June 5, 1951 M. P. PRACHE 2,555,456

ELECTRONIC GENERATOR OF HIGH-FREQUENCY ALTERNATING CURRENTS

Filed Feb. 26, 1948 3 Sheets-Sheet 1

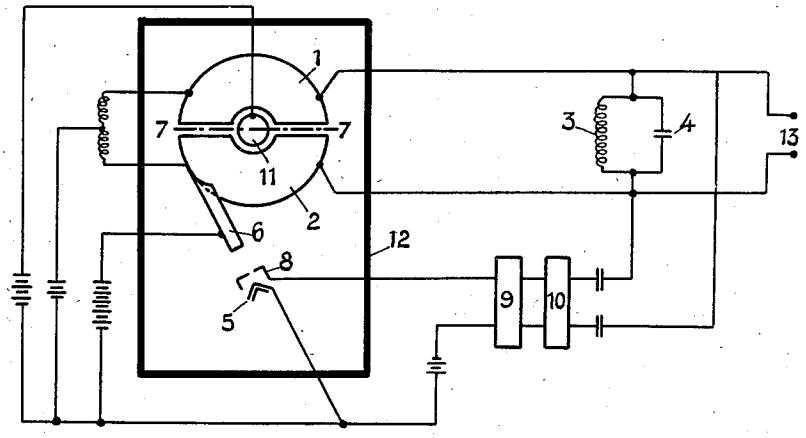

fig.1.

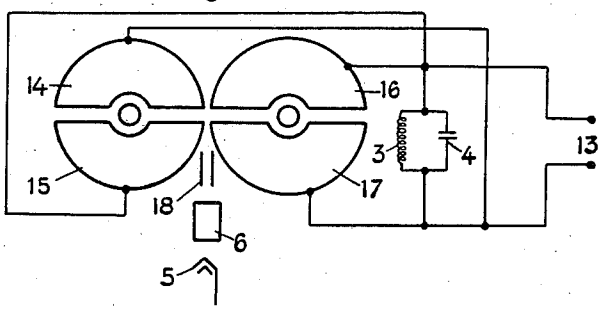

fig.2.

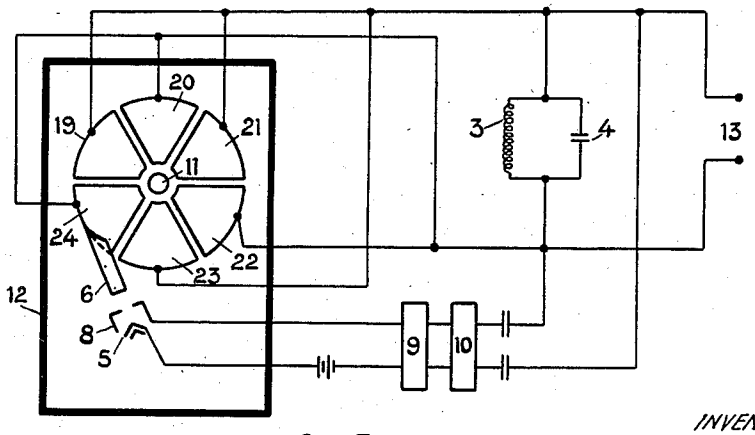

fig.3.

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Filed Feb. 26, 1948 3 Sheets-Sheet 2

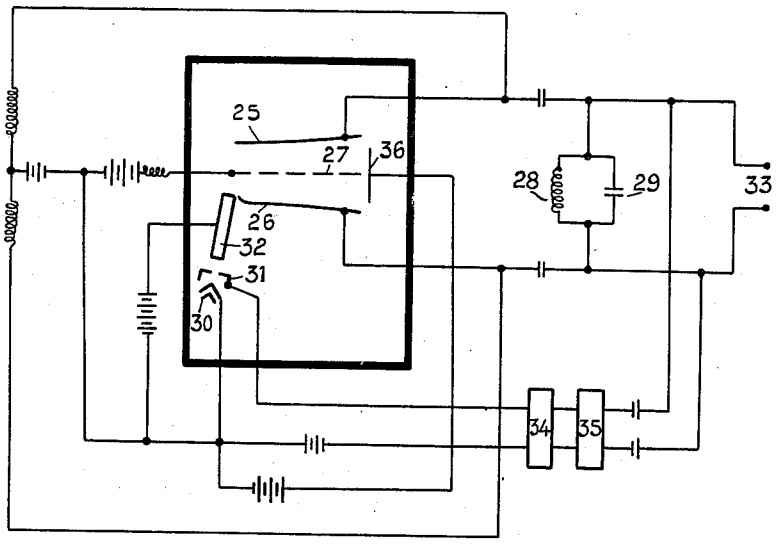

fig. 4.

