June 12, 1934. H. E. HOLLMANN 1,962,196

HIGH FREQUENCY OSCILLATOR

Filed Aug. 9, 1930

Fig. 1

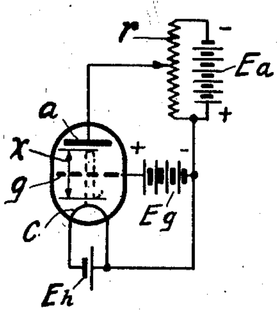


Fig. 2

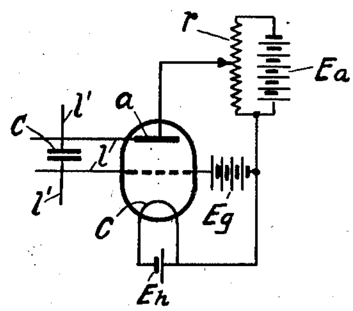


Fig. 3

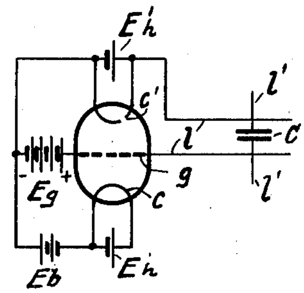


Fig. 4

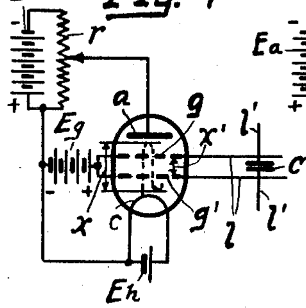


Fig. 5

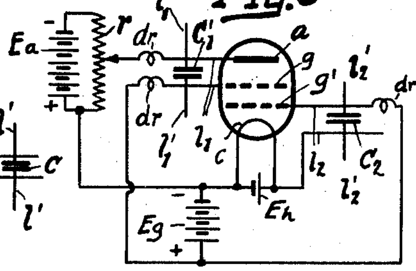


Fig. 6

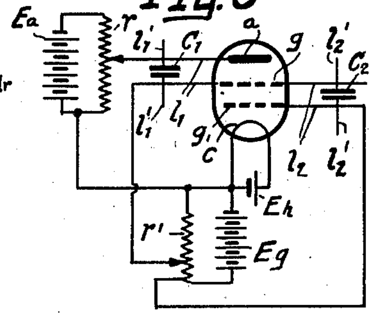


Fig. 7

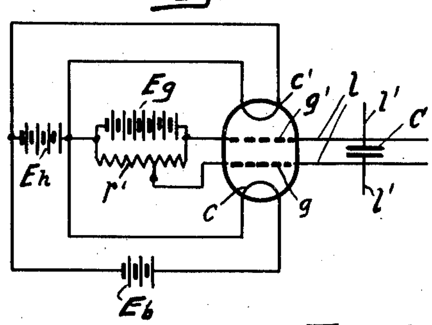


Fig. 8

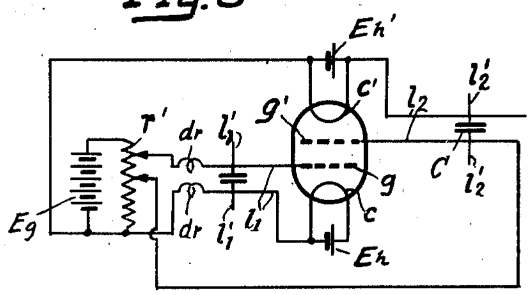
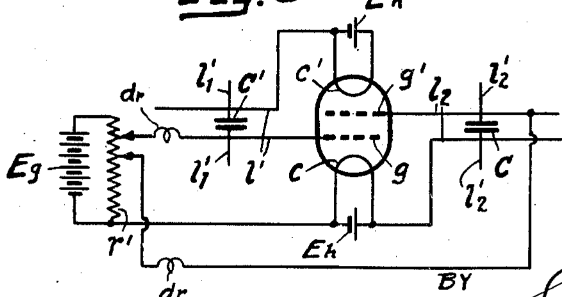


Fig. 9



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Patented June 12, 1934 1,962,196

