

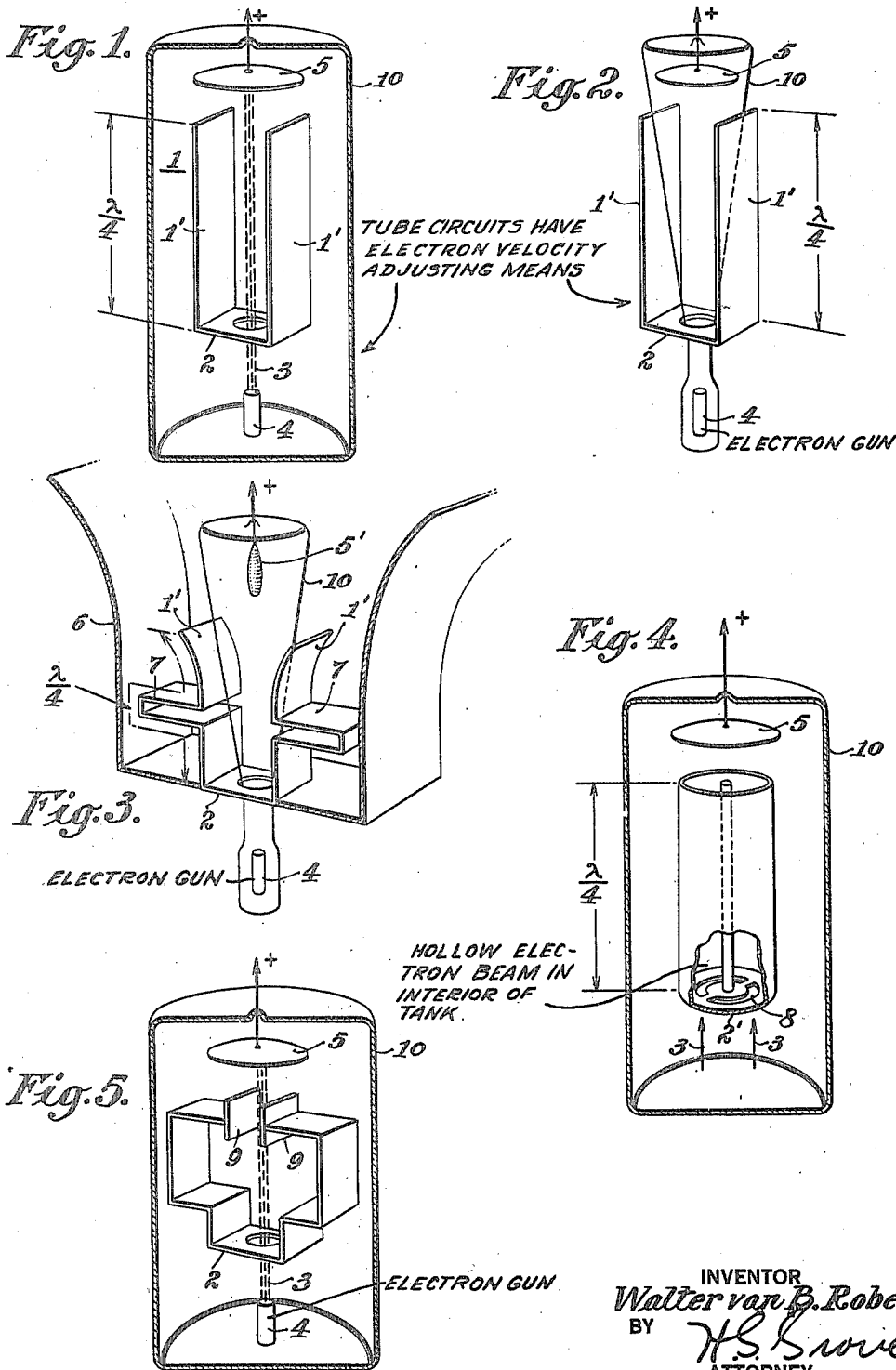
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ULTRA HIGH FREQUENCY OSCILLATOR

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ULTRA HIGH FREQUENCY OSCILLATOR

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The present invention relates to improvements in ultra high frequency oscillators.

It is known in the art to velocity modulate or otherwise effectively break up into groups an electron beam and to cause the beam (so grouped) to traverse a portion of space associated with a tank circuit, more or less along at least some of the lines of force thereof, in which an alternating electric field exists, and to collect the emerging beam on a separate electrode. If the grouping of the electrons corresponds to the natural frequency of the tank circuit, alternating power is absorbed from the electron beam by the tank, while the actual electrons all go to the collector. This collector may be relatively large so as to dissipate the heat created by electron impact. Such a known arrangement is referred to in the art as an inductive output tube and is described in an article by A. V. Haef, published in "Electronics," February, 1939, and in an article by A. V. Haef and L. S. Nergaard, published in the "Proc. of the I. R. E.," March, 1940.

