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ULTRA HIGH FREQUENCY OSCILLATOR

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FIG. 1

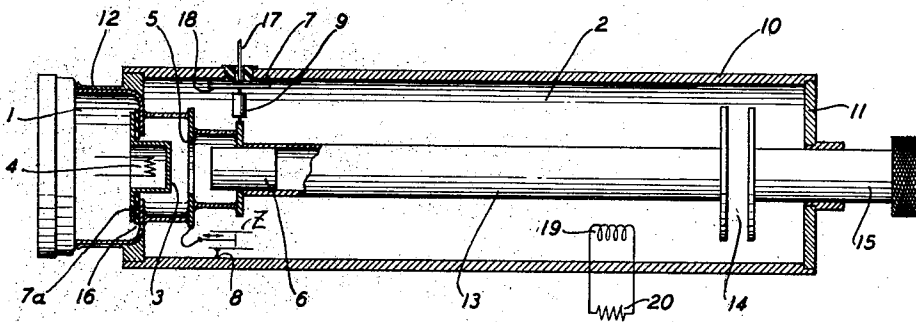
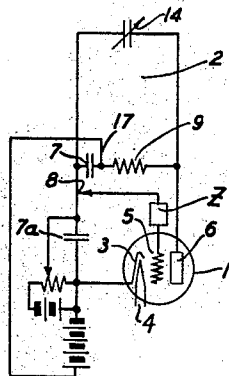


FIG. 2



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ULTRA HIGH FREQUENCY OSCILLATOR

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6 Claims. (Cl. 315-4)

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This invention relates to ultra-high frequency oscillators and particularly to means adapting its lower frequency prototype circuit, which embodies the conventional use of a space charge triode and a regenerative coupling between its output and input circuits, to efficient operation at the extremely high frequencies here concerned, which are in the centimeter range.

The generic object of the invention, conformable to the above, is to provide a simple but efficient feedback amplifier within the ultra-high frequency range. More specific objects will be given, as having greater pertinency and meaning at that place, following a brief description of the invention in the aspects which are deemed patentably novel.

In the operation of oscillators in the ultra-high frequency range it has been found that circuits having distributed constants are superior to lumped constant circuits for frequency determination, feedback coupling, and the like. The present invention employs a cavity resonator, as the term is generically used, and the requirements may be satisfied by various forms of the same of which a section of coaxial conductor is presently favored. Such a form of cavity resonator, sometimes denominated "coaxial cavity" and sometimes merely by the term "coaxial," comprises in a simple form, as adapted for present purposes, a hollow cylindrical outside conductor or shield element having closed ends and a co-operating inner conductor which is coaxial with the same and connected, through a capacitance, at one end with the closure element of the outside conductor, leaving the other end insulated.

The teachings of the present invention make possible the use of a single cavity resonator with the electrode enclosing part of the space charge triode tube within its envelope. The tube has its electrodes related to the resonator in the specific manner that confers novelty and utility, in a patentable sense, on the invention. The idea of a single cavity is significant since prior practice, and the more obvious practice would provide two cavity members, one between the cathode and control electrode and the other between the control electrode and anode. The above resonator-electrode relations are satisfied for the present single cavity oscillator by positioning the tube adjacent one end of the resonator, namely, that end adjacent the insulated end of the inner conductor, and by an alternating current connection from the cathode to the near end of the outer conductor, a similar connection from the anode to the free end of the inner conductor and a like-

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wise similar connection through a general impedance Z to be described from the control electrode to the inner cylindrical wall element of the outer conductor at a point spaced from the closure elements thereof at relative distances depending on conditions for most effective operation.

One result of the connections as above, as is indicated by the simplified schematic to be described in detail later, is that the circuit is a variant of the conventional Hartley feedback oscillator, differing to the extent that the connections of the cathode and control electrodes have been inverted as compared thereto so that the cathode is connected to the end of the inductance instead of to an intermediate point thereon. The reason for this expedient, and the structure of the invention which makes possible its effective realization, is that at the extremely high frequencies concerned the electron transit time from cathode to anode becomes of significance in relation to the cycle time of the resultant characteristic oscillations, instead of having an insignificant relative value as in the prior art relating to otherwise similar devices operating at lower frequencies.