UNITED STATES PATENT OFFICE

1,962,196

HIGH FREQUENCY OSCILLATOR

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Application August 9, 1930, Serial No. 474,258
In Germany August 13, 1929

13 Claims. (Cl. 250—36)

My invention relates to electronic oscillators and more particularly to oscillators of the type which operate according to what is known in the literature of the art as the Barkhausen-Kurz or braking field method for generating ultrahigh frequency electrical oscillations. A detailed analysis of this method is given in Zeitschrift für Physik, vol. 21, No. 1 of 1920, in an article by Barkhausen & Kurz, and also more recently in an article by the inventor of the present application appearing in the Proceedings of the Institute of Radio Engineers, vol. 17, No. 2, of February 1929. This method differs considerably from the customary methods used in practice for generating high frequency oscillations by means of vacuum tubes, using regenerative arrangements. The period of the oscillations generated is dependent principally on the operating voltage applied to the electrodes and the distance of the electrodes from each other. This is basically distinct from the regenerative circuits as commonly used in the radio art for producing oscillations and according to which the natural discharge oscillations of an oscillatory circuit are maintained at a constant amplitude by a feed-back arrangement from the oscillatory circuit associated with the output of a vacuum tube, to the input or control circuit of such tube.

It has been found in practice that it is not possible to increase the frequency without limit by decreasing the period of transit of the electrons, that is, by increasing the operating voltage applied to the electrodes or by decreasing the distance between the electrodes, but that the oscillations will cease entirely if the operating voltage exceeds a given limit or the distance of the electrode is made too small.

It is an object of my invention to provide means whereby oscillations can be produced by the above specified method with a frequency above the aforementioned critical limit.

Another object of my invention is to provide means in connection with an oscillator of the type referred to, whereby an oscillating circuit, preferably a two-wire system coupled with the oscillator, is excited in a rhythm corresponding to a multiple of the frequency of the fundamental electron oscillations.

Another object of my invention is to provide means in connection with an oscillator of the type referred to whereby an oscillating system, preferably a two-wire system, tuned to a multiple frequency of the fundamental oscillation frequency is acted upon only during a fraction of one half cycle of the fundamental frequency.

Another object of my invention is to provide a vacuum tube adapted for the production of ultra high frequency oscillations according to the principle referred to, in which the electron oscillations take place under control of two grid electrodes arranged in the path of the electronic discharge.

These and further objects of my invention will become more apparent as the following detailed description proceeds, which is taken with reference to the accompanying drawing, in which I have illustrated by way of example a number of modifications of circuits, in which my invention may be embodied.

Similar reference characters refer to similar elements throughout the different views of the drawing.

In Fig. 1, I have shown for purposes of illustration and better understanding a simple circuit arrangement for producing electron oscillations, in accordance with the principle referred to.

Fig. 2 is a similar circuit to Fig. 1, according to which an oscillating two wire system is associated with the oscillator tube for purposes of practical utilization of the oscillations, such as for radiation for signalling purposes.

In Fig. 3, I have shown an alternative circuit for producing oscillations of the type referred to, which has been found to be particularly suitable in practice.

Figs. 4 to inclusive Fig. 9 illustrate a number of examples of improved circuits in which the novel feature of my present invention is embodied.

Referring more particularly to Fig. 1, I have shown a vacuum tube of the ordinary type having a cathode *c*, grid electrode *g* and anode *a*. The cathode is maintained at electron emitting temperature by means of a heating battery E_h. A positive potential in respect to the cathode is applied to the grid electrode *g* by means of a grid biasing battery E_g. The anode may be directly connected to the cathode or may be given a negative potential in respect to the cathode, for which purpose I have shown an anode biasing battery E_a in connection with a potentiometer *r*. Part of the electrons emitted by the cathode *c* and attracted by the positive grid electrode will pass through the meshes of the grid and run against the opposing field of the anode until their velocity has become zero, and they will be reversed and return toward the grid. In this manner an oscillating electron discharge, indicated in dotted lines in the drawing, will take place over an oscillating distance or amplitude x.

