May 14, 1935. C. W. HANSELL 2,001,133

HIGH FREQUENCY OSCILLATOR

Filed July 28, 1930

Fig. 1

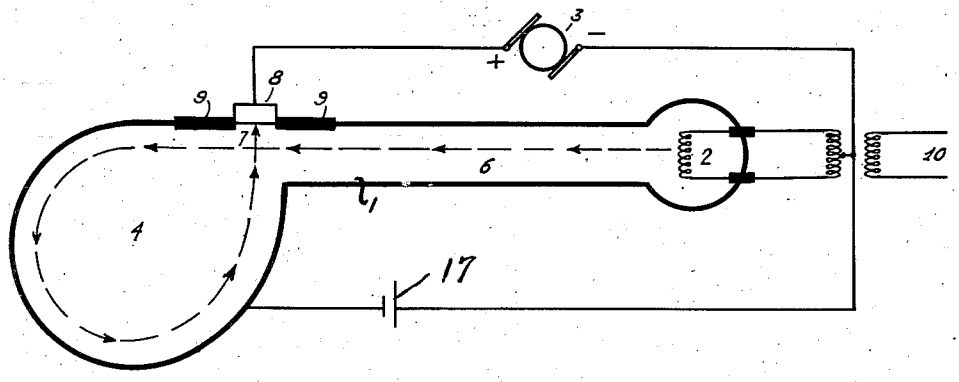


Fig. 2

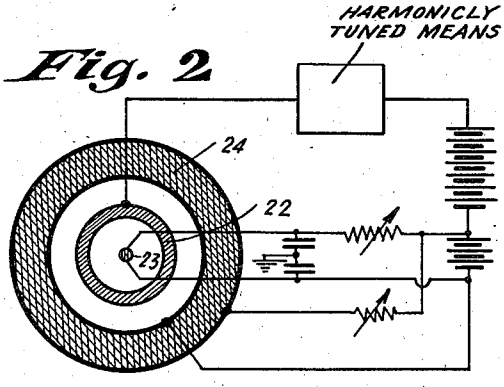
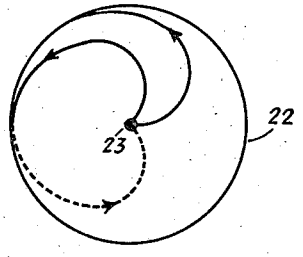


Fig. 3



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HIGH FREQUENCY OSCILLATOR

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7 Claims. (Cl. 250—36)

This invention relates to high frequency generators and more particularly to the type of high frequency generator which can produce waves of ultra-high radio frequency.

Heretofore the production of high frequency electromagnetic oscillations of the order of 60,000 kilocycles or more has been attended with great difficulty. Radio transmission by means of high frequencies has been found to be very advantageous because of the low amount of power required for transmission, the smaller and less expensive apparatus, and other respects, compared to the transmission by long waves. While the generation of high frequency oscillations of the order of 60,000 kilocycles or less has been found possible heretofore, the production of higher frequencies with useful amounts of power has been very difficult and has not been accomplished with the desired efficiency.

The object of the invention is to produce high frequencies of the order of 300,000 kilocycles or more. Another object of the invention is to produce such frequencies by means of apparatus already developed for operation at lower frequencies. Another object is to produce such waves with great facility and at small cost. Further objects will appear during the description of the invention.

The invention is more fully set forth in combination with the accompanying drawing, in which Fig. 1 represents schematically a longitudinal cross section of a device used to generate short radio waves in accordance with my invention;

Fig. 2 is a transverse cross section through a tube known as the magnetron, which may also be used to generate these short waves; and

Fig. 3 represents an enlarged schematic view of the tube shown in Fig. 2.

In Fig. 1 there is shown a device 1 comprising a filament 2 which is energized by a source 10 of current which is shown as alternating, although direct current is equally applicable. At one end of the device is a flared or circular portion 4 so positioned that the filament is at one end of a tangent portion 6 of the tube. 7 designates an opening in the circular portion of the tube and into this opening is inserted the plate or anode 8. The other side of the anode is connected to a source of current 3 and to the filament 2. On either side of the anode is an insulating mounting or bushing 9.