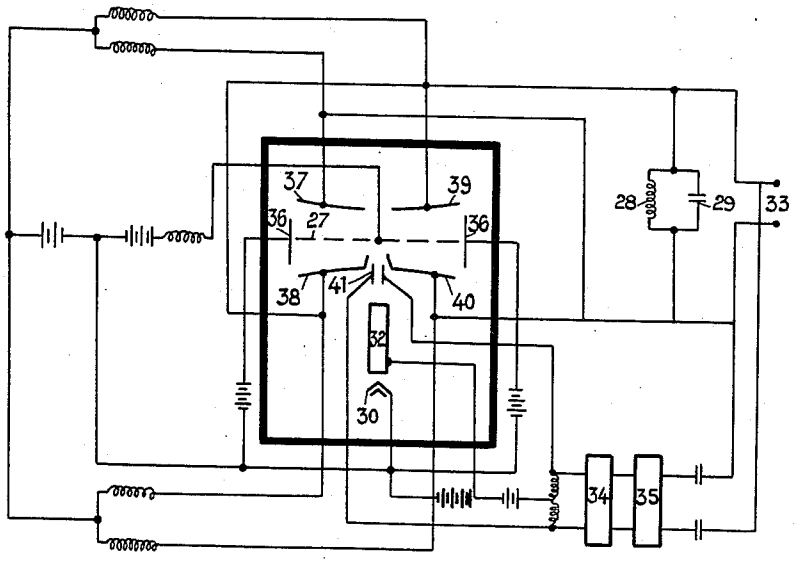

fig. 5.

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ELECTRONIC GENERATOR OF HIGH-FREQUENCY ALTERNATING CURRENTS

Filed Feb. 26, 1948 3 Sheets-Sheet 3

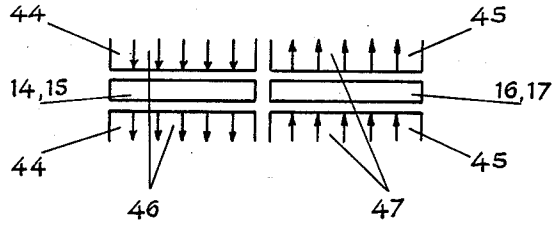

fig.7.

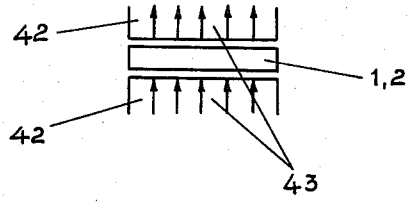

fig.6.

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2,555,456

ELECTRONIC GENERATOR OF HIGH-FREQUENCY ALTERNATING CURRENTS

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2 Claims. (Cl. 250—36)

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The object of the invention is to improve the efficiency of, and avoid certain drawbacks, such as those due to heating, in, apparatus of the retarding field type for generating or amplifying high-frequency alternating current, as for example transit time magnetrons and positive grid tubes.

In high frequency alternating current generating apparatus known under the name of transit time magnetrons, or positive grid tubes, the electrons are emitted by the source in a continuous manner. The useful electrons, that is to say those which yield energy to the field of the electrodes, are only emitted during a fraction of the alternating field period to which the electrodes are submitted. The electrons emitted during the remainder of the period absorb, on the contrary, the energy of the field which accelerates them by straightening their path. These electrons then strike against the electrodes where the kinetic energy which has been transmitted to them by the field is transformed into heat. As a result, these apparatus have a relatively low efficiency. On the other hand, the heating of the electrodes referred to imposes a restriction on the intensity of the electronic current called into play or else entails adding to the apparatus cooling devices which are costly and of complicated maintenance.

One object of the present invention consists in avoiding these drawbacks by introducing the electrons in the field of the electrode only during the favorable fraction of the period, that is to say during the time when the electrons will be slowed down by the alternating field of the electrodes. This can be accomplished for example by placing, in front of the source of electrons, a grid whose object is to stop the electronic current when it is brought to a suitable negative potential or any other similar electronic device. This device is connected electrically to the output terminals of the apparatus, if necessary by means of an attenuator and a phase shifter controlled in such a way that the electronic current is stopped during the portion of the period in which the electrons would be accelerated by the field of the electrodes.