In Fig. 2, I have shown a circuit arrangement identical to that in Fig. 1 together with an oscillating two wire or Lecher wire system l connected to the anode and grid electrode and bridged by a displaceable condenser C of comparatively large capacity. Along the wires l, as is well known, a standing wave will be produced whose wave length may directly be measured by means of a neon tube, which will light up at the anti-nodal points of the standing wave. In order to utilize the waves for radiation for signalling purposes, open wires l' are connected to both armatures of the condenser C and serve for radiating the energy into space, as is well known in the art.

In Fig. 3, I have shown another tube which has been found to be very suitable for the production of oscillations of the type in question. This tube includes two cathodes, c, c', respectively, arranged opposite each other, and a grid electrode g between the cathodes. I have shown the cathodes heated by separate heating batteries E_h and E'_h. It is to be understood that a common heating battery may be provided for both cathodes. The grid electrode is given a positive potential with respect to the cathodes in a way similar to Fig. 1, by means of a grid battery E_g, and the two-wire oscillating system l is connected to the grid and one of the cathode electrodes. It may be advantageous to provide a further biasing battery E_b for one of the cathode electrodes. In operation of this tube electrons emitted by one of the two cathodes and passing through the grid towards the remaining cathode affect the space discharge about this cathode and thus perform a control of the discharge current, and maintain the oscillations.

I have described this tube in more detail in my copending application, filed January 7th, 1930, Serial No. 419,089, and entitled "Method and apparatus for the generation of short wave length oscillations".

According to the novel feature of my invention the disadvantage of the limited range of wave lengths existing in the known circuit arrangements according to Figs. 1 to 3 is overcome in that an oscillating system coupled with the oscillator tube is excited not in a frequency equal to the fundamental frequency of the electron movements, but in a frequency which is a multiple thereof.

A simple circuit to attain this aim is shown by Fig. 4. Fig. 4 differs from Fig. 2 essentially in that two grid electrodes are provided between the cathode and the anode in lieu of one grid electrode, as shown by Figs. 1 or 2. These two grid electrodes are both connected to the same or approximately the same positive potential, whereas the anode or "braking" electrode may be directly connected with the cathode or may be given a negative potential with respect to the cathode, as by means of an anode battery E_a and potentiometer r.

Under these conditions an electron movement will take place analogous to the well known arrangement as referred to in connection with Fig. 1, the difference being that in the present case the electrons have to pass in succession the two grids and will carry out a to and fro movement about the two grid electrodes. It is assumed that the frequency determined by the back and forth movements of the electrons corresponding to the distance x be n. The oscillating two wire system l is connected to the two grids g and g'. Thus the oscillating system l is excited in a rhythm different from the frequency n of the electron movements, but being determined by the time of transit of the electrons from one grid to the other that is over distance x', this frequency being called n'. If therefore the oscillating system l is tuned to this latter frequency, an impulse will be given to it, by the electrons leaving the cathode in one direction. When the electrons have passed the two grids, the oscillating system will be without influence and will then receive a second impulse in the opposite direction during the return of the electrons after their reversion at the braking or anode electrode. In this manner the oscillating condition is maintained. Apparently this phenomenon is equivalent to a kind of impulse or shock excitation, whereby the frequency is determined by the transit of the electrons from one grid to the other, which is a multiple of the free fundamental frequency of the electron movement. It will be understood that the order of the multiple frequency to which the wire system is tuned must at least be equal to the order of the fraction of the fundamental oscillating period during which fraction the wire system is excited, or expressed in other terms, the multiple frequency to which the wire system connected to the grid electrodes is tuned, must at least be equal to the ratio of the time of transit of the electrons over the entire oscillating distance (x) to their time of transit between the grid electrodes (x').

Instead of connecting the two grids with a common oscillating system, a separate oscillating system may be connected between each of the grids and the adjacent cathode or anode, respectively, such as is shown in Fig. 5, in which the two oscillating systems are distinguished from each other by indexes 1 and 2, respectively. I have also shown choke coils dr, in this figure, for blocking the anode and grid battery against the high frequency portions of the circuit.

