April 13, 1948. C. E. HALLMARK 2,439,512

ULTRA HIGH FREQUENCY POWER OSCILLATOR

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FIG. 1

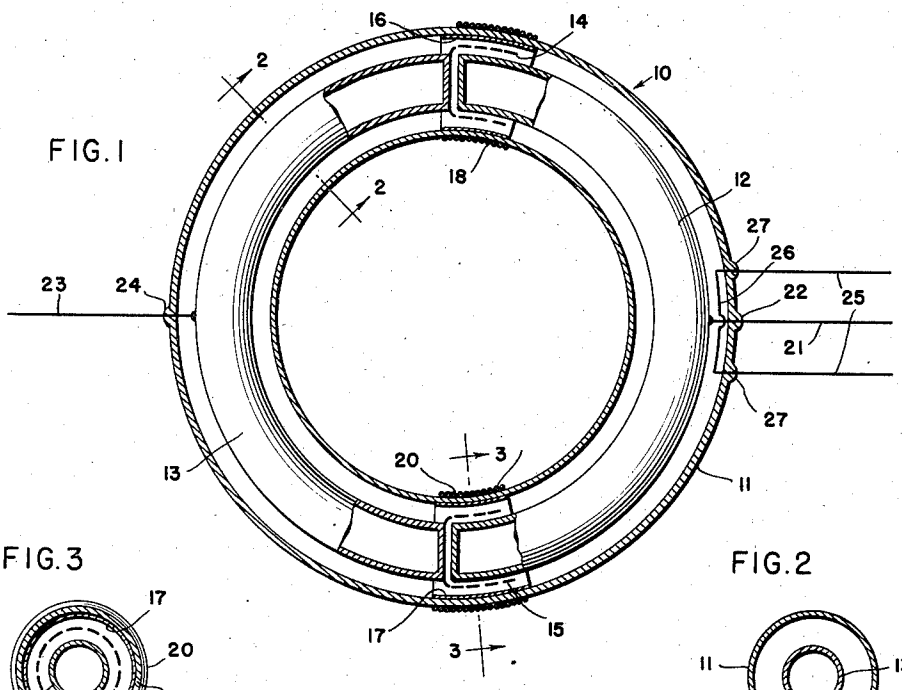


FIG. 3

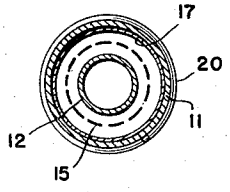
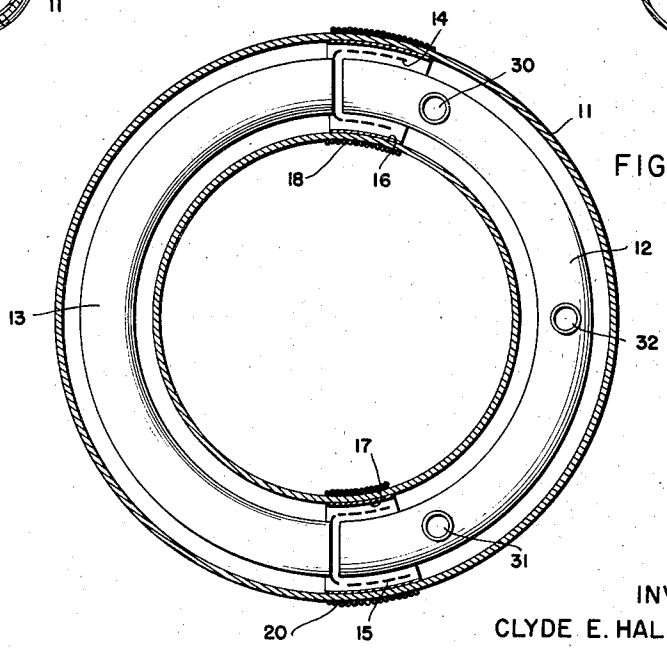


FIG. 2

FIG. 4



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FIG. 5

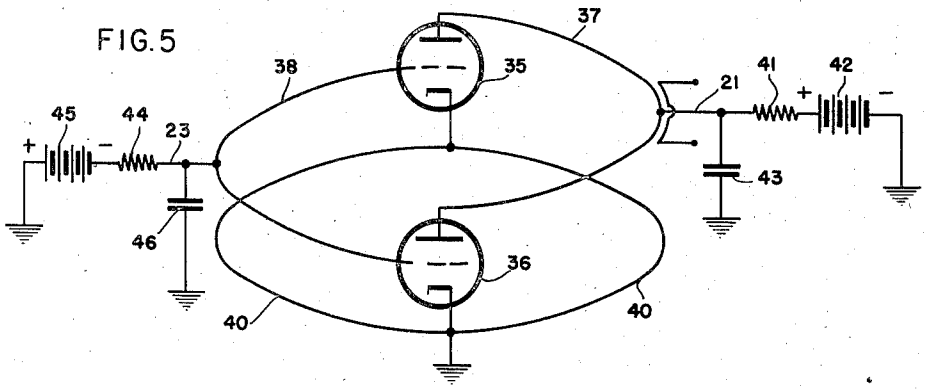