It is also known in such a system to maintain oscillations by utilizing the electrostatic field resident in another portion of the tank or in a separate circuit coupled thereto to cause the aforesaid electron grouping, as by feed-back effects. In the simplest form of tank circuits, however, namely, in the concentric line having a length equal to one-quarter of the length of the operating wave and short-circuited at one end, this last known scheme cannot be used without the addition to the quarter wave tank of further circuit elements. This last form of tank circuit is characterized by a single fundamental degree of freedom.

In accordance with the present invention, the dimensions of the tank circuit are minimized and the construction thereof simplified by utilizing the magnetic field associated with a part of the tank structure for controlling the direction of the electron beam and abstracting power from the beam not in virtue of grouping of the electrons but as a result of transverse deflections thereof.

The preferred embodiment of the invention is an ultra high frequency oscillator comprising a tank circuit having associated therewith a space in which there is a relatively strong magnetic field due to oscillations in the tank and a relatively weak electrostatic field, and another space characterized by a relatively weak magnetic field but a relatively strong electrostatic field, and an electron beam or stream arranged to traverse said spaces in the order named, and furthermore to traverse both of said fields substantially normally to at least a portion of the lines of force of each, and finally a collector electrode sepa-

rate from said tank for collecting said electron beam after its passage through the said fields.

The detailed operation of the invention, however, will best be understood by reference to the accompanying drawing, wherein:

Fig. 1 shows the invention in its simplest form;

Fig. 2 shows a modification of the system of Fig. 1, wherein the tank itself is not required to be within the evacuated envelope;

Fig. 3 shows a further modification of the form of tank circuit and also an associated horn type of wave radiator;

Fig. 4 is a further modification of the invention employing a concentric line type of resonator or tank; and

Fig. 5 shows another modification which the tank circuit may take.

Referring now to Fig. 1, there is shown within an evacuated envelope 10 a quarter-wave

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tank I composed of two strip or ribbon shaped conductors 1', 1' connected together at one end by a metallic member 2 having an aperture therethrough for the passage of the electron beam 3 emanating from gun 4. Gun 4 may be a cathode or any suitable element for producing and projecting a stream of electrons. Member 2 is of good electrically conducting material and is located at a voltage nodal point of the tank. An electrode 5 serves to collect the electron beam after it has traversed the length of the tank. The theory of operation will now be given: Let us assume oscillations to be present starting from inevitable infinitesimal random causes and building up to a limiting amplitude (as is the case where the feed back mechanism is effective at small amplitudes); and let us assume, furthermore, that the electron beam velocity has been adjusted so that the time of flight through the tank is a half period of the oscillation. The time of flight may be made a multiple of this value, but for simplicity of explanation a half period of time of flight of the electrons will be assumed. Let us now consider an electron which passes through the aperture in member 2 at time t , the instant when the tank current is maximum. Since at this instant the magnetic field between the two conductors 1', 1', is a maximum and is perpendicular to the plane including the longitudinal center line of the two strip conductors 1', 1' (i. e., plane of the paper), the electron will be deflected sideways toward one or the other of the conductors 1', 1'. Assume that the deflection is to the right. A half period later the electron will therefore pass the open end of the tank, and the potential of the open ends of the tank will be at zero. Suppose for the mo-

ment that the potential of the right end had been negative just prior to the emergence of the electron from the tank and that this potential changes to positive immediately thereafter. A suitable adjustment of the time of flight will always be possible that will make the potential of the end of the tank nearest to which the electron passes change in the sense stated above as the electron passes. In any case, the phase of this change can always be reversed by giving the pair of conductors a half twist between the two ends of the tank; or, what amounts to the same thing, by criss-cross connecting the two open ends of the tank to the two shorted ends thereof in order to obtain this relation. Thus, it will be seen that the electron in departing from the center line as it approaches the end of the tank, has been travelling against the crosswise force acting upon it and has been slowed down. After the electron emerges from the tank and approaches the collector electrode 5, it also moves against the potential gradient, since the potential of the end of the tank reverses just as the electron passes. Thus, energy is absorbed from the electron into the tank and tends to reinforce the oscillations assumed therein. Similarly, it may be shown that an electron passing the aperture in plate member 2 half a period later will also give up energy to the tank. In the ideal case, the greatest efficiency would be obtained by permitting the beam to pass the aperture only during short intervals in the vicinity of the successive times when the tank current is maximum, in a manner analogous to the flow of space current of a class C vacuum tube amplifier of the usual type. Even without recourse to any such expedient, the integrated exchange of energy over a whole cycle between the beam 3 and the tank 1 gives a net increase of tank energy at the expense of electron energy, thus maintaining oscillations if the tank losses per cycle are kept less than the energy fed back per cycle.