In the case that the natural frequency of the oscillating system l does not correspond exactly to the frequency n', determined by the time of transit of the electrons from one grid to the other, but is slightly greater than this frequency, a reaction will take place of the alternating voltages induced on the electrodes upon the interelectrode electron movement, whereby the exciting frequency n' gradually merges into the natural frequency of the oscillating system. This phenomenon, which has been termed as frequency feed back or frequency reaction, is described in more detail in my copending application filed June 20, 1929, Serial No. 372,406.

According to Fig. 6, I have shown a circuit by which the frequency determined by the time of transit of the electrons from one grid to the other may be increased first by a frequency feed back on the fundamental frequency n of the electron movement, and secondly by a further frequency feed back on the higher frequency n', determined by the time of transit between the two grid electrodes. For this purpose a first oscillating system l_1 is connected to the grid g and the anode a and is tuned to a frequency above the fundamental frequency of the electron movements within the space between cathode and anode (distance x). In this manner a frequency rise of the fundamental frequency takes place, which means a proportional frequency rise in the impulse system l_2. By furthermore tuning the latter system to a frequency above the frequency determined by the time of transit of the electrons between the two grids (distance x') a further additional frequency rise may be obtained. In this manner it has been possible to generate undamped oscillations with higher frequencies than have hitherto been attainable by purely electrical means.

Referring now to Fig. 7, this is analogous to Fig. 4, from which it differs merely in that a tube with two cathode electrodes is used instead of an ordinary tube, such as has been explained in connection with Fig. 3. I have furthermore shown in Fig. 7 potentiometer r' for applying different or slightly different positive potential to each of the grid electrodes by means of a potentiometer associated with the grid battery E_g. I have also shown, according to Fig. 7, a common heating battery E_h for the cathodes.

Referring to Fig. 8, this is essentially equivalent to Fig. 5 in that two oscillatory systems l_1 and l_2, are provided, each one being connected to one of the cathodes and the adjacent grid electrode. In this figure I have also provided a potentiometer r' for adjusting different grid potentials, as well as choke coils *dr*, for preventing the high frequency currents from entering into the grid battery.

In Fig. 9, I have illustrated a further circuit similar to Fig. 8, which has been found to operate favorably and according to which oscillating systems are connected between each of the grid electrodes and the cathode separated therefrom by the remaining grid electrode. In such an arrangement the control of the counter movements of the electronic discharges from both cathodes is performed in a favorable manner.

In case that the permeability of both of the grid electrodes, i. e. the ratio of the free spaces of the grid to the solid parts of the same is made very small, a condition will be reached, at which the electrons passing through one grid will not travel through the second grid, but will impinge upon the same or will be forced to return by the electrons emitted from the other cathode and entering the space between the two grids, in such a manner, that a pendular movement of the electrons between both of the grids is entertained. This effect may be favorably influenced by suitable tuning of the oscillating system, in which case the alternating voltages induced on the two grid electrodes are enabled to perform a control of the pendulum movement of the electrons between both of the grid electrodes.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described for obvious modifications will occur to a person skilled in the art.

I claim:—

1. In an electronic oscillator, a vacuum tube, means to produce an oscillating electron discharge within said tube at ultrahigh frequency whereby the electron stream reciprocates its movement in opposite direction, at least two grid electrodes arranged in alignment in the path of said discharge, and a two-wire oscillating system connected to said grid electrodes and tuned to a frequency being a definite multiple of the frequency of oscillation of said discharge, said grid electrodes being spaced apart by a distance which is a fractional part of the length of the path of the oscillating electron discharge, that said wire system is excited during a fraction only of the period of oscillation of said discharge whereby said fraction is at least equal to the order of said definite multiple.

2. In an electronic oscillator, a vacuum tube, two main electrodes within said tube, means to produce a reciprocating high frequency movement of electrons between said main electrodes, at least two further grid electrodes arranged between said main electrodes, a two wire oscillating system connected to said grid electrodes and tuned to a multiple frequency of the fundamental frequency of said electron movement, whereby the distance of said grid electrodes is such that the time of transit of the electrons from one grid to the other is equal to a fractional part of one half-cycle of the fundamental period of oscillation of one reciprocating electron movement, said fraction being at least of the order of said multiple frequency in respect to said fundamental period of oscillation.