The Hartley circuit in mind is well disclosed in United States Patent 1,356,763, October 26, 1920. The positioning of a cathode tap intermediate the anode and control electrode taps of the Hartley circuit results in a phase reversal attending the regenerative feedback from the output to the input circuit of the tube, which compensates for the inherent 180-degree phase shift in the tube itself, and therefore makes possible the 360-degree (or, which amounts to the same thing, an effective 0-degree) phase shift in the round trip path as a whole which is necessary in order to perpetuate the effects of a given impulse at the anode by the cyclical recurrence of successive impulses in like phase at that point. However, at the high frequencies here concerned the relatively long electron transit time itself tends to compensate for the inherent phase shift of the tube so as to make possible an optimum feedback without complete phase reversal in the external circuit. It is necessary to add some phase shift, depending on the frequency range, for example, as would be provided by impedance Z to be described. Another illustration of this particular expedient, although not practiced in the same electrical and structural environment as in the present instance, may be seen in Fig. 3 of United States patent to Heising 2,068,324, January 19, 1937. An example of a type of tube,

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which is well adapted for the present purpose is the General Electric tube known as the GL-446. Although this tube is characterized by small spacings between electrodes and therefore by as small transit times as may be achieved by tube design, the invention is not limited to the use of tubes which are extreme as to interelectrode spacing.

Although it is characteristic of the circuit of the invention that it lends itself well to the above expedients, that is, the achievement of an optimum phase condition and the use of a single cavity resonator, the invention, especially as to the relation of the tube elements to the surrounding coaxial cavity, has other characteristics which distinguish it from the prior art and which promote the above generic object of the invention. The positioning of the electrode enclosing part of the tube within the structure which simulates the usual frequency determining circuit not only promotes conservation of space and physical and electrical protection for the tube but even makes possible an efficient organization as a whole by preventing undesirable radiation and coupling effects on account of the tube elements themselves and their connections. The particular ordering of the connections of the tube electrodes to the coaxial cavity makes this possible besides making possible the above avoidance of phase reversal. It should be noted that the avoidance of such phase reversal as achieved by said ordering, even at these very high frequencies and with the indicated tube, is not necessary since the requisite 360-degree over-all phase shift could be achieved in other ways.

The prime advantages of the single cavity oscillator as distinguished from a double cavity oscillator, appear to derive from the mechanical simplicity obtainable. The fact that but one frequency determining circuit is used makes possible frequency adjustments by a single simple control. Moreover, the absence of any other frequency determining elements precludes the possibility of a hopping back and forth from one frequency to the other as has been postulated as a cause of blocking for some double cavity oscillators.

Consistently with the above statement of the characteristics of the invention, a more specific object of the invention is to achieve an ultra-high frequency oscillator using a single cavity resonator with the benefits tending to be conferred thereby as just enumerated and more particularly where the whole tube structure is enclosed in said single resonator with the additional benefits thereby conferred having to do with conservation of space and resultant physical and electrical protection for said tube, as well as avoidance of undesirable radiation and coupling effects, also as above enumerated.

This invention can be more readily understood by reference to the following detailed description of one embodiment as shown in the drawing in which:

Fig. 1 is an elevation, partly in section, of a practical embodiment of the invention; and

Fig. 2 is a simplified schematic to illustrate the equivalent electric circuit of the invention.