Instead of the grid, an electric or magnetic deflecting apparatus similar to those of cathode-ray tubes may also be used. This apparatus, arranged in front of the electron source, will be connected as above to the output terminals in such a way that the electrons are deviated out of the electrode field during the unfavorable fraction of the period. In the latter case, use may advantageously be made of two groups of electrodes arranged symmetrically with respect to the electron source, interconnected in such a way that the potentials of the electrodes are in opposition and that these electrodes are submitted to oppositely directed magnetic fields. The favorable periods for the two groups of electrodes will be alternated and use may be made of the two alternations of current of the electron emitting source, the deflecting apparatus transmitting the beam into the favorable group of electrodes.

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In the case of magnetron type of apparatus, this will moreover offer the advantage of preventing the electrons from being deviated out of their straight path by the lines of force of the magnetic field which escape from the part situated below the pole pieces.

When the apparatus is to be used as an oscillator circuit, the overvoltage factor of the oscillating circuit and of the utilisation apparatus should be such that the oscillations are sustained spontaneously in this circuit under the action of the energy yielded by the electronic current.

On the contrary, when the apparatus is to be used as an amplifier, the oscillating circuit and the D. C. grid biasing voltage must be so selected that on the one hand the zone of high factor of overvoltage extends along the entire frequency band to be amplified and, on the other hand, that no spontaneous oscillations occur in the absence of outer excitation. The oscillations of the device are then controlled by the applied voltage to be amplified at a suitable point of the circuit; for example, when the interruption of the electronic beam is carried out by means of a deflecting apparatus, the control voltage may be applied to the grid of the electron source.

The present invention will be better understood by means of the following description based on the attached drawings in which:

Fig. 1 shows an embodiment of an apparatus of the magnetron type according to the invention, wherein the stream of electrons is stopped, during the unfavorable phase of the oscillation period, by means of a grid;

Fig. 2 shows another embodiment of an apparatus of the same type, wherein a deflecting device alternately deflects the electron stream towards the group of electrodes for which the phase of the oscillation period is favorable;

Fig. 3 is a modified embodiment of the apparatus shown in Fig. 1, wherein the semi-cylindrical electrodes are divided into fractions;

Fig. 4 shows an embodiment of an apparatus of the positive grid tube type provided with a grid device adapted to stop the electron stream during the unfavorable phase of the oscillation period;

Fig. 5 shows another embodiment of an apparatus of the same type as hereinbefore, wherein a deflecting device alternately deflects the electron stream towards the group of electrodes for

which the phase of the oscillation period is favorable;

Fig. 6 is a detail view showing the magnetic field to which the electrodes of the apparatus shown in Fig. 1 are subjected;

Fig. 7 is a similar view to that of the previous figure, applying to the case of the apparatus shown in Fig. 2.

The apparatus, described by way of example in Fig. 1, fundamentally includes two pairs of metallic plates preferably interconnected two by two by hollow semi-cylinders thus forming electrodes 1 and 2 similar to those of the split-anode magnetron or of the cyclotron. Plane metallic grids may be placed face to face, in front of the pair of plates and perpendicularly to these plates in order to cause a more abrupt transition between the potentials of the two pairs of plates. The two electrodes thus formed are connected to the two ends of an outer circuit endowed with resonance and formed for example by the connection in parallel of an inductance 3 and a condenser 4. The electron generating apparatus may be a device similar to the apparatus used in cathode-ray tubes and comprises a hot filament 5 which emits the electrons and a gun 6 which concentrates these electrons into a substantially parallel or slightly converging beam; the device is arranged in such a way that the electrons are projected between the plates, parallel to these plates and perpendicularly to the plane of separation 7—7, at one end of the field.

Moreover, a grid 8 is interposed between the filament 5 and the gun 6. The filament-grid circuit is connected to the two ends of the oscillating circuit 3, 4 by means of an attenuator 9 and a phase-shifter 10. Finally, a metallic electrode 11 connected to the filament may be placed in the centre of the apparatus. The filament 5, the grid 8, the gun 6 and the electrodes 1, 2 and 11 are enclosed in an evacuated enclosure 12.