3. In an electronic oscillator, a vacuum tube having cathode, anode and at least two grid electrodes, means to apply a positive potential to said grid electrodes in respect to said cathode and said anode, to produce a high frequency to and fro movement of electrons about said electrodes, and an oscillating two wire system connected to said grid electrodes tuned to a multiple frequency in respect to the fundamental frequency of said electron to and fro movement.

4. In an electronic oscillator, a vacuum tube having a cathode, an anode and at least two grid electrodes arranged in alignment between said cathode and said anode, means to apply a positive potential to said grid electrodes with respect to said anode and said cathode, a two-wire tuning system connected to said grid electrodes with a displaceable bridging condenser for said two-wire tuning system for adjusting the tuning thereof.

5. In an electronic oscillator, a vacuum tube having cathode, anode and at least two grid electrodes, means to apply a positive potential to said grid electrodes in respect to said cathode, to produce a high frequency to and fro movement of electrons about said grid electrodes, a two wire oscillating system, connected to said grid electrodes, a displaceable bridging condenser for tuning said system to a multiple frequency in respect to the fundamental frequency of said electron movement, whereby the order of said multiple frequency is at least equal to the ratio of the time of transit of the electrons over the oscillating distance to the time of transit from one of said grid electrodes to the other of said grid electrodes.

6. In an electronic oscillator comprising a vacuum tube, having two cathodes, arranged opposite each other and at least two grid electrodes disposed between said cathodes, and an oscillating two wire system connected to said grid electrodes.

7. In an electronic oscillator comprising a vacuum tube having two cathodes arranged opposite each other, at least two grid electrodes disposed intermediate said cathodes, means to apply a positive potential to said grid electrodes in respect to said cathodes, for producing a high frequency to and fro movement of electrons about said grid electrodes, and a two wire oscillating system connected to said grid electrodes.

8. In an electronic oscillator as described in claim 7, in which means are provided to apply different positive potential to said grid electrodes.

9. In an electronic oscillator as described in claim 6, with additional means of applying biasing potential to one of said cathodes in respect to the other one of said cathodes.

10. In an ultra high frequency electronic oscillator, a vacuous container having a cathode, an anode and two impedance control elements located along the path between said cathode and anode, means for impressing a high positive potential with respect to said cathode upon each of said impedance elements, and means for impressing upon said anode a potential at least as negative as that of said cathode, the separation of said control elements being substantially less than that of said cathode and anode whereby an electron in transit experiences two reactions at instants which are separated by a fraction of the time required for the full transit.

11. An oscillator comprising an evacuated container having a cathode, an anode and a plurality of impedance control elements positioned between said cathode and anode, means for bringing said anode to a potential which is negative with respect to that of said cathode, means for bringing said control elements to respective potentials which are highly positive relative to that of said cathode whereby said oscillator is adapted to produce oscillations of the Barkhausen Kurz type and differently tuned oscillation circuits connected to said control elements, one of said oscillation circuits being tuned to a frequency higher than that of the Barkhausen oscillations normally corresponding to said impressed potentials and the spacing between the cathode and anode and the other of said oscillation circuits being tuned to a frequency higher than that of the natural oscillation frequency of the first recited oscillation circuit.

12. An electron oscillator comprising an evacuated container, a cathode, a second electrode, a path connecting said cathode and said electrode including means for maintaining said second electrode at a potential at least as negative as that of said cathode, two impedance control elements physically separated and located between said cathode and second electrode, means for impressing highly positive potentials with respect to said cathode upon said impedance control elements, an oscillation circuit connected between said cathode and the impedance element more remote therefrom and a second oscillation circuit connected between said second electrode and the other impedance element, one of said oscillation circuits being tuned to substantially a multiple of the fundamental frequency component of the oscillations produced.

13. An oscillator comprising an evacuated container including a cathode, an anode and two separated grids located therebetween, means for rendering said anode negative and said grids highly positive with respect to said cathode, a Lecher wire oscillation circuit connected to said two grids, and means for tuning said Lecher wire system.

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