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S. Y. WHITE

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ELECTRICAL OSCILLATION GENERATOR

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Fig. 1.

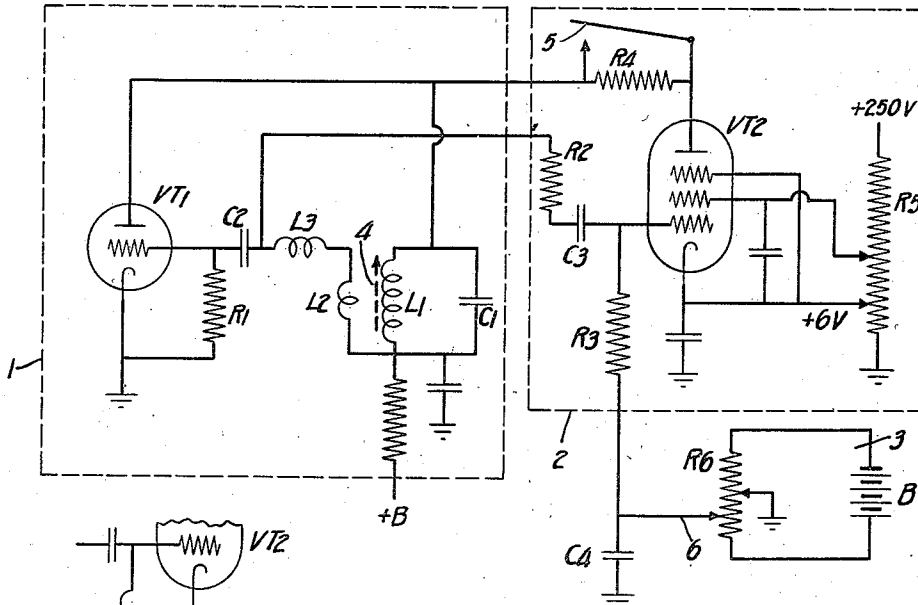


Fig. 3.

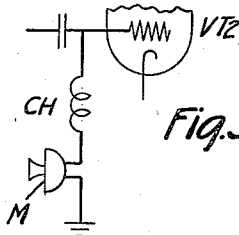
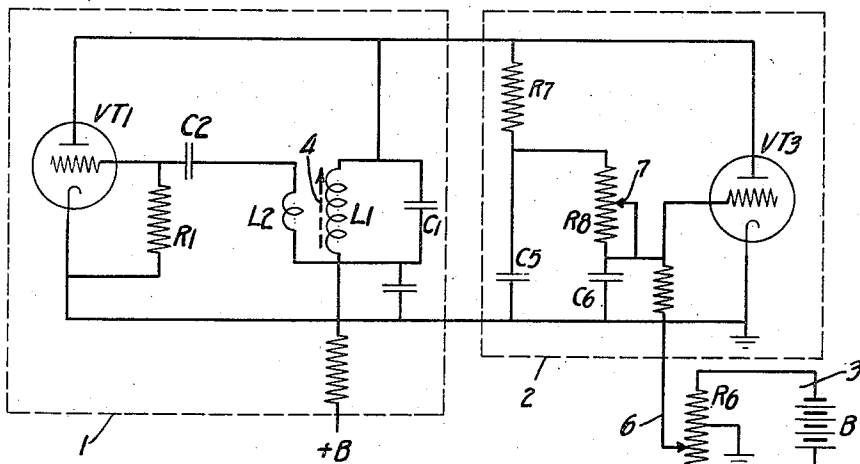


Fig. 2.



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## UNITED STATES PATENT OFFICE

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## ELECTRICAL OSCILLATION GENERATOR

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Application February 29, 1940, Serial No. 321,380

6 Claims. (Cl. 250—36)

This invention relates to a generator of electrical oscillations and more especially to such a generator adapted to generate ultra-high frequency oscillations of the order of 20 megacycles and higher. It is the purpose of the present invention to provide such a generator in the form of an electron discharge tube oscillator having a tuned circuit and an electric discharge control tube associated therewith to vary the frequency of the oscillator. An embodiment of the present invention is disclosed in connection with a superheterodyne radio receiver in my co-pending application Serial No. 321,377, filed February 29, 1940, of which the present application is a continuation in part.