The apparatus is placed (see Fig. 6) in a coil or between the poles of a magnet or of an electromagnet 42, 42 which sets up in the region of the electrodes 1, 2 a substantially constant magnetic field 43 at right angles to the plane of the plates. The value of this magnetic field and the velocity of the electrons at the entrance to the field are controlled in such a way that the electrons travel, within the electrodes 1, 2, along spiral shaped paths converging slowly towards the centre of the apparatus. The oscillating circuit is such that its resonance frequency is equal to the frequency of revolution of the electrons in the apparatus.

The grid circuit is controlled in such a way that under the action of the alternating potential existing at the terminals of the circuit, the grid is brought, during a part of the oscillating period, to a negative potential with respect to the filament, such that it stops the passage of electrons. The phase-shifter 10 is controlled in such a way that all the electrons which would be accelerated by the electric field produced by the circuit oscillating between the electrodes 1 and 2 are stopped, that is to say that the electrons which pass through the grid are all delayed by the electric field and thus yield energy to the oscillating circuit. The alternative energy thus produced is transmitted to a utilisation circuit 13 connected to the terminals of the oscillating circuit. The electrode 11 restores to the filament the electrons which have finished their course, eventually by means of a D. C. voltage.

Instead of the grid, any other device may be used which stops the electrons or also a device which throws the electrons out of the field and, in particular, an electrostatic or electromagnetic deflecting system similar to those of the cathode tube and placed at the exit of the electron source.

It is also possible advantageously to use the device which is diagrammatically shown in Fig. 2, wherein the two pairs of electrodes 14, 15 and 16, 17 are located symmetrically with respect to the source of electrons and are subjected (see Fig. 7) to the action of permanent magnets or electromagnets 44, 44 and 45, 45, which set up oppositely directed constant magnet fields 46 and 47; in this manner the favorable periods for each of the two pairs of electrodes occur alternately. The deflecting apparatus formed by the plates 18 placed at the exit of the gun 6 will direct the electron beam alternately into each pair of electrodes during the favorable period of each pair. Moreover, as already stated, the electrons will not be deviated from their straight path by the lines of force of the magnetic field which escape from the part situated under the pole pieces.

In order to obtain an electric current of higher frequency, a resonance frequency, which is a full multiple n of the rotational frequency of revolution determined by the magnetic induction according to the classical formula:

$$f=\frac{kB}{2\pi}$$

will be applied to the oscillating circuit. In the above formula, B is the magnetic induction between the electrodes, k the ratio of the load to the mass of the electron.

Instead of the electrodes 1 and 2, use may be made of a number of electrodes equal to $2n$ arranged in adjacent circular sectors as shown in Fig. 3, for $n=3$. The electrodes 19, 21, 23 . . . will be connected to one of the poles of the oscillating circuit 3, 4 and the electrodes 20, 22, 24 . . . to the other pole.

Similarly, in high frequency alternating current generating apparatus known under the name of positive grid tubes, the electrons are introduced into the electrical field in a continuous manner. Only the electrons emitted during a certain fraction of the period of alternating oscillation produce the useful alternating energy in the outer circuit. The electrons emitted during the remainder of the period, on the contrary, absorb the energy from the outer circuit and waste the same in the form of heat as a result of the impacts which they sustain against the plate. As a result, these apparatus have naturally a poor efficiency. As in the case of the transit time magnetron, these drawbacks are avoided, according to the present invention, by introducing the electrons in the field of the apparatus only during the part of the period of oscillation when they yield energy to the outer circuit or even during a fraction of this part. This may be realised by creating the electrons outside the alternating electric field and in placing in front of the electron source a grid whose potential is controlled by the output circuit, in such a way that it prevents the introduction of electrons in the alternating field during the fraction of the period in which these electrons would absorb the energy of the alternating field.

Instead of the grid, use may be made of any other similar device usual in electronic optics or again an electric or magnetic deflecting device

which throws the electrons out of the field during the unfavorable fraction of the period.

Fig. 4 shows merely by way of example an assembly constituting one possible method of carrying out the invention.

The oscillation generating apparatus includes two plates 25 and 26 arranged symmetrically on each side of a plane metallic grid 27 which may have very wide meshes to avoid energy losses due to impacts of the electrons. These two plates are connected to the two ends of a circuit endowed with resonance and formed, for example, by the paralleling of an inductance 28 and a capacity 29.

