change in frequency which would otherwise occur due to changes in the internal impedances of the tube caused by change in voltage on the plate 18. The value of capacity in the condenser 60 necessary to compensate for such battery voltage changes not being strictly critical, small impedance variations therein within the proper limits have no effect on the frequency.

It will be noted that the effect upon the frequency of voltage variations in the battery 30 and also in the battery 24 may be compensated for by circuit elements as the resistors 40 and 42, and the condenser 60 the adjustments of which need not be strictly critical thereby rendering the frequency of oscillations independent not only of battery voltage variations but also of small impedance variations in such circuit elements that may be utilized to eliminate the effect of such battery voltage variations on the frequency.

It will also be noted that the output power of the oscillator may be controlled to some extent by the condenser 60 an increase in the capacity of which, for example, increases the output of the oscillator.

Fig. 2 shows apparatus for generating oscillations similar to that shown in Fig. 1, the corresponding parts being designated by like reference numerals suffixed by the letter "a". In Fig. 2, a reactance device in the form of a variable condenser 60a connected with the compensating grid 14a and the cathode 22a is adapted to so reduce the excess interelectrode capacity between the grid electrodes 14a and 16a as to permit the proper adjustment of the phase and magnitude of the oscillation currents to balance out or neutralize impedance changes caused by polarizing battery voltage changes on the plate 18a and the grid 16a to thereby eliminate frequency changes in the oscillation currents in the output circuit in the same manner as described in connection with Fig. 1. It will be understood that where the interelectrode capacity associated with the stabiliz-

ing or compensating grid 14 or 14a within the tube itself is too large, the connection of the condenser 60a in Fig. 2 may be utilized and that where such interelectrode capacity within the tube itself is too small, the connection of the condenser 60 in Fig. 1 may be utilized; and that where the interelectrode coupling within the tube itself is correct of itself to permit stabilizing the effect on the frequency of plate and grid polarizing voltage changes, the condensers 60 and 60a may be dispensed with.

Fig. 3 shows another modification of the oscillation generator shown in Fig. 1, the circuits being identical with the exception that a tunable circuit 70 of suitable frequency characteristics and comprised of an inductance coil 72 and a variable condenser 74 is substituted for the crystal system including the piezoelectric quartz crystal 50 of Fig. 1. A stopping condenser 76 prevents the coil 72 from short-circuiting the resistor 40b. In Fig. 3, the parts corresponding to the similar parts of Fig. 1 are designated by like reference numerals suffixed by the letter "b". The grid electrode 14b like the grid electrodes 14 of Fig. 1 or 14a of Fig. 2 may be used as a compensating grid or stabilizing grid to stabilize the frequency of oscillations generated by balancing out or neutralizing the effect of battery voltage variations on the plate 18b and the grid 16b to thereby render the frequency independent of battery voltage variations. While the condenser 60b in Fig. 3 is shown connecting the control grid 14b and the screen grid 16b, as in Fig. 1, a connection for the condenser 60b of Fig. 3 may be provided like that shown for the condenser 60a of Fig. 2 for the purposes described in connection with Figs. 1 and 2.

Fig. 4 shows another modification wherein a condenser 80 and a tunable circuit 82 comprising an inductance coil 84 and a variable condenser 60c are connected in circuit with the grid 14c and the cathode 12c of the space discharge device 10c. Circuit elements corresponding with those in Figs. 1, 2 and 3 are indicated by like reference numerals suffixed by the letter "c". By suitable selection and adjustment of the circuit elements including the input condenser 60c, the output condenser 38c, the resistors 40c and 42c, as described in connection with Fig. 1, an oscillation generator of very stable frequency may be obtained the frequency of which is independent not only of voltage fluctuations in the batteries 24c and 30c but also of small impedance changes in the circuit elements.

While in Figs. 1 to 4, a tetrode or four-electrode tube has been illustrated, it will be understood that other forms of multi-element tubes may be utilized; and while in Figs. 1, 2 and 4 a particular piezoelectric system 50, 50a, or 50c, respectively, has been illustrated, it will be understood that other forms of piezoelectric systems or tuned circuit arrangements may be utilized such as a tuned circuit having a coil and condenser connected in parallel circuit relation as shown in Fig. 3, at 70.

The tuned output circuit of any of the oscillation generators shown in any of the figures may, if desired, be associated in a known manner with a suitable amplifier such as a screen grid amplifier to isolate the oscillator from changing load conditions in the final output circuit (not shown).

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable of application in other organizations and is

therefore to be limited not to the particular embodiments disclosed, but only by the scope of the appended claims and the state of the prior art.