A further object of the invention is to provide means whereby the control of the frequency of the oscillations is effected without correspondingly great changes in their amplitude. For this purpose the action of the control tube is made to simulate a pure reactance which imparts neither positive nor negative resistance of any considerable amount into the oscillator circuit. In the illustrated embodiment of the invention, this object is secured by providing a tuned tank, or frequency determining circuit in the plate circuit of the oscillator tube and means whereby energy may be fed from the plate circuit of the control tube into the frequency determining circuit which is 90 degrees out of phase with the energy in such circuit. Where the oscillations are generated by means of a vacuum tube whose plate circuit is tuned, grid voltage of the proper phase to sustain the oscillations may be generated by means of a tickler circuit. It is a further object of the invention to utilize the phase shift produced by the leakage inductance of the grid tickler coil in association with another phase shift to produce a voltage on the grid of the control tube which may be 90° out of phase with the energy in the tuned plate circuit. When this voltage is amplified in the control tube, it will appear in the plate circuit as a simulation of a pure reactance.

Another object of the invention is to provide means for securing the desired phase shift in the energy supplied to the frequency determining circuit by the control tube, in the form of a plurality of phase shifting elements connected in series in the grid circuit of the control tube, one of said elements constituting a resistor. The phase shift secured by the resistor is thus additive to that secured in the tickler coil and a total phase shift of 90° or more may thus be readily secured.

In any case where it may for any reason be undesirable to secure the total desired phase shift in the grid circuit of the control tube, it is a still further object of the invention to provide means in the plate circuit of the control tube for securing a portion of the total phase shift. In one illustrated embodiment of the invention, this auxiliary phase shifting means comprises a resistor having one end connected to the tuned oscillator circuit and its other end connected to the plate of the control tube. It will also be understood that the phase shifting means described may be used in any desired combinations, the total phase shift being secured in the grid circuit of the control tube or a portion only being secured in the grid circuit and the balance secured in its plate circuit. Other objects of the invention will become apparent to those skilled in the art as the description thereof proceeds. For the better understanding of the invention, however, reference is made to the accompanying drawing in which:

Fig. 1 is a schematic circuit diagram of an electron discharge tube oscillator arrangement embodying the invention;

Fig. 2 is a schematic circuit diagram of a modified form of oscillator arrangement embodying the invention; and

Fig. 3 shows schematically a modified form of input circuit for the control tube shown in Fig. 1.

Referring to Fig. 1, the invention is shown as comprising a generator 1 of electrical oscillations of ultra-high frequencies, a control unit 2 for controlling the frequency of the oscillations, and a source of control voltage 3 for varying the effect of the control unit 2. It has been found that when arranged for the generation of frequencies of the order of 100 megacycles, especial attention must be given to the design of the oscillator and its associated circuits. Experience has shown that the cathode of the oscillator tube, herein shown as VT1, must be grounded in order to eliminate heater-to-cathode cyclic effects, when the source of heater voltage is an alternating current or a direct current from the battery which also supplies a motor generator or vibrator type of plate supply voltage. At these high frequencies the grid of the tube has extremely poor admittance effects, and if attempts are made to tune the grid circuit, conditions almost invariably occur where the system will commence oscillating at a parasitic frequency determined by the constants of the plate circuit. It is, therefore, preferred to use an oscillator whose plate circuit is tuned, and a tickler circuit