The operation of the device is as follows:

When the filament 2 is energized from the source of current 10, negative electrons are emitted in the customary manner. These electrons are attracted by the positively charged plate and travel in a substantially straight line along the portion 6 of the tube. The circular shell 4 may be given a charge similar to that of the filament, or may be made slightly more negative than the filament by battery 17, in order to repel the electronic stream. The negative charge on the circular portion 4 will repel the electrons and cause them to bend around in the manner shown by the arrows in the figure. The opening 7 will be so positioned as to be in line with the electrons after they have followed the periphery of the curved portion 4.

When the electrons initially enter the shell 4 from the straight portion 6 they will have under proper conditions such a high velocity that they will fly past the anode 8 due to their own momentum. After curving, the electronic stream will point toward the anode, but before finally reaching the anode the electronic stream must cross its own path. In doing so it will interrupt the stream entering the curved shell 4 from the straight portion 6, due to the mutual repulsion between electrons. The oncoming stream from the filament will remain interrupted until the first electrons have reached the anode. The stream from the filament will then be enabled to pass by and enter the curved shell 4, and the process will be repeated periodically.

It will be obvious that the principle of operation of this device is quite similar to that of the ordinary air or steam whistle, and a comparison between the two will be an aid to understanding this invention.

The frequency of interruption of the electronic stream will determine the frequency of the desired oscillation in the plate circuit. My experiments so far indicate that the frequency is dependent substantially on the anode voltage and increases with increase in voltage. In other words it is determined by the time taken for an electron to travel twice around the loop, which is determined by the anode voltage and the dimensions of the tube; that is, the time of one-half cycle is equal to the time taken for an electron to traverse the shell 4.

Fig. 2 shows a cross section of a modification of the device in a more practical form. In this system, an ordinary magnetron tube is used to obtain the desired high frequency oscillations. The customary cylindrical anode is shown at 22, and at the longitudinal axis of the cylinder is the filament 23. On the outside of the tube

is the field coil 24. When the field coil is energized, a strong magnetic field is set up coaxial with the filament and at right angles to the plane of the figure.

When the filament is energized during operation of the tube it will emit electrons which will be attracted toward the anode 22 and these tend to travel directly toward the anode. An electron in motion constitutes an electric current and is subject to the same laws as a current-carrying conductor. The electrons moving across the magnetic field will have a force exerted on them at right angles to their direction of motion and proportional to their velocity and to the strength of the magnetic field. The electrons will thus be forced to follow a curved path, as shown in Fig. 3, and if the field is of sufficient strength, will not reach the anode at all but will return to the filament, following the image of their outward path, and giving up their kinetic energy in doing so. This is the condition commonly known as "cut off" in a magnetron tube.

At a critical plate voltage for a definite field strength the electronic stream will just skim the surface of the anode 22 and some of the electrons will strike the anode while others will return by a similarly shaped path to the filament. The complete path of the electronic stream from filament to plate and back to filament will be approximately that of a cardioid, as is shown in Fig. 3. If the plate voltage is increased all of the electrons will be attracted to the plate, and if the field strength is increased none of the electrons will reach the plate. At a critical relation between plate voltage and magnetic field some of the electrons will return to the filament, as previously described. This will increase the space charge near the filament and decrease the flow of electrons from the filament toward the plate. This in turn will decrease the number of electrons reflected back from the plate a short time later, and thereby the space charge near the filament will decrease. This will again allow the flow of electrons from the filament toward the plate, and the process will be repeated periodically. The frequency will depend chiefly on the anode voltage and increases when the voltage is increased. In other words, it is determined by the time taken for an electron to travel from filament back to the filament and approximately equal to twice the length of time of such travel for a complete period. The strength of the magnetic field determines the amplitude of the oscillations and the efficiency but has relatively little to do with the frequency.