The electron generating apparatus is formed by an incandescent filament 30, a grid 31 and a gun 32 which concentrates the electrons into a parallel or slightly converging beam. This assembly is arranged in such a way that the electrons enter the alternating field at the outlet of 32. The grid 27 is carried to a positive potential with respect to the cathode 30. The potential of the plates 25 and 26 and the potential of the gun 32 are controlled in such a way that the electrons issuing from 32 cannot, after passing through the grid 27, reach the plate 26. A portion of the alternating potential at the terminals of the utilisation circuit 33 is applied between the cathode 30 and the grid 31 by means of an attenuator 34 and a phase shifter 35. The phase shifter 35 is controlled in such a way that the grid 31 is carried to a negative potential such that it prevents the introduction of electrons in the gun 32 during, the fraction of the period in which these electrons would be accelerated by the alternating field existing between 25 and 26. On the other hand, the grid is raised to a positive potential with respect to the cathode during the fraction of the period in which the electrons emitted are slowed down by the alternating field existing between 25 and 26. These electrons then effect a series of oscillations of decreasing amplitude between the two plates 25 and 26, by yielding energy to the oscillating circuit. The gun 32 is preferably slightly inclined with respect to the plane of the grid so that during the oscillations, the electrons move laterally while diverging from the gun.

The D. C. potential applied to the grid 27 is controlled in such a way that the period of oscillation of the electrons in the field of the plates 25 and 26 coincides with the natural period of the oscillating circuit.

An electrode 36 raised to a suitable potential with respect to the cathode collects the electrons at the outlet of the field. Preferably, the plates 25 and 26 are inclined in such a manner that the electric field between these plates decreases from the gun 32 to the collecting electrode 36. This decrease is controlled in such a way that the oscillations of the electrons remain tautochronous during the entire duration of their travel in the alternating field.

Instead of the grid 31, use may also be made of a magnetic or electric deflecting apparatus placed at the outlet of the gun which introduces the electrons in the field of the plates 25 and 26 only during the favorable fraction of the period. In such a case, use may advantageously be made, as shown in Fig. 5, of two pairs of deflecting plates 37, 38, 39 and 40 between which the electrons are alternately introduced. The plates are cross-connected to the terminals of the oscillating circuit 28, 29 as shown in the figure.

The plates are connected to the two outlet terminals of the phase shifter 35. This latter is controlled in such a way that the deflector 41 sends the electrons towards the pair of plates whose field will cause a slowing down of the electrons.

By using an oscillating circuit 28, 29 having a high factor of overvoltage, the apparatus of Figs. 4 and 5 may be used as generators of alternating current with a period equal to the resonance period of this circuit.

The apparatus may also be used as generators of controlled frequency oscillations, that is to say as amplifiers, in a certain range of frequencies. To this end, a resonating circuit will be used exhibiting a more or less uniform resonance in the whole range of frequencies to be amplified and the introduction of the electrons in the field of the plates 25 and 26 will be interrupted at the same rate as the frequency to be amplified. In the case of Fig. 4, this will be obtained by controlling the potential of the grid 31 by an alternating potential of frequency equal to the frequency to be amplified.

I claim:

1. In an apparatus of the retarding field type for generating high-frequency alternating current, known by the name of positive grid tube, the combination of a source of electrons, an electron gun, a grid, two pairs of electrodes symmetrically arranged with respect to the said source of electrons, which produce the retarding field and each of which is formed of two plates arranged on either side of the said grid and in diverging directions with respect thereto, whereby the oscillations remain tautochronous throughout the time of their travel through the alternating field, and of a deflecting apparatus controlled by the output circuit of the apparatus by means of an attenuator and a phase-shifter, whereby the electrons are alternately directed into the pair of electrodes the retarding field of which retards the electrons by absorbing their energy.

2. In an apparatus of the retarding field type for generating high-frequency alternating current, known by the name of positive grid tube, the combination of an output circuit, a source of electrons, an electron gun, a positive grid, two pairs of electrodes symmetrically arranged with respect to said source of electrons, which produce the retarding field and each of which is formed of two plates arranged on each side of said grid and in diverging directions with respect to the grid from the electron gun center line outwards, whereby the oscillations remain tautochronous throughout the time of their travel through the alternating field, an attenuator and a phase-shifter in said output circuit, and a deflecting device between said electron gun and an adjacent pair of said electrodes connected to be controlled by said attenuator and phase-shifter, whereby the electrons are alternately directed into the last-mentioned pair of electrodes the retarding field of which retards the electrons by absorbing their energy.

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