Nov. 28, 1944. O. HEIL 2,363,962

HIGH FREQUENCY APPARATUS

Original Filed Feb. 23, 1935 2 Sheets-Sheet 1

Fig. 1

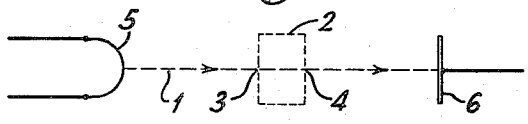


Fig. 2

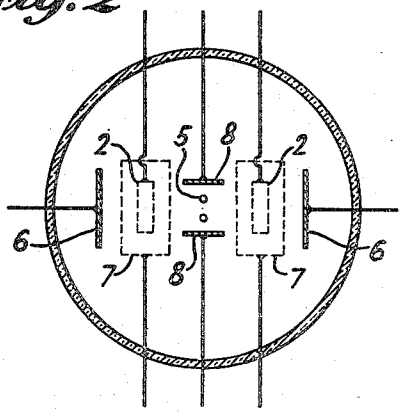


Fig. 4

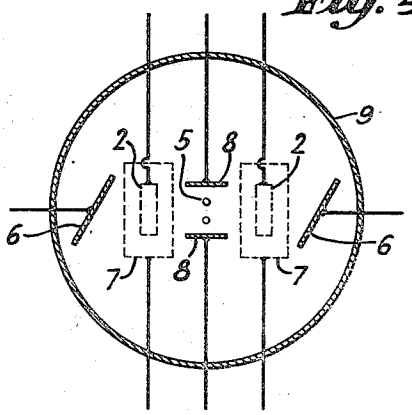


Fig. 3

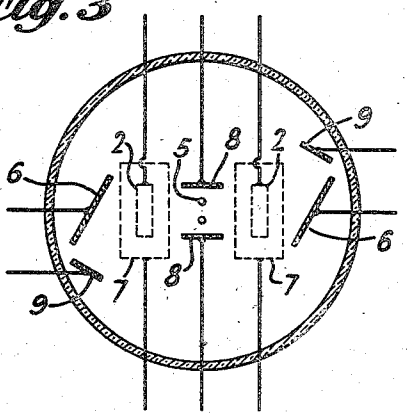


Fig. 5

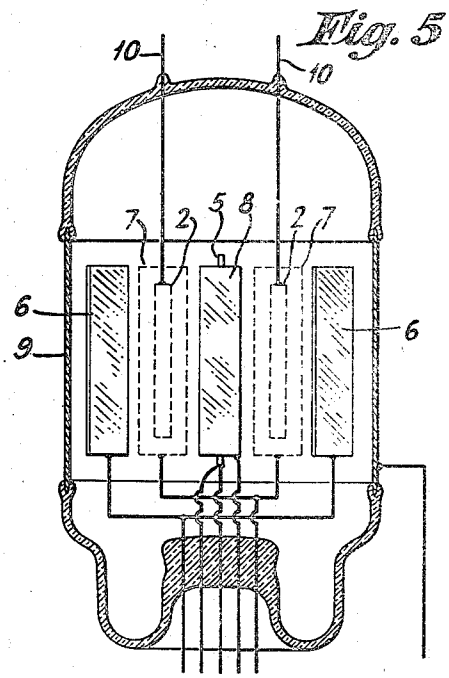
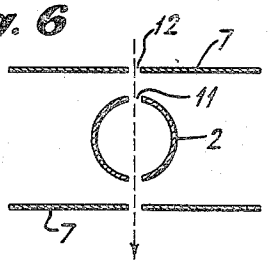