The wave form of the electronic current which flows to the anode will ordinarily be quite far from a sine wave and will be more nearly rectangular in shape. Such a wave form is rich in harmonics and the useful output from the tube may be obtained at harmonics of the fundamental frequency by tuning the circuits connected between filament and anode to the harmonics.

It is also possible to make the tube produce its oscillations directly at harmonic frequencies by having groups of electrons traversing the space between filament and anode rather than a continuous stream, and in practice, it is difficult to know which effect predominates in producing energy at harmonic frequencies.

The applicant does not wish to limit himself to any one theory or combination of theories to explain his results. The theory herein set forth is the best available at the present time, and the applicant wishes it to be understood that he is not bound by this explanation of its operation. Experiments so far have produced oscillations having a wave length of 30 centimeters, and it is easily possible to obtain wave lengths of 10 centimeters or less.

The structure set forth is merely illustrative and does not comprise the only means for obtaining these results; for example, the shape of the tube shown in Fig. 1 may be varied and the relative position of the electrodes changed. For example, the filament may have other forms and shapes than those shown and may also be of the indirectly-heated type. The same is true of the other elements of the invention. Also, the ordinary three-electrode tube may be employed as a high frequency oscillator. In such a case the grid and the filament could be electrically connected so that both serve as the source of electrons, or the grid could be so biased as to emit secondary electrons which serve as the source of the high frequencies. It is obvious that water cooling of the anode and better vacuum will result in greater efficiency and perhaps higher frequencies.

Having described my invention, what I desire to secure by Letters Patent of the United States is:

1. A device for producing ultra-high frequency oscillations, comprising a filament for emitting electrons, an anode for attracting electrons, and means for causing the stream of electrons to travel in a curved path so as to cross itself, said means comprising a curved shell which has a potential at least as negative as that of the filament, the anode being positioned in an opening in the curved shell and insulated therefrom.

2. A device for producing utra-high frequency oscillations, comprising a curved shell, a straight tube attached tangentially to the curved shell, a filament in one end of the straight tube, an opening in the curved shell near the point of attachment of the tube to the shell, and an anode positioned in said opening, the anode serving to attract the electrons from the filament and to accelerate them to such a velocity that they pass the anode, due to their momentum, traverse the curved path in the shell, and finally reach the anode over a path which crosses upon itself.

3. In high frequency apparatus comprising an electron emitting element and an anode, the method of producing high frequency oscillations which comprises uni-directionally propelling along a straight line a stream of electrons in the form of a beam from said electron emitting element towards said anode, and deflecting said stream of electrons at an angle into itself periodically.

4. In high frequency apparatus comprising an electron emitting element and an anode, the method of producing high frequency oscillations which comprises uni-directionally propelling a stream of electrons in the form of a beam from said electron emitting element towards said anode along the shortest possible path therebetween, deflecting said stream of electrons into a curved path so that the stream crosses itself at an angle, thereby interrupting the incoming stream, and thereafter periodically interrupting the stream flow to produce oscillations of the desired frequency.

5. The method of producing high frequency oscillations which comprises constantly propelling a stream of electrons in a single direction along a confined path, and making said stream of electrons cross upon its own path at an angle periodically.

6. An oscillation generator device for producing ultra high frequency oscillations comprising a

filament for emitting electrons, an anode, means for maintaining said anode at a positive potential for attracting electrons, an element arranged to be in the path of the electrons on the side of said anode away from said filament, means for maintaining said element at a negative potential with respect to said anode for deflecting said stream of electrons into its own path at an angle after they have passed said anode for interrupting said stream, said anode being positioned to receive said deflected electrons after they have crossed their original path of travel.

7. The method of producing high frequency oscillations which comprises propelling a stream of electrons in a single direction along a confined path, and making said stream of electrons cross upon its own path at an angle periodically.

CLARENCE W. HANSELL.