provides a grid voltage of the proper phase to generate the oscillations. The resonant plate circuit may have lumped constants comprising the coil L1 and the fixed condenser C1, as shown, a variable condenser being unsuitable for tuning due to the varying L—C ratio, which gives much more stability at one end of the tuning range than at the other, thereby providing greatly exaggerated variations over the range of tuning control of the control tube. By making condenser C1 of a fixed value and varying the inductance of coil L1 so as to change its permeability, as by means of a powdered ferromagnetic core, as indicated at 4, substantially equal percentage effects of the oscillator tuning are secured throughout the range of tuning. An additional advantage of effecting the tuning of the oscillator by change of permeability lies in a more simplified switching procedure where different coils are used for tuning over different frequency ranges. Each such coil may have attached to it permanently its own tuning condenser, thus forming a circulating path of low resistance and when the oscillator is used in a superheterodyne receiver, the only switching connections required are those at the grids and plates of the tubes. It is found that the ordinary hydrogen reduced iron cores are not at all suitable for permeability tuning at frequencies of the order of 100 megacycles. However, it has been found that ferromagnetic cores known under the trade name "Aladdinite" are very satisfactory. These cores are made from a synthetically produced ferromagnetic mass powder consisting substantially wholly of magnetic oxide of iron in the form of minute particles, substantially all of which, as they appear under a microscope, are of generally rounded form. These particles are preferably molded into cores by mixing with several per cent of "Bakelite" as a binder.

The grid of the oscillator VT1 is shown as being energized through condenser C2 and coils L2 and L3 connected in series. Stable oscillators which may be calibrated to oscillate at definite frequencies are highly desirable. There is a 180° phase difference between the plate and grid voltages of the tube, and, where a tickler coil is used to provide the feed-back, this is always given a polarity such as to reverse the phase of the grid relative to that of the plate. The mutual inductance of the tickler coil with coil L1 of the tank circuit is designated as L2 and its leakage inductance by the reference character L3. Depending upon the physical placement of the component parts, the length of leads employed and numerous other factors, the ratio between these two inductances L2—L3, as well as their actual values, may vary between wide limits.

A desirable oscillator for use with a control tube in a system of this type would be one without phase angle, that is, one in which the plate energy exactly reinforces the grid energy with no reactive component. This ideal condition would require a vacuum tube which is a simple generator of negative resistance, an arrangement which may be closely approximated in practice. If the oscillator is well designed with respect to this feature, its plate supply voltage may vary within rather wide limits without substantially affecting the frequency of the oscillations generated, although their amplitude will be affected to some extent. With respect to the require-

ments of the control tube which modifies the frequency of the oscillations, these are exactly the opposite. It is desired that this generate pure reactance only and neither negative nor positive resistance. It is necessary, therefore, that the control tube be coupled into the tube circuit to be controlled in such manner that phase shifts of considerable value are secured either in the energy feed to the grid or the energy of the plate circuit, or both.

A standard means of shifting phase is to place a reactance in series with a resistance and take the voltage drop across the reactance. In practice, only a limited phase shift can occur, since a 90° shift would require an infinite resistance and a perfect reactance. In practice, approximations of 90° can be reached as a limit, but since at radio frequencies only relatively small resistances can be employed, it is only practical to secure a 60° or 70° phase shift instead of the desirable 90°. A further phase shift, however, may be secured by connecting another phase shifting network in series with the first, the second network being capable of producing an additional phase shift that can approximate 90°. Since the two phase shifting means in cascade have the possibility of approximating a 180° phase shift, it is possible to utilize a portion of each in any desired combination to produce a resultant phase shift of 90° which, of course, simulates a pure reactance.

Referring to Fig. 1 and considering the frequency determining circuit which is grounded at the lower end of coil L1, the grid receives charging current through L1. The grid current at the end of L2 is thus exactly 180° out of phase with the circulating current in L1. Before reaching the grid of tube VT1, the current must pass through some series leakage inductance, represented by L3, which produces a reactance of rather small amount, but which is quite effective due to the very heavy current flowing through it. At the grid of VT1, energy is supplied which is so phased in relation to that of the plate tank circuit as to cause the tube to oscillate. The amount of phasing due to L3 may be varied as desired by making it of the proper value, even, if necessary, by winding an additional uncoupled coil in series with the grid, or, by more loosely coupling L2, and by making this coil larger we can increase the leakage inductance to any desired amount without having any physical coil, as represented by L3. With this energy, preliminarily phased, as described, the grid energy of tube VT2 may now be further phased in the same direction by means of the circuit comprising resistor R2 and the grid-cathode capacity of the control tube VT2. It will be understood that condensers C2 and C3 are merely for the purpose of blocking the direct current and are so large that their phasing effect is negligible.