Fig. 6



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HIGH FREQUENCY APPARATUS

Original Filed Feb. 23, 1935 2 Sheets-Sheet 2

Fig. 7

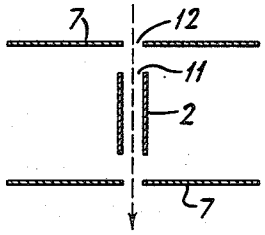


Fig. 8

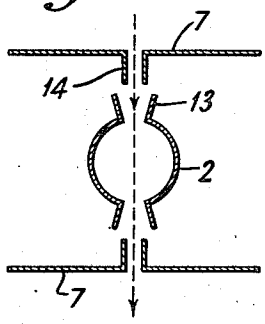


Fig. 9

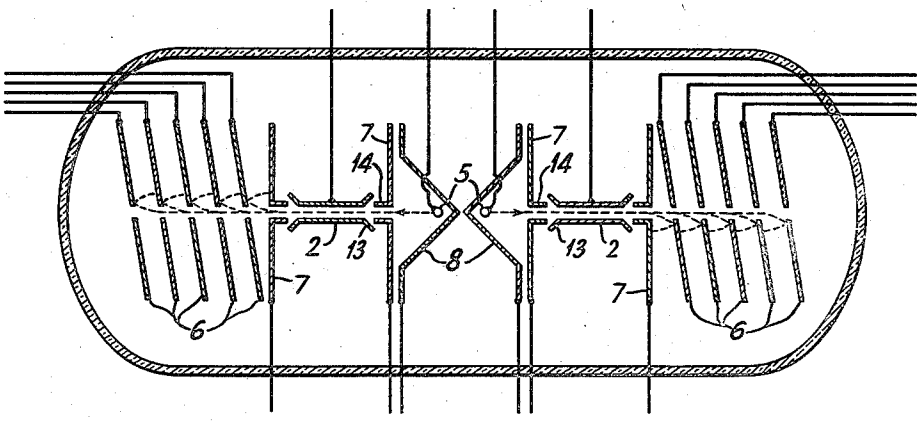
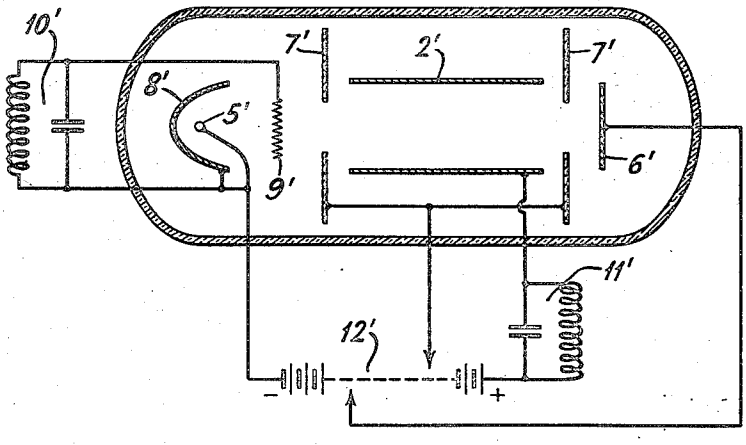


Fig. 10



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Patented Nov. 28, 1944 2,363,962

UNITED STATES PATENT OFFICE

2,363,962

HIGH FREQUENCY APPARATUS

Oskar Heil, Ludwigshafen-on-the-Rhine, Germany, assignor to Radio Corporation of America, a corporation of Delaware

Original application February 23, 1935, Serial No. 7,894, now Patent No. 2,235,497, dated March 18, 1941. Divided and this application August 23, 1940, Serial No. 353,833. In Germany February 23, 1934

35 Claims. (Cl. 250—27)

This invention relates to a method of and apparatus for producing short electromagnetic waves.

As is well known, undamped short electromagnetic waves are produced either by the back coupling method utilized in connection with long waves, or by an arrangement utilizing oscillating electrons, for example as proposed by Barkhausen and Kurz, or by means of an arrangement utilizing revolving electrons, such as the magnetron.

The present invention is based on an entirely novel principle of short wave generation, and neither back coupling, nor revolving electrons are utilized therein.

The present application is a division of my earlier filed application, Serial No. 7,894 filed February 23, 1935, Patent No. 2,235,497, dated March 18, 1941, and assigned to the same assignee as the present application.

In order that the invention may be well understood, a few fundamental definitions will be first of all referred to.

The Faraday cage is a hollow metal body. It has the property that an electric charge located in its interior has the same relation towards the exterior as if it were located on the metal. Therefore, an electron located in the hollow space of the Faraday cage has the same effect outwardly as if it had settled on the metal itself, and hence movement of an electron within the cage has no effect on the cage and changing voltage on the cage has no effect on an electron within the cage since the interior of the cage is a field free space.

It is furthermore known that an electron in flight approaching a conductor or receding therefrom represents an electric current away from or towards said conductor.

The invention will now be explained, remembering the above definitions, by reference to Figure 1 of the attached drawings, it being understood that this figure has for its sole object to facilitate explanation of the principle of the invention.

An electron 1 moves on the dotted path through a Faraday cage 2. On its way up to the point 3 it represents a negative current upon the Faraday cage. As soon as the electron has arrived at 3 this current suddenly ceases. While the electron moves within the Faraday cage from 3 to 4 no observation can be made outside. The effect is the same as if the electron had settled on the metal of the cage. When, however, the electron leaves the Faraday cage at 4 there will be a sudden current in the opposite direction, since the electron is now receding. It is understood of course that a circuit is connected between the cage 2 and cathode 5 and collector 6, and that proper voltage sources are connected between cathode 5, electrode 2 and collector 6 to make electrons move from cathode 5 to collector 6.

In the whole of these considerations the most important factor is the time during which the electron moves in the cage. For brevity this period of time will hereinafter be referred to as "period of dwell." The length of the period of dwell is proportional to the distance 3—4 and inversely proportional to the velocity of the electron. If the distance 3—4 is a fixed one, the period of dwell or transit time of the electron through the hollow electrode depends solely upon the velocity of the electron. If the Faraday cage is caused to be strongly positive as compared to the electron emitting cathode 5, then electrons of great velocity will fly therethrough and the period of dwell will be very short. If the Faraday cage is caused to be only slightly positive as compared to the cathode, then slow moving electrons will fly therethrough and the period of dwell will be very long. If a very rapidly alternating potential is applied to the Faraday cage in the form of oscillations of very high frequency, then the period of dwell will depend upon the potential to which the Faraday cage is raised at the instant the electron enters. While the period of dwell elapses the potential of the Faraday cage is altered, so that when the electron emerges the cage will be at a different potential.