In the tank of Fig. 1, there is a relatively strong magnetic field and a weak electrostatic field in the vicinity of the short circuiting member 2, and a weak magnetic field and a strong electrostatic field in the vicinity of the open ends of the tank circuit. Thus, it will be apparent that the electrons in their travel pass first through the strong magnetic field with its corresponding weak electrostatic field and then through the weak magnetic field and the strong electrostatic field.

Fig. 2 shows how the electron beam and the collector electrode may be contained in an evacuated glass tube 10 which extends between the tank members. This construction of having the tank members 1', 1' outside the envelope avoids the necessity of degassing the tank elements.

Fig. 3 shows a modified tank structure and also an associated horn structure for promoting radiation of waves in a desired direction. As to the tank, the side members 1', 1' are folded at 7 so as to decrease the distance the beam charges must travel in going from the preponderantly magnetic field portion of the tank to the preponderantly electrostatic portion while keeping the natural frequency of the tank unaltered. This permits operating the electron beam at lower velocities. The open ends of the tank sides 1', 1' may also be bent apart, as shown, to promote radiation from the tank or may be bent together to reduce radiation, if desired, in the manner shown in Fig. 5. Fig. 3 is also provided with a metal rectangular or cylindrical box 6 enclosing the tank 1', 1'. This box has expand-

ing dimensions and forms a horn type radiator for the power flowing out as radiation from the end of the tank. The collector electrode 5' is here arranged to have such a shape as not to interfere with the radiation from the tank.

Fig. 4 shows a two conductor type of tank circuit embodying the same principles of the invention. In this figure, the tank is a quarter wave

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concentric affair of a single degree of freedom having in its short circuiting member 2' a substantially annular slot 8 which is broken by a few radial connections between the inner and outer conductors. The electrons pass through the slot 8 and may emanate from the gun as a hollow tubular electron beam.

In Fig. 5 the tank circuit strips are connected together at one end by an apertured member which permits the electrons to enter therein, and have at their other ends a pair of plates 9, 9 to permit the electrons to emerge.

What is claimed is:

1. The method of sustaining oscillations in a single tank circuit having static and magnetic fields produced by said oscillations, the magnetic field being preponderant in one portion only of the tank and the electric field being preponderant in another portion only of the tank, which comprises passing a beam of charges through said fields in succession in the order named in a direction such that the chief component of each of said fields is transverse to the said beam, and collecting the beam emerging from said fields.

2. In an oscillator, a single resonant tank circuit therefor which is characterized by static and magnetic fields preponderantly associated respectively with different portions of the tank circuit, said magnetic field portion comprising a closed conductor having an aperture in the center thereof, said tank circuit being formed of two substantially parallel conductors, means for causing electrons in the form of space current to pass through said aperture and between said conductors over the entire length of said tank circuit to thereby traverse said fields in succession, said tank circuit having such dimensions that the motion of said electrons is controlled by the first of said fields to be traversed and the reaction between said controlled electrons and said other field transfers oscillatory energy from said electrons to said tank circuit.

3. A single resonant electrical tank having a closed end and a single open end and characterized by a transverse magnetic field preponderantly associated with the closed end and an electric field preponderantly associated with the open end, means for projecting a beam of charges through said magnetic field in the region where the lines of force thereof are transverse to the direction of the beam and then for projecting said beam transversely through said electric field, and means for adjusting the velocity of said beam to cause power to be absorbed by way of said electric field by said tank.

4. In an oscillator, an oscillatory circuit comprising a pair of conductors electrically connected together at one end and open at the other end, said conductors each being effectively one-quarter of a wavelength long at the operating frequency, means for projecting a beam of charges through said oscillatory circuit from said closed end to

said open end, and means for collecting the charges emerging from the open end of said oscillatory circuit, the time of flight of the charges through said oscillatory circuit being substantially an integral multiple including unity of a half period of the oscillation, whereby the magnetic field produced by the oscillatory energy in said oscillatory circuit deflects said beam and energy is absorbed from the charges in said beam as they emerge from the open end of said oscillatory circuit for reinforcing the oscillations in said oscillatory circuit.