By a suitable choice of the values of L3 and R2 it is possible to produce the desired degree of reactance with a maximum stability of the oscillator and a minimum loading effect due to the connection of the control tube VT2 with the oscillator. Considerable difficulty is met with in networks of this type where the oscillator is one used in a superheterodyne receiver and is required to supply voltage to the mixer device as well as having a control tube, such as VT2, connected across it. The system is prone to be so heavily overloaded as to cease oscillation entirely, or if excessive amounts of negative resistance are generated in the control tube, parasitic oscilla-

tions are likely to occur at a frequency determined by some tuned loop, which may be almost anywhere in the system, or even coupled rather loosely to the circuit system. With the circuit arrangement described, phase relations may be established so that the control tube VT2 acts substantially as a pure reactance in controlling the frequency of the oscillations generated by tube VT1. Under these conditions the energy fed into the frequency determining circuit L1—C1 by the control tube is 90° out of phase with the circulating current in this circuit. It can be determined when this phase relationship exists by energizing the control tube and noting that the frequency changes but the strength of oscillation as evidenced by the grid current of the oscillator does not change. The phase angle may be over-controlled past 90° and we can observe the resultant resistive component as being either positive or negative by noting the change in the oscillator grid current.

Instead of securing the double phasing effect by the arrangement previously described, it may be secured in a somewhat satisfactory manner by the inclusion of a resistor R4 in series with the plate of tube VT2 and the tank circuit comprising coil L1, in which the preliminary phasing is secured by resistor R2 alone at the input of the tube and additional phasing secured in an additive sense by R4. In cases where it may be desired to eliminate the effect of resistor R4, a suitable short circuiting switch may be provided therefor, as indicated at 5.

The control tube VT2 is provided with the usual supply voltage, its inner grid being given a normal bias of approximately -6 volts by connecting its cathode to the bleeder resistor R5 at a point approximately this number of volts above ground. This permits the operation of the tube at the mid-point of its control range, as determined by plotting a curve of grid bias against oscillator frequency, which results in an S-shaped curve, so that we secure operation about the mid-point thereof. This mid-point usually occurs at about -6 volts and if this value is changed to -3 volts, the tube becomes much more effective and if changed to -9 volts, the control tube becomes practically ineffective.

The source of control voltage 3 comprises a resistor R6 connected across the terminals of a battery B, and a contact 6 adjustable along R6 and connected to the inner grid of VT2 through a circuit comprising resistor R3. By providing a voltage control on the inner grid of the control tube over a range of  $\pm 3$  volts by the adjustment of contact 6, the oscillator frequency may be varied over the desired range of frequencies.

In the operation of the oscillator device, the adjustable contact 6 is adjusted until the grid bias of the inner grid of control tube VT2 has a normal value of approximately -6 volts. The oscillator frequency is then adjusted to approximately the correct value by adjustment of the permeability tuning control 4. Adjustment of the oscillator frequency to a higher or lower value through the action of the control tube may then be readily effected by adjustment of the contact 6 along resistor R6. The output of the oscillator may be utilized in any desired manner where radio frequency carrier currents are required as, for example, in connection with the mixing device of a superheterodyne receiver, or by impressing audio modulations on the grid of the control tube, a frequency modulated transmitter is provided.

Fig. 2 shows a modified form of the invention

in which an alternative arrangement for securing the desired 90° phase shift is provided. In this arrangement a phase shift of, for example, 70°, may be secured in the circuit comprising the series connection of resistor R7 and condenser C5 and a further phase shift of the order of 70° in the same direction secured in the circuit comprising the series connection of resistor R8 and condenser C6. It is thus possible to pick out a resistance value of resistor R8 by means of the adjustable contact 7 which gives the desired 90° phase shift and the control tube VT3 will then act as a pure reactance connected across the frequency determining circuit comprising L1 and C1. As in the case of Fig. 1, the degree of control of the frequency generated is regulated by varying the grid voltage of the control tube by means of the adjustable contact 6. Since the resistors R7 and R8 must be given very large values in order to produce the required phase shifts, the voltage available for operating the grid of the control tube is reduced to such a low value that only a small control of the plate current is secured and hence only a very limited degree of frequency control is possible.