The most important fact which may be deduced from the preceding considerations is as follows: Electrons entering the Faraday cage during the negative half period are slow and will not leave the cage until the following positive half period. Electrons entering the Faraday cage during the positive half period are fast and will mostly leave the cage during the same half period.

More specifically if an unmodulated stream of electrons is directed through the hollow electrode and assuming an alternating voltage is applied to the electrode, the electrons approaching the electrode will be either accelerated or decelerated depending upon the voltage at the moment applied to the electrode, that is, electrons will be accelerated if the voltage on the electrode is beginning or is in its positive half cycle or will be decelerated if the voltage is beginning or is in its negative half cycle. With any hollow electrode, since the space within the electrode is

all at the same potential, that is, is a field free space, the speed of the individual electrons through the electrode will be that which the individual electrons have upon entering the hollow electrode, that is, the accelerated electrons will continue to move rapidly at a constant speed through the electrode and the decelerated electrons at a slow constant speed through the tubular electrode. The result is that the fast electrons overtake the slow electrons causing a resulting change in the density of different portions of the electron beam, with a dense cloud of electrons separated by sections where the electrons are few. The extent to which this action takes place is determined by the length of the tube and the transit time or speed of electrons. This space within the hollow electrode may thus be considered a space where the electrons drift to form the dense and rarified portions of the beam and the result is a density modulation of the electrons stream.

Considering now the electron balance of the Faraday cage the result obtained is as follows: In the negative half period the ingress of electrons is predominant. In the positive half period the egress of electrons is predominant. But a negative body becomes more negative by the ingress of electrons and a positive body becomes more positive by the egress of electrons. Thus, the high frequency alternating potential applied to the Faraday cage is aided by the electrons. The electrons will lend energy to the high frequency oscillation and will themselves maintain the oscillation of any oscillating circuit connected to the electrode. It is obvious that the alternating potential introductorily mentioned in connection with these considerations as being applied from outside is not required, the oscillations will start automatically as in any generator. The presence of an alternating potential has been assumed merely to facilitate the understanding of the invention.

Further and in more detail, as the electrons leave the hollow electrode, depending upon the cycle of the applied voltage, the electrons will either give up or take away energy from the electrode. If the electrons leave during the positive portion of a cycle, they are slowed down and give up energy to the electrode, thus producing an inductive output effect and inducing a voltage in the electrode. On the other hand, if the electrons leave during the negative portion of the cycle, they are accelerated and absorb energy from the electrode. Normally this hollow electrode when incorporated within a tube of the kind under consideration has such length and the voltages applied are such that there is a net transfer of energy from the electrons to the electrode, which if applied to an oscillating circuit connected to the electrode may be used to furnish the modulating voltage to the electrode. On the other hand, if the electrons are first modulated before being directed through the tube, the electrode can be used as an inductive output electrode. The frequency at which the electron stream is modulated, the natural period of frequency of oscillation of the tubular electrode and its associated circuit, and the transit time of the electrons may be so adjusted that the oscillating circuit will receive energy from the modulated electron stream.

It will be apparent from the foregoing that according to this invention apparatus for producing short electromagnetic waves comprises, in an electron discharge tube, hollow metal bodies adapted to form electrically oscillating electrodes and caused to perform such oscillation by electrons flying therethrough.

Some details will now be described which appear to be of advantage in the practical embodiment of the invention.

In the production of very short waves the flight of the electrons to the hollow metal body and the flight of the electrons away therefrom must be very rapid. This may be achieved by disposing between the cathode and the hollow metal body, or hollow metal body and the anode a strongly positive grid (accelerating electrode), or by disposing a positive grid around the hollow body.

Preferably, the electrons are caused to form a pencil or beam by providing a negative electrode surrounding the cathode after the manner of a Wehnelt cylinder. This makes it possible to utilize smaller hollow metal bodies and the capacity of same will be small.

The said negative electrode or a control grid may be utilized to control the flow of the electrons. This will enable the waves to be generated to be conveniently modulated by an oscillating circuit connected between the cathode and control grid.

A double system, with two opposing hollow bodies, may be disposed in a single electron discharge tube. To these hollow bodies may be connected Lecher wires or some other oscillating circuit.

The velocity of the electrons which have passed through the hollow metal body differs. A number of them passes through the hollow body practically without loss, a small number of them loses speed. Therefore, if the anode of the electron discharge tube is made strongly positive, all the electrons will reach it. But they will strongly heat the anode, so that the tube will operate with poor efficiency. If on the other hand, the ancde is caused to be only slightly more positive than the cathode, the heat generated will be very slight. But in this case the small number of electrons having a low velocity will not reach the anode, they will pass to the grid surrounding the hollow metal body instead, so that said grid will be unnecessarily heated.

These defects may be eliminated by disposing the anode not at right angles but slantingly to the flow of the electrons. The slow electrons are thereby thrown to one side and may be intercepted by a further auxiliary anode. Instead of the slanting anode, V-section anodes may be employed. The said auxiliary anode may surround the whole system cylindrically. It picks up all energy losses and, if required may be cooled from outside by water, air or the like, so that even very large power tubes become manageable.