5. An oscillator in accordance with claim 4, characterized in this that each of said conductors is folded in order to decrease the distance said beam travels through said tank.

6. An oscillator in accordance with claim 4, characterized in this that the oscillatory circuit is in the form of a coaxial resonator and that the beam of charges takes the form of a hollow tubular electron stream.

7. A resonant electrical tank having a magnetic field preponderantly associated with one portion and an electrical field preponderantly associated with another portion, said one portion comprising a closed end having an aperture therein, means for projecting a beam of charges through said aperture and then transversely through said electric field, whereby said charges travel transversely through both of said fields in succession, and means for adjusting the velocity of said beam to cause power to be absorbed by said tank from said beam.

8. In an oscillator, an oscillatory circuit comprising a pair of ribbon-like conductors extending in the same general direction for the greater part of their lengths and electrically connected together at one end and open at the other end, said conductors each being effectively one-quarter of a wavelength long at the operating frequency, means for projecting a beam of charges between said conductors from said closed end to said open end, and a collector electrode for collecting the charges emerging from the open end of said oscillatory circuit, the time of flight of the charges through said oscillatory circuit being substantially an integral multiple including unity of a half period of the oscillation, whereby the magnetic field produced by the oscillatory energy in said oscillatory circuit deflects said beam and energy is absorbed from the charges in said beam as they emerge from the open end of said oscillatory circuit for reinforcing the oscillations in said oscillatory circuit.

9. An oscillator in accordance with claim 8, characterized in this that an evacuated envelope surrounds said oscillatory circuit, said beam projecting means, and also said collector electrode.

10. An oscillator in accordance with claim 8, characterized in this that an evacuated envelope surrounds said beam projecting means and said collector electrode, and is located between the conductors of said oscillatory circuit.

11. An oscillator comprising a single oscillatory circuit in the form of a pair of substantially parallel conductors connected together at one end by a metallic plate and open at the other end, said plate having an aperture therein, an electron gun outside of said oscillatory circuit and at one end thereof for projecting a beam of electrons through said aperture, a collector electrode also outside said oscillatory circuit and at the other end thereof for collecting the electrons traversing the length of said circuit, said conductors having such

length that there exists a strong magnetic field and a weak electrostatic field in the vicinity of said plate and a weak magnetic field and a strong electrostatic field in the vicinity of the open end of said oscillatory circuit, the chief component of each of said strong fields being transverse to the direction of travel of said beam, and the velocity of the electrons in said beam being such that said beam in its travel passes through both of said strong fields in succession.

12. A resonant electrical tank having a single fundamental degree of freedom and characterized by a field preponderantly magnetic associated with one portion and a fluid preponderantly electric associated with another portion, said magnetic field portion comprising a closed conductor having an aperture therein, means for projecting a beam of charges through said aperture and then transversely through said electric field, whereby said charges travel transversely through both of said fields in succession, and means for adjusting the velocity of said beam to cause power to be absorbed by said tank from said beam.

13. A resonant electrical tank having distributed inductance and capacity and inherently having associated with one portion a field which is preponderantly magnetic, and with another portion a field which is preponderantly electric, said magnetic field portion comprising a closed conductor having an aperture therein, and means for projecting a beam of charges through said aperture and then transversely through said electric field, whereby said charges travel transversely through both of said fields in succession, the length of said tank being so related to the velocity of the charges that power is absorbed from the beam at the natural frequency of the tank.

14. A resonant electrical tank having distributed inductance and capacity and inherently having a magnetic field preponderantly associated with one portion, and an electrical field preponderantly associated with another portion, means for projecting a beam of charges transversely through said fields in the order named, the length of said tank being so related to the velocity of the charges that power is absorbed from the beam at the natural frequency of the tank, and a horn type radiator surrounding said tank and having dimensions expanding from the preponderantly magnetic field portion to the preponderantly electric field portion.

15. In an oscillator, an oscillatory circuit comprising a pair of conductors electrically connected together at one end and open at the other end, said conductors each being effectively one-quarter of a wavelength long at the operating frequency, means for projecting a beam of charges through said oscillatory circuit from said closed end to said open end, and means for collecting the charges emerging from the open end of said oscillatory circuit, the time of flight of the charges through said oscillatory circuit being substantially an integral multiple including unity of a half period of the oscillation, whereby the magnetic field produced by the oscillatory energy in said oscillatory circuit deflects said beam and energy is absorbed from the charges in said beam as they emerge from the open end of said oscillatory circuit for reinforcing the oscillations in said oscillatory circuit, and a horn type radiator surrounding the conductors of said oscillatory circuit and having dimensions expanding from the connected end of the conductors to the open end thereof.

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