What is claimed is:

- 5 1. An oscillation generator including a space discharge device having a cathode element, an outer grid element and a plate element for generating output oscillations, and having another element disposed between said cathode element and said grid element, means for supplying polarizing voltages to said plate and grid elements, and reactance means interconnected with said another element and one of said other elements for feeding part of said output oscillations to said another element, said reactance means having such a value of capacitance as to balance out the effect of impedance changes caused by variations of said voltages on said plate and grid elements and thereby to eliminate frequency variations caused by said plate and grid voltage variations.
2. Apparatus for generating constant frequency oscillations including an electron discharge device having cathode, plate or anode, and outer grid electrodes, and having an inner grid electrode disposed between said cathode and outer grid electrodes, and means for causing said cathode, outer grid and plate electrodes to generate oscillations, said means including a power supply source of voltage, means connected with said outer grid electrode for determining the frequency of said oscillations, resistance means interconnecting said cathode and inner grid electrodes and having such resistance as to render the frequency of said oscillations substantially independent of substantial impedance variations therein, resistance means interconnecting said source with said outer grid electrode and having such resistance as to render the frequency of said oscillations substantially independent of substantial impedance variations therein, output circuit tuning means connecting said source and said cathode with said plate electrode, supplying plate voltage to said plate electrode, and having such tuning capacity less than that corresponding to the maximum value of current in said means interconnecting said cathode and inner grid electrodes as to render the frequency of said oscillations substantially independent of substantial impedance variations in said output circuit, and means including a condenser connecting said inner grid electrode with another of said electrodes for rendering the frequency of said oscillations substantially independent of variations in either said source voltage or said plate voltage.
3. Apparatus in accordance with claim 2 wherein the frequency determining means includes mechanical vibratory means.
4. Apparatus in accordance with claim 2 wherein the frequency determining means includes piezoelectric means.
5. Apparatus in accordance with claim 2 wherein the frequency determining means includes an inductance coil and a condenser.
6. Apparatus in accordance with claim 2 wherein an inductance coil is connected in circuit with the condenser.
7. Apparatus in accordance with claim 2 wherein the condenser connects the inner grid electrode with the outer grid electrode.
8. Apparatus in accordance with claim 2 wherein the condenser connects the inner grid electrode with the cathode.
9. Apparatus for generating oscillations in-

cluding an electron discharge device having cathode, grid and plate or anode electrodes and having another electrode disposed between said cathode and grid electrodes, means for causing said cathode, grid and plate electrodes to generate oscillations, said means including a tunable output circuit connecting said plate and cathode electrodes, means for supplying plate voltage to said plate electrode, and impedance means directly connecting said another electrode with said cathode for rendering the frequency of said oscillations substantially independent of variations in said plate voltage.

10. Apparatus for generating oscillations including an electron discharge device having cathode, grid and plate or anode electrodes and having another electrode disposed between said cathode and grid electrodes, means for causing said cathode, grid and plate electrodes to generate oscillations, said means including a tunable output circuit connecting said plate and cathode electrodes, means for supplying plate voltage to said plate electrode, and impedance means directly connecting said another electrode with said grid electrode for rendering the frequency of said oscillations substantially independent of variations in said plate voltage.

11. Oscillation producing apparatus including a space discharge device having cathode, outer grid and plate electrodes and an inner electrode disposed between said cathode and outer grid electrodes, means for causing said cathode, outer grid and plate electrodes to generate oscillations, a tunable output circuit interconnecting said plate and cathode electrodes, means for supplying polarizing voltage to said outer grid and plate electrodes, and impedance means directly connecting said inner grid electrode with another of said electrodes for rendering the frequency of said oscillations substantially independent of variations in the polarizing voltage of one of said polarized electrodes.

12. Oscillation producing apparatus including a space discharge device having cathode, outer grid and plate electrodes and an inner electrode disposed between said cathode and outer grid electrodes, means for causing said cathode, outer grid and plate electrodes to generate oscillations, a tunable output circuit interconnecting said plate and cathode electrodes, means for supplying polarizing voltage to said outer grid and plate electrodes, impedance means directly connecting said inner grid electrode with another of said electrodes for rendering the frequency of said oscillations substantially independent of variations in the polarizing voltage of one of said polarized electrodes, and means interconnecting said outer grid and cathode electrodes for determining the frequency of said oscillations.

13. Oscillation producing apparatus including a space discharge device having cathode, plate, inner grid, and outer grid electrodes, means interconnecting said electrodes for causing said cathode, plate and outer grid electrodes to generate oscillations, means for supplying plate polarizing voltage to said plate electrode, reactance means connecting said inner grid electrode with another of said electrodes for rendering the frequency of said oscillations substantially independent of variations in said plate voltage, and output circuit tunable impedance means interconnecting said plate and cathode electrodes and having such capacitance less than that corresponding to the maximum value of the inner grid current as to render the frequency of said oscillations

lations substantially independent of substantial impedance changes in said output circuit.