The heat generated in the interior of the tube by the impact of very fast electrons with the hollow body, the positive grid and the anode plate proved to be a certain defect of the method described in the foregoing. To remove this defect it is proposed to provide the hollow metal body acting as electrically oscillating electrode with apertures corresponding to the section of the pencils of electrons. These apertures facilitate the ingress and egress of the directed pencils of rays of electrons and correspond in shape to the section of the narrow strongly collected rays of electrons, which may be of slit or point section that is of rectangular or circular cross section. The strongly positive grids (accelerating electrodes) are also preferably partly or wholly re-

placed by electrodes which are provided with apertures for the passage of electrons or rays of electrons, said apertures again corresponding to the section of the rays of electrons.

The provision of apertures in the hollow metal bodies and in the positive grids has for a result that practically no electrons impinge upon the metal parts.

With a view to concentrating the rays of electrons and to reducing the capacity between the accelerating electrodes and the hollow metal bodies it is advisable to provide the apertures of the hollow metal bodies and of the accelerating electrodes with projections. These projections may be in the form of funnels disposed either vertically or at an angle relative to the said apertures.

In carrying into effect the method according to the invention it appeared to be of particular advantage to provide the braking and intercepting electrodes (anodes) in the form of a plurality of parallel metal plates insulated one from the other and disposed in the direction of the electron rays, said plates also having apertures corresponding to the section of the rays of electrons. The plates are not disposed at right angles but in a slightly inclined position relatively to the direction of the electron rays and the potential of successive plates is gradually more and more negative. As a result, only slow electrons will impinge upon the metal. The greater the number of the plates employed the smaller will be the heat generated by the impact of electrons.

In carrying into effect the present method it is of advantage not to employ a very high vacuum in the electron discharge tubes utilized, so that narrow pencils of high electron current may be obtained. In this manner a certain ionic space charge is obtained which compensates and even over-compensates the space charge due to the electrons.

Because of the high mass of the positive ions their inertia will be so high that the ions can be considered stationary as far as the effects of high frequency fields are concerned. Therefore, the presence of a small amount of gas will enhance the operation of the high frequency tube by neutralizing the detrimental effects of the electronic space charge.

The nature of the invention will now be explained by reference to the accompanying drawings, it being understood that it is not intended thereby to limit the invention to the specific embodiments illustrated in the drawings. It is obvious that those skilled in the art will be able to devise other embodiments without departing from the spirit of the present invention.

Figures 2, 3 and 4 are diagrammatic cross sectional views of apparatus constructed according to the invention.

Figure 5 is an elevation of apparatus shown in Figure 4.

Figures 6, 7 and 8 are diagrammatical cross sectional views of the hollow metal body and the accelerating electrode.

Figure 9 is a diagrammatic representation of the complete electrode arrangement.

Figure 10 is a diagrammatic representation of a modification of an electron discharge device made according to my invention and its associated circuit.

Referring now to Figures 2 and 3, two plates 8 forming the negative electrode are arranged adjacent to the cathode 5. Said negative electrode 8 focuses the electrons emitted by the cathode into two oppositely disposed beams and directs said electrons. The electrons are given a very great velocity by the positive grids 7 (accelerating electrodes) and fly transversely through the hollow metal bodies 2 to the anodes 6, producing oscillations in these metal bodies 2.

In Figure 3, in addition to the anodes 6 which in this case are disposed at an angle relatively to the direction of the rays of electrodes, there are provided auxiliary anodes 9 (braking and intercepting anodes) which intercept the slow electrons, that is slow electrons having less energy than the faster electrons are deflected by electrode 6 at low positive potential to the collector electrode 9 at the higher positive potential.

More specifically the electrons from the cathode 5 are formed into beams by the negatively biased focusing electrodes 8 which can also be used as a control electrode as pointed out above. Each beam is directed through an accelerating and shielding element or grid 7, a hollow inductive output electrode 2, a second accelerating and shielding element or grid 7 and then collected by an auxiliary collecting electrode or anode 6. The electrodes may have various shapes but in each the output electrode is shielded from the cathode by the accelerating or shielding electrode and from the collector by a second accelerating or shielding electrode. As pointed out above, electrons which approach the hollow tubular electrode 2 during the negative half cycle are slowed down and leave during the next positive half cycle whereas electrons approaching the electrode 2 during a positive half cycle are accelerated and leave the hollow electrode during the same half cycle. Thus the velocity of the electrons is varied and velocity modulation occurs in the space between the first accelerating electrode 7 and the hollow tubular electrode 2. After entering the space within the hollow electrode the electrons drift through at the velocity which they had on entering the electrode since no field influences their movement through the electrode. As a result the fast electrons overtake the slow electrons within this drift space and leave the tubular electrode 2 in more or less well defined groups so that portions of the beam are more dense than other portions. This results in a change of density of different portions of the electron stream. Since the electrons leave the electrode during the positive half cycle they tend to slow down due to the positive voltage on the hollow electrode but on doing so give up energy to the electrode 2 so that any oscillating circuit connected between this electrode and the accelerating electrodes 7 receives energy from the decelerated electrons. It is for this reason that the device will remain in oscillation and act as an oscillating generator.