Several oscillator-control tube combinations are well known in the art, and all the suitable ones were carefully investigated at 150,000 kilocycles. It was found that ranges of control did not exceed 0.4 per cent and the action of the control tubes quenched the oscillator. With the arrangement herein shown in Fig. 1, control ranges of 2 per cent were obtainable without quenching the oscillator or generating parasites.

Fig. 3 shows a modified form of input circuit for the control tube VT2 of Fig. 1 to provide for frequency modulation of the oscillator output. This circuit comprises a microphone M connected to the inner grid of the control tube through the choke coil CH. In the operation of this form of the invention, the output of the oscillator tube is frequency modulated in accordance with the voice modulations impressed on the microphone. The tank circuit of the oscillator may be coupled to a transmitting antenna (not shown) by any known type of transmission line.

I have described what I believe to be the best embodiments of my invention. I do not wish, however, to be confined to the embodiments shown, but what I desire to cover by Letters Patent is set forth in the appended claims.

#### I claim:

1. Means for generating electrical oscillations including, in combination, an electron discharge tube oscillator having a frequency determining circuit, an electron discharge control tube having its plate connected to said circuit, and means coupling the control tube and the frequency determining circuit including a plurality of phase shifting elements so arranged as to be capable of feeding energy from the control tube into the frequency determining circuit which is 90° out of phase with the energy in said circuit, one of said phase shifting elements consisting of an impedance connected in series between the plate of the control tube and the high potential side of the frequency determining circuit.

2. Means for generating electrical oscillations including, in combination, an electron discharge tube oscillator having a frequency determining circuit, a circuit connected to the grid of the oscillator tube including a feed-back coil coupled to said frequency determining circuit, an electron discharge control tube having its plate connected to the frequency determining circuit, and

means coupling the control tube and the frequency determining circuit so arranged as to be capable of feeding energy from the control tube into the frequency determining circuit which is 90° out of phase with the energy in said circuit, said coupling means comprising a coil connected in series with the feed-back coil.

3. Means for generating electrical oscillations including, in combination, an electron discharge tube oscillator having a frequency determining circuit, a circuit connected to the grid of the oscillator tube including a feed-back coil coupled to said frequency determining circuit, an electron discharge control tube having its plate connected to the frequency determining circuit, and means coupling the control tube and the frequency determining circuit so arranged as to be capable of feeding energy from the control tube into the frequency determining circuit which is 90° out of phase with the energy in said circuit, said coupling means comprising a coil and resistor connected in series with the feed-back coil.

4. Means for generating electrical oscillations including, in combination, an electron discharge tube oscillator having a frequency determining circuit, a circuit connected to the grid of the oscillator tube including a feed-back coil coupled to said frequency determining circuit, an electron discharge control tube, a circuit comprising a resistor connecting the plate of the control tube to the frequency determining circuit, and additional means coupling the control tube and the frequency determining circuit so arranged as to be capable of feeding energy from the control tube into the frequency determining circuit which is 90° out of phase with the energy in said circuit, said additional coupling means compris-

ing a coil connected in series with the feed-back coil.

5. Means for generating electrical oscillations including, in combination, an electron discharge tube oscillator having a frequency determining circuit, a circuit connected to the grid of the oscillator tube including a feed-back coil coupled to said frequency determining circuit, an electron discharge control tube, a circuit comprising a resistor connecting the plate of the control tube to the frequency determining circuit, and additional means coupling the control tube and the frequency determining circuit so arranged as to be capable of feeding energy from the control tube into the frequency determining circuit which is 90° out of phase with the energy in said circuit, said additional coupling means comprising a resistor connected in series with the feed-back coil.

6. Means for generating electrical oscillations including, in combination, an electron discharge tube oscillator having a frequency determining circuit, a circuit connected to the grid of the oscillator tube including a feed-back coil coupled to said frequency determining circuit, an electron discharge control tube, a circuit comprising a resistor connecting the plate of the control tube to the frequency determining circuit, and additional means coupling the control tube and the frequency determining circuit so arranged as to be capable of feeding energy from the control tube into the frequency determining circuit which is 90° out of phase with the energy in said circuit, said additional coupling means comprising a coil and resistor connected in series with the feed-back coil.

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