With reference to either figure, the oscillator comprises, in general, the space charge triode tube 1, the frequency determining circuit or structure 2, and the accessory and constituent elements to be described and enumerated. In Fig. 2, in which similar elements are designated similarly as in Fig. 1, the tube 1 is shown as a conventional space charge triode comprising the

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cathode 3 shown partially diagrammatically with its heater 4 whose source is not shown, control electrode 5, and anode 6. Batteries, or other equivalent direct potential sources, are shown associated with these electrodes in conventional manner. The frequency determining coaxial conductor, which is otherwise conventional, is shown connected to the tube electrodes in an unconventional manner, at least when thinking of the prototype low frequency circuit, in that the portions of the coil comprised in the same which are specific to the input and output circuits of the tube, overlap and are related in such a way that there is no phase reversal in the feedback from the anode to the control electrode. This results from the connection of the cathode instead of the control element, to the end of the effective coil element, shown in schematic Fig. 2 as a conductor of a transmission line simulating the inductance element of the coaxial of Fig. 1. The significance of this circuit arrangement is as pointed out in the statement of invention. That is, the control electrode lead terminates in a tap 8 (best shown in Fig. 2) movable on the effective inductance element of the frequency determining circuit 2. The position of the tap determines the degree of feedback. In practice this tap is adjusted for maximum power output. This lead includes an impedance Z shown in block. This impedance provides means for phase adjustment, as pointed out in the statement of invention. Its character depends upon the frequency and hence upon the phase shift needed. It may be, for example, an RC circuit or a coaxial adjustable stub. In some instances a simple wire connection is adequate. In Fig. 1 a coaxial adjustable stub is shown. The resistance element 9 is a high frequency resistance through which the anode current is supplied without short-circuiting the frequency determining circuit. For this reason it should be of a high value and low loss so as not to absorb energy from said circuit. Condenser 7 is for the purpose of preventing any high frequency currents which are induced in resistance 9 from flowing outside to some non-useful load. To this end resistance 9 may be constituted by a sputtered Pyrex rod as is indicated in Fig. 1 better than in Fig. 2. The resistance element 9 and its blocking condenser 7 may be placed at any convenient point along the line so long as its high frequency impedance is large as compared to the impedance of the line at that point. Electrically it should be placed at the lowest impedance point for it to have least effect on the high frequency behavior.

In Fig. 1 the structural elements of the oscillator are shown with the same labeling as in Fig. 2. It is evident from the showing of the tube 1 that it is adapted for its purpose here disclosed, or the like, although it should be understood that the invention in its patentably novel aspects has no relation to the particular structure of the tube and widely varying forms of the tube could be used. The particular tube here shown might well be the General Electric tube known by the designation GL-446 which is well adapted for connection to a cavity resonator because of the relative directions of extension of the electrodes, their respective configurations, and the like. The equivalent frequency determining circuit is constituted by the coaxial comprising shield or outer conductor element 10 closed at the end remote from the tube by closure element 11 and, at the tube end, by the metallic member 12 of the tube to which it may be attached by frictional means

or the like. The inner conductor of the coaxial is indicated by reference numeral 13. It is divided near its end remote from the tube to constitute a variable condenser 14 which simulates the tuning condenser similarly identified in Fig. 2, although in the absence of a condenser the circuit would operate by reason of the equivalent interelectrode capacitances of the tube except that unless this expedient were used it might be difficult to achieve the desired frequency. Alternatively, the condenser could be dispensed with in favor of a variable length cavity. This alternative is deemed too obvious and simple to require illustration. This condenser is made operative by the manually operated slidable, or trombone, operating member 15. The cathode is made an integral part of the associated structure by the particular mounting shown in which it is insulatingly separated by means 16 from the metallic element 12 of the tube which is electrically integral with the coaxial. This provides an alternating current connection between the cathode and grid or frequency determining circuit while maintaining a direct current separation therebetween. The resultant equivalent capacitor is indicated by the label 7a, this being indicated in Fig. 2 as well. The anode supply is shown in Fig. 1 as coming from a circuit terminating at 17 where it is connected to the high frequency resistance element 9. An alternating current connection between the junction of the anode source and resistance 9 on the one hand and the coaxial cavity on the other hand is achieved by the condenser action between the inner surface of the outer conductor 10 and the condenser electrode-simulating element 18, the equivalent condenser being identified as 7. For the sake of simplicity no means are shown in Fig. 1 for applying a biasing potential to the control electrode as shown in Fig. 2. Said control electrode is shown directly connected to the coaxial through impedance Z, as in Fig. 2, although in Fig. 1 this impedance is shown in one of its specific forms, namely, as a coaxial adjustable stub. An energy take-off for a load is shown schematically by output coil 19 magnetically coupled to the coaxial and connected to load simulating resistance 20.