14. Oscillation producing apparatus including a space discharge device having cathode, inner grid, outer grid, and plate electrodes, means for causing said cathode, outer grid and plate electrodes to generate oscillations, means for supplying plate polarizing voltage to said plate and outer grid electrodes, reactance means connecting said inner grid electrode with another of said electrodes for stabilizing the frequency of said oscillations and output circuit tunable impedance means interconnecting said plate and cathode electrodes and having such capacitance less than that corresponding to the maximum value of the inner grid current as to render the frequency of said oscillations substantially independent of substantial impedance changes in said output circuit and means interconnecting said outer grid and cathode electrodes for determining the frequency of said oscillations.

15. Oscillation producing apparatus including a space discharge device having cathode, plate, inner grid, and outer grid electrodes, means interconnecting said electrodes for causing said cathode, plate and outer grid electrodes to generate oscillations, means for supplying plate polarizing voltage to said plate electrode, reactance means connecting said inner grid electrode with another of said electrodes for rendering the frequency of said oscillations substantially independent of variations in said plate voltage, and output circuit tunable impedance means interconnecting said plate and cathode electrodes and having such reactance with respect to that corresponding to the maximum value of the inner grid current as to render the frequency of said oscillations substantially independent of substantial impedance changes in said output circuit.

16. Oscillation producing apparatus including a space discharge device having cathode, inner grid, outer grid and plate electrodes, means for causing said cathode, outer grid and plate electrodes to generate oscillations, means for supplying polarizing voltage to said plate and outer grid electrodes, reactance means connecting said inner grid electrode with another of said electrodes for stabilizing the frequency of said oscillations and output circuit tunable impedance means interconnecting said plate and cathode electrodes and having such reactance with respect to that corresponding to the maximum value of the inner grid current as to render the frequency of said oscillations substantially independent of substantial impedance changes in said output circuit and piezoelectric means interconnecting said outer grid and cathode electrodes for determining the frequency of said oscillations.

17. Oscillation producing apparatus including a space discharge device having cathode, inner grid, outer grid and plate electrodes, means for causing said cathode, outer grid and plate electrodes to generate oscillations, a grid circuit interconnecting said inner grid and cathode electrodes, and an output circuit including tunable impedance means interconnecting said plate and cathode electrodes and having such capacitance less than that corresponding to the maximum value of the current in said inner grid circuit as to render the oscillation frequency substantially independent of substantial impedance changes in said output circuit.

18. Oscillation producing apparatus including a space discharge device having plate, cathode

and a plurality of grid electrodes, and means including a tunable output circuit connected with said plate and cathode electrodes for causing said plate, cathode and one of said grid electrodes to generate oscillations, said output circuit including impedance means having such reactance less than that corresponding to the maximum value of the current in another of said grid electrodes as to render the frequency of said oscillations substantially independent of substantial impedance changes in said output circuit.

19. Oscillation producing apparatus comprising means including a space discharge device having cathode, plate and a plurality of grid electrodes, a tunable output circuit connected with said plate and cathode electrodes and a source of polarizing voltage connected with said plate and one of said grid electrodes for causing said device to generate oscillations, said output circuit including impedance means having such reactance less than that corresponding to the maximum value of the current in another of said grid electrodes as to render the frequency of said oscillations substantially independent of substantial impedance changes in said output circuit, and impedance means connected with another grid electrode for rendering the frequency of said oscillations substantially independent of variations in said voltage.

20. Oscillation producing apparatus including a space discharge device having cathode, plate, inner grid and outer grid electrodes, means interconnecting said electrodes for causing said cathode, plate and outer grid electrodes to generate oscillations, means connected with said oscillation generating electrodes for determining the frequency of said oscillations, a circuit including resistance means interconnecting said cathode and inner grid electrodes and having such resistance as to render the frequency of said oscillations substantially independent of substantial impedance variations therein, a power supply source of voltage, resistance means for supplying polarizing voltage to said outer grid electrode from said source and having such resistance as to render the frequency of said oscillations substantially independent of substantial impedance variations therein, means for supplying plate voltage to said plate electrode from said source, reactance means connecting said inner grid electrode with another of said electrodes for rendering the frequency of said oscillations substantially independent of variations in said plate voltage, and an output circuit including a tunable impedance device interconnecting said plate and cathode electrodes and having such selected capacitance with respect to that corresponding to the maximum value of current in said inner grid-cathode circuit as to render the frequency of said oscillations substantially independent of substantial impedance changes in said output circuit.

21. Oscillation producing apparatus comprising a space discharge device having cathode, inner grid, outer grid, and plate electrodes, a source of voltage connected with said cathode, connections including a tunable anti-resonant circuit connecting said plate with said cathode and said source, a circuit including a resistor connecting said outer grid with said source, a circuit including a resistor connecting said inner grid with said cathode, a circuit including a condenser connecting said inner grid electrode with another of said electrodes said condenser having such a capacitance as to render the frequency of oscillations

generated substantially independent of variations in the magnitude of the voltage of said source, and a circuit including a frequency determining device connecting said outer grid with
5 said cathode said resistors, said tunable circuit and said condenser having such relative values

of impedance as to render said frequency substantially independent of substantial impedance variations therein whereby said frequency is determined only by said frequency-determining device.

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