Figure 4 illustrates how the additional anode 9 may be disposed to surround the whole system in the form of a metal shell.

Figure 5 also illustrates the connection of the hollow metal bodies acting as oscillating electrodes to the Lecher wires 10.

Figures 6, 7, 8 and 9 show various possible embodiments of the hollow metal bodies and of the accelerating electrodes, the hollow metal bodies being indicated at 2 and the accelerating electrodes being indicated at 7. The directed pencils of electrons pass through the apertures 11 of the hollow metal body and the apertures 12 of the accelerating electrodes in the direction of the arrow shown.

The hollow metal bodies are preferably cylindrical, but they may be composed of plane plates, as shown in Figures 7 and 9. If the pencil or beam of electrons is of point or circular section rather than rectangular as in the case of a ribbon shaped beam, the said hollow metal bodies may be structures revolutionarily symmetrical to the direction of the pencil of electrons, that is the electrodes 2 may be tubular members. The projections of the hollow metal bodies are indicated at 13, and those of the accelerating electrodes at 14. The projections may be disposed at right angles or slantingly with respect to the corresponding apertures of the hollow bodies or accelerating electrodes.

In Figure 9 the cathode emitting the electrons is indicated at 5 and as shown it is surrounded by the negative electrode 8 which focuses the electrons in a pencil or beam and directs them. The electrons are accelerated by the positive electrode 7 and after passing through the hollow metal body 2 impinge upon the inclined braking or intercepting electrodes 6. The plate first passed by the electrons is strongly positive, and each successive plate is less positive than the preceding one. The electrons flying through the apertures of the plates are gradually braked and caused to turn round. The electrons entering at a low speed are caused to turn round sooner, the fast electrons later. Having turned round the electrons are deflected laterally owing to the slanting disposition of the plates and fall on the rear face of the plate through which they have just passed. The path of the electrons is indicated in dotted lines.

In Figure 10 the electron discharge device comprises a cathode 5' and beam forming electrode 8' adjacent the cathode. The collector electrode 6' has positioned between it accelerating electrodes 7' and hollow electrode 2'. The electron stream from the cathode 5' may be modulated by a control grid 9' positioned between the cathode and the first accelerating electrode, the signal being applied between the cathode 5' and grid 9' by an input circuit 10'. The output circuit 11' is connected as suggested above to the output electrode or hollow electrode 2', the accelerating electrodes 7' being maintained at a slightly less positive potential than the electrode 2', the voltage source being indicated at 12'. In this arrangement the electron beam may be density modulated before it enters the space between the two accelerating electrodes. This permits the use of the tube as an amplifier as well as an oscillator.

It is obvious that instead of utilizing the electrodes 5 and 8 for forming the pencils of electrons, electrode systems, such as employed in X-ray tubes and Braun tubes, may be utilized.

It is preferred to connect two systems of electrodes to one Lecher system or some other oscillating circuit, which may be disposed within the tube, if so desired.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge device including an evacuated envelope containing means including a cathode for forming electrons from the cathode into a directed beam, a collector electrode for collecting electrons in said beam, a grid adjacent said cathode, a first apertured electrode adjacent said grid, a hollow electrode positioned between said first apertured electrode and said collector electrode for providing a field free space through which said beam is directed, means for applying between said first apertured electrode and said hollow electrode a high frequency potential, a second apertured electrode between said hollow electrode and said collector and means connected between said hollow electrode and said second apertured electrode responsive to the passage of the beam between the hollow electrode and the second apertured electrode.

2. The method of operating an apparatus for generating high frequency electromagnetic waves including an electron discharge device having a cathode for supplying electrons and a collector electrode for receiving electrons which comprises forming a beam of electrons, directing said beam to the collector electrode, applying a high frequency field to said beam intermediate the cathode and the collector to alternately accelerate and decelerate the electrons in the beam, passing said accelerated and decelerated electrons through a field free space for grouping said electrons and extracting energy from the grouped electrons in another space between the field free space and the collector.

3. The method of operating apparatus for generating electrical oscillations and including an electron discharge device having a cathode for supplying electrons and a collector electrode for receiving electrons which comprises forming a beam of electrons, directing said beam to the collector electrode, applying a high frequency field to said beam intermediate the cathode and the collector to alternately accelerate and decelerate the electrons in the beam, passing said accelerated and decelerated electrons through a field free space for grouping said electrons and extracting energy from the grouped electrons from another space between the field free space and the collector, and subjecting the beam to a gaseous atmosphere of sufficient density to neutralize the electron space charge of the electrons in said beam.

4. An apparatus for producing high frequency electromagnetic waves and including an electron discharge tube for use at high frequencies comprising a cathode for supplying electrons, means for forming said electrons into a beam and a collector electrode for said beam for collecting electrons, a hollow member positioned between the cathode and collector through which said beam of electrons is directed, a shielding element positioned between the cathode and one end of the hollow member and defining a space, and a second shielding element positioned between the other end of said hollow member and said collector and defining a second space and an oscillatory circuit means connected between said shielding elements and said hollow member.