It appears from the above-detailed description that an oscillator having the circuit characteristics as illustrated by Fig. 2 has been constituted by the structure disclosed in Fig. 1 comprising a space charge triode which is completely enclosed in the coaxial cavity and having its respective electrodes connected in a particular manner to the elements of said coaxial cavity.

Although a certain specific embodiment of the invention has been shown and described, it will be understood, of course, that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A regenerative electron tube oscillator comprising, an electron tube having an electrode enclosing part including a cathode and two cold electrodes, and a single cavity resonator which, in combination with the interelectrode capacitances of the tube, constitutes a parallel resonance inductor-capacitor circuit for determining the frequency of said oscillator, at least the electrode enclosing part of said tube being within said resonator and constituting a closure means at one end thereof, the cathode being connected to said end, a substantial portion of the inductor-

capacitor circuit being directly coupled between said cathode and one of said cold electrodes and the other cold electrode being connected to the inductor portion of said resonator intermediate the above said connection points of the cathode and first-mentioned cold electrode.

2. An ultra-high frequency oscillator comprising, a space charge triode tube having an electrode enclosing part including a cathode and two cold electrodes, and a single coaxial cavity resonator, at least the electrode enclosing part of said tube being within the outer boundaries of the cavity resonator and effectively constituting a closure means at one end thereof, and the cathode and one cold electrode thereof being directly coupled to the cavity resonator at points between which substantial alternate potentials occur during the operation of the oscillator, and the other cold electrode being connected to a point of the resonator intermediate thereof.

3. The oscillator recited in claim 1 in which said triode tube comprises, a cathode, a control electrode and an anode, of which the cathode and anode provide the recited connections to the inductor-capacitor circuit, the control electrode being connected to a point of the resonator intermediate the cathode and anode connection points.

4. An ultra-high frequency oscillator comprising, a space charge triode including a cathode, and a grid and anode aligned therewith, a single coaxial cavity resonator including an outer hollow cylindrical conductor substantially closed at either end and a coaxial inner conductor comprising spacially separated portions effectively providing a gap intermediate its ends, said inner conductor being connected at one end to one end of the outer conductor and having its other end electrically insulated from said outer conductor, said triode tube constituting a closure means for the other end of said outer conductor, at least the electrode enclosing part of said tube being within said outer conductor of the coaxial cavity resonator, a direct coupling from the anode to the insulated end of the inner conductor, a direct coupling from the cathode to the end of the outer conductor which is opposed to said insulated end of the inner conductor, and a connection from the control electrode to a point on the inner surface of the outer conductor intermediate the ends thereof.

5. The oscillator recited in claim 4 including means mounting said spacially separated portions of the inner conductor and adapted to permit relative motion therebetween and including an actuating means for at least one of said portions whereby to vary the length of said gap and therefore the capacitance between said portions.

6. An ultra-high frequency oscillator comprising, a space charge triode tube having a cathode, a control electrode and an anode, a single coaxial cavity resonator comprising an outer hollow cylindrical conductor enclosed at each end and a concentric inner conductor comprising spacially separated portions effectively providing a gap intermediate its ends, said inner conductor being connected at the one end to a given end of the outer conductor and with its other end, which is electrically insulated from said outer conductor, extending a distance substantially short of the opposite end of the outer conductor, said triode tube being mounted inside the outer conductor, constituting a closure means at said opposite end of the outer conductor and within the space between the insulated end of

the inner conductor and the opposed end of the outer conductor, said tube having its cathode adjacent said opposite end of the outer conductor and its anode adjacent said insulated end of the inner conductor, means providing direct couplings between said cathode and anode and the next adjacent parts of the coaxial cavity resonator, and a similar coupling from the control electrode to the inner wall of the outer coaxial conductor intermediate the ends thereof.

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