5. An electron discharge tube for use at high frequencies comprising a cathode for supplying electrons, means for forming said electrons into a beam and a collector electrode for said beam

for collecting electrons, a hollow member positioned between the cathode and collector through which said beam of electrons is directed, an electrode element positioned between the cathode and one end of the hollow member and defining a space, and a second electrode element positioned between the other end of said hollow member and said collector and defining a second space, oscillatory means connected with said hollow member, a voltage source, and connections between said voltage source and said electrode elements for maintaining said electrode elements at a positive potential with respect to said cathode.

6. The method of operating an apparatus for producing electrical oscillations and including a high frequency tube which comprises generating a supply of electrons, focusing said electrons into a beam, accelerating said electrons along a beam path, modulating said beam in one space for cyclically varying the velocity of electrons in said beam, causing said modulated beam to pass through a field free space to accentuate the variations of velocity of the electrons, extracting energy from said modulated beam in another space and collecting said electrons after extracting energy therefrom.

7. The method of operating apparatus for producing electrical oscillations and including an electron discharge device comprising generating a beam of electrons, modulating said beam of electrons to cyclically vary the speed of the electrons in said beam, passing said modulated beam through a field free space, extracting energy from said modulated beam after its passage through said field free space and collecting the electrons after extraction of energy therefrom.

8. The method of operating an apparatus for generating electrical oscillations and including an electron discharge device comprising generating a beam of electrons, modulating said beam of electrons, passing said modulated beam through an alternating field, passing the beam through a field free space following said alternating field, passing the beam through a second alternating field for transferring energy to said second field and collecting said electrons.

9. The method of operating apparatus for generating electrical oscillations including a tube which comprises generating an electron beam, accelerating said electron beam and in the order named subjecting said beam to a high frequency field for varying the velocity of the electrons in said beam, passing said beam through a field free space, subjecting said beam to a second frequency field for extracting energy therefrom and collecting said electrons.

10. The method of operating apparatus for generating electrical oscillations and including a high frequency tube which comprises generating a beam of electrons and in the order named accelerating said beam of electrons, subjecting said beam of electrons to a high frequency field for varying the velocity of the electrons in said beam, passing said modulated beam through a field free space, extracting energy from said modulated beam of electrons and collecting said electrons.

11. An electron discharge device including a cathode for supplying electrons, means for forming said electrons into a beam, a collector electrode for receiving electrons in said beam, a grid electrode for modulating said electron beam, and an output circuit including a hollow conducting member between the collector electrode and modulating grid electrode and surrounding the beam for extracting energy inductively from said modulated beam of electrons.

12. An electron discharge device for use at high frequencies including a cathode for supplying electrons, means for forming said electrons into a beam, a collector electrode for the electrons in said beam, electrode means positioned between said cathode and collector for subjecting the beam to a first high frequency field for velocity modulating said beam, a control electrode between said cathode and electrode means for applying a modulating voltage to said beam prior to its passage to said electrode means and a second electrode means defining a second high frequency field space through which the beam passes before being collected by said collector ror extracting energy inductively from said velocity modulated beam, and oscillating circuit means connected to said electrode means for providing voltages for the application of the first high frequency field and for applying the second high frequency field for extracting energy from the electron stream.

13. An electron discharge device for use at high frequencies including a cathode for supplying electrons, means for forming electrons into a beam and means for collecting the electrons in said beam, a pair of electrode members positioned between the cathode and collector through which said beam of electrons is directed, and conducting means surrounding said beam between said pair of electrode members and cooperating with said electrode members for providing a plurality of high frequency fields through which said electron beam is directed for successively velocity modulating said beam of electrons and inductively extracting energy from said velocity modulated beam of electrons, and oscillating circuit means connected between the electrode members and said conducting means.

14. An electron discharge device for use at high frequencies including a cathode for supplying electrons, means for forming said electrons into a beam, and means for collecting electrons in said beam, a grid for modulating said beam of electrons, a circuit connected to said grid for applying alternating voltages to said grid, a first electrode means through which said beam of electrons is directed for subjecting said electron beam to a high frequency field for velocity modulating said beam of electrons and a second electrode means between said first electrode means and collecting means for subjecting the beam to a second high frequency field for inductively extracting energy from said modulated beam of electrons, and circuit means connected to said electrode means for providing the voltage for modulating the beam and for extracting energy from the beam.

15. In an electronic device, an electron source, means including an element and a source of voltage for making the potential of the element positive relative to said source for causing electrons to traverse a space path, means producing a high frequency field in the initial portion of said space path having an electric component in the direction to produce retarding and accelerating effects on electrons along the path of travel of said electrons, external circuit means producing a high frequency field in a subsequent portion of said space path having an electric component in the direction to produce retarding and accelerating effects on electrons along the path of travel of

said electrons, said field in said initial portion of said space path alternately accelerating and retarding electrons in successive half periods to cause the accelerated electrons in their subsequent travel along said space path to tend to overtake the retarded electrons whereby they arrive in the region of said subsequent portion in proper phase with respect to said field to deliver energy to said external circuit means.

16. In an electronic device, means providing a space path, a source of electrons, a conducting member having means positively charging the member for causing electrons to traverse said space path, means producing in an initial portion of said space path a high frequency field having an electric component in such direction that said field alternately accelerates and retards electrons traversing said portion, in successive half periods of said field, to cause the accelerated electrons to tend to overtake the retarded electrons in their subsequent travel along said path, and means producing an alternating field having an electric component tending to retard said electrons at a portion of said space path where said accelerated and previously retarded electrons are in substantially the same phase, for abstracting energy from said accelerated and previously retarded electrons.

17. In an electronic device, means providing a space path, a source of electrons, an electrode and means for positively charging the electrode for imparting velocity to the electrons and causing them to traverse said space at suitable velocity, means providing between two points in an initial portion of the path a high frequency alternating field exerting alternately retarding and accelerating effects on electrons between said points in alternate half periods of said field whereby increments of energy are alternately given to and abstracted from the field in this region, and means providing similar field conditions further on along the path of electron travel at a point where the accelerated electrons have sufficiently caught up with the retarded electrons, and are in proper phase, to deliver energy to the field.

18. In ultra high frequency electronic apparatus, an evacuated enclosure, means providing a space path for electron travel therein, a source of electrons, means producing an ultra high frequency electric field which has in each of a succession of regions spaced along said path of electron travel an electric component in such direction as to affect the velocity of electron travel, means for causing electrons from said source to enter the influence of said field and to traverse said space at suitable velocity, whereby electrons in an initial region of said field are retarded in one half period and accelerated in the next half period, and means maintaining the field and electron velocity relations such that those electrons which were retarded in said initial field region and also those electrons which in the next half period were accelerated in said initial field region both deliver energy to the field in a further region along the path of electron travel where the accelerated electrons have sufficiently caught up with the electrons which entered the initial region a half period earlier and were retarded.

19. In electronic apparatus, an elongated evacuated tube, a cathode and positive accelerating electrode at one end, a positive electrode at the opposite end, with an intervening elongated space path for the travel of electrons, means for making the potential of said electrodes positive, spaced conductor means producing ultra-high frequency fields at discrete regions spaced apart along said path, said fields having electric intensity components in the direction of electron travel, and means so relating the frequency and phase of said field components and the velocity of the electrons that electrons which are retarded in an earlier region of said regions are also retarded in a subsequent region and delivery energy to the field in both of said regions, and electrons which are accelerated in said earlier region catch up sufficiently with the electrons of the preceding half cycle, which were retarded, to be in proper phase in such subsequent region to experience retardation and deliver energy to the field in said subsequent region.

20. The process of generating electrical oscillations which comprises subjecting an electron stream at a point along its course to an accelerating force and to a retarding force in periodic alternation while permitting both the accelerated and the retarded electrons to pass said point and subsequently deriving energy from the stream at another point further along in its course where accelerated electrons tend to overtake retarded electrons and both are in proper phase to deliver energy to the adjacent electric field, all of said electrons passing said two points in the same direction.

21. The method of generating and amplifying a high frequency wave comprising subjecting a stream of electrons, initially continuous, to a high frequency alternating electric field, causing said field in a given region alternately to decelerate and accelerate electrons in said stream to produce a redistribution of the positional relations of the electrons lengthwise of the stream while allowing both the decelerated and accelerated electrons to traverse said region in the same direction and abstracting energy into said field from said stream at a point further along the stream where previously accelerated electrons tend to overtake decelerated electrons and both are in a retarding phase of said field and are traveling in said same direction.

22. The method of generating electrical oscillations which comprises subjecting an electron stream at a point along its course to alternately accelerating and retarding forces to produce in electrons passing such point in succeeding half periods differential velocities whereby the accelerated electrons tend to overtake the retarded electrons, and abstracting energy from said electrons at another point further along in their path of travel at which both the previously accelerated and retarded electrons are in similar phase, all of said electrons passing both of said points in the same direction.

23. An electron discharge device having a cathode electrode means for supplying a beam of electrons and a collector for said beam of electrons, a grid adjacent said cathode for modulating said electron beam, and electrode means defining a space in which a high frequency field exists during operation of said electron discharge device and positioned between the collector and said grid, and a tank circuit connected to said last electrode means, the modulated stream of electrons passing through said high frequency field for inductively extracting energy from the electron stream.

24. An electron discharge device having a cathode for supplying electrons, means for focusing said electrons into a directed beam, and a collector for said electrons, a grid electrode adjacent said cathode for modulating said electrons,

and an input circuit connected to said grid, electrode means positioned between said grid and said collector and including a first electrode means for subjecting said electron beam to a high frequency field for velocity modulating the electrons and a second electrode means for inductively extracting energy from said modulated electrons and circuit means connected to said electrode means and cooperating therewith for velocity modulating the stream and for inductively extracting energy from said stream.

25. An electron discharge device for use at high frequencies and having a cathode for supplying electrons, means for forming said electrons into a beam, and a collector electrode for said beam for collecting electrons, a hollow conducting member positioned between the cathode and collector through which said electrons are directed, an electrode means positioned between said hollow conducting member and said cathode and between said hollow conducting member and said collector for providing two successive high frequency fields through which said beam of electrons is directed, and an oscillating tank circuit connected between said hollow conducting means and said electrode means.

26. An electron discharge device having a cathode for supplying a stream of electrons and means for receiving said electrons, a hollow conducting member through which said electrons are directed and positioned between said cathode and said means, and a second hollow conducting member surrounding and enclosing said first hollow conducting member for providing with said first hollow conducting member a first high frequency field in which the electron stream is modulated, and a second high frequency field in which energy is extracted from the electron stream, means for applying a positive potential to one of said hollow conducting members and circuit means for extracting energy from said hollow conducting members.

27. An electron discharge device having a cathode for supplying oppositely disposed streams of electrons and means for receiving said electrons, a first hollow conducting member in the path of each stream through which the electrons are directed to the receiving means, and a second hollow conducting member surrounding said first hollow conducting member and providing with said first hollow conducting member a first high frequency field through which each stream of electrons is directed to be modulated, and a second high frequency field through which each stream of electrons is directed after having been modulated, and circuit means associated with said hollow conducting members for providing an output circuit for said device, and means for applying a positive voltage to said outer hollow conducting members.

28. The method of operating an apparatus for generating electrical oscillations and including electron discharge device which comprises the steps of causing the initiation of a space flow of electrons, causing said flow to be subjected to successive processes of density and velocity modulation in accordance with certain signal intelligence and abstracting energy from said stream inductively, subsequent to the velocity modulation process.

29. The method of operating an apparatus for generating electrical oscillations and including an electron discharge device which comprises the steps of causing the initiation of a space flow of electrons, causing said flow to be subjected to successive processes of density and velocity modulation, applying a signal to vary the degree to which the density modulation process is effective, and abstracting energy from the stream inductively, subsequent to the velocity modulation process.

30. An electron discharge device having cathode means for supplying a stream of electrons and a hollow conducting member through which said stream of electrons is directed, and a second hollow conducting member surrounding and enclosing said first hollow conducting member and defining a plurality of spaces successively traversed by said stream of electrons, high frequency fields existing in said spaces during operation of said electron discharge device, means for receiving the electrons after passage through said hollow conducting members, means for applying a positive potential to one of said hollow conducting members, and circuit means for extracting energy from said hollow conducting members.

31. An electron discharge device having cathode means for supplying a stream of electrons, a hollow conducting member having opposite foraminous walls through which electrons are directed, and a second hollow conducting member surrounding said first hollow conducting member and defining a first space between one foraminous wall of the first hollow conducting member and the wall of said second hollow conducting member, and a second space between the other foraminous wall of the first conducting member and the wall of the second hollow conducting member adjacent thereto, high frequency fields existing in said spaces during operation of said electron discharge device and to which said stream of electrons is successively subjected, means for applying a positive potential to one of said hollow conducting members and circuit means for extracting energy from said hollow conducting members.

32. Apparatus for producing high frequency electromagnetic waves including a cathode for supplying electrons, means including circuit means for producing an alternating electric field, means for directing said electrons through said field to periodically change the velocities of said electrons, means for providing a substantially field-free space in which said velocity varied electrons become grouped, means for causing said grouped electrons to produce an oscillating electromagnetic field, and modulating mear , including a grid for modulating said electrons before the velocity variation thereof.

33. High frequency apparatus for producing high frequency electromagnetic waves and including a source of electrons, means including circuit means for producing a high frequency electric field, means for directing electrons from said source of electrons through said field to vary the velocity of said electrons, means providing a substantially field-free space in which said velocity varied electrons become grouped, means for causing said grouped electrons to produce a second high frequency field and means for controlling the current density of said electrons before the velocity variation thereof.

34. High frequency apparatus for generating high frequency electromagnetic waves and including a cathode for supplying a stream of electrons, a first conducting member through which said stream of electrons is directed, a second conducting member surrounding said first conducting member and defining a plurality of spaces successively traversed by said stream of electrons,

high frequency fields existing in said spaces during operation of said electron discharge device, said first conducting member providing a field-free space between said plurality of spaces and circuit means associated with said conducting members for extracting energy.

35. Apparatus for producing electrical oscillations including a cathode for directing a stream of electrons along a space discharge path, a first means and a second means positioned in said path in succession for defining spaces in which high frequency electromagnetic fields may be generated, and circuit means associated with said means for providing a first high frequency field in the first space to vary the velocity of the electrons in said electron stream and for providing a second high frequency field in the second space for extracting energy from said electrons.

OSKAR HEIL.

CERTIFICATE OF CORRECTION.

Patent No. 2,363,962. November 28, 1944.

OSKAR HEIL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 34, after the word "emerges" insert --therefrom--; page 5, first column, line 56, claim 9, after "second" insert --high--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of February, A. D. 1945.

Leslie Frazer

(Seal) Acting Commissioner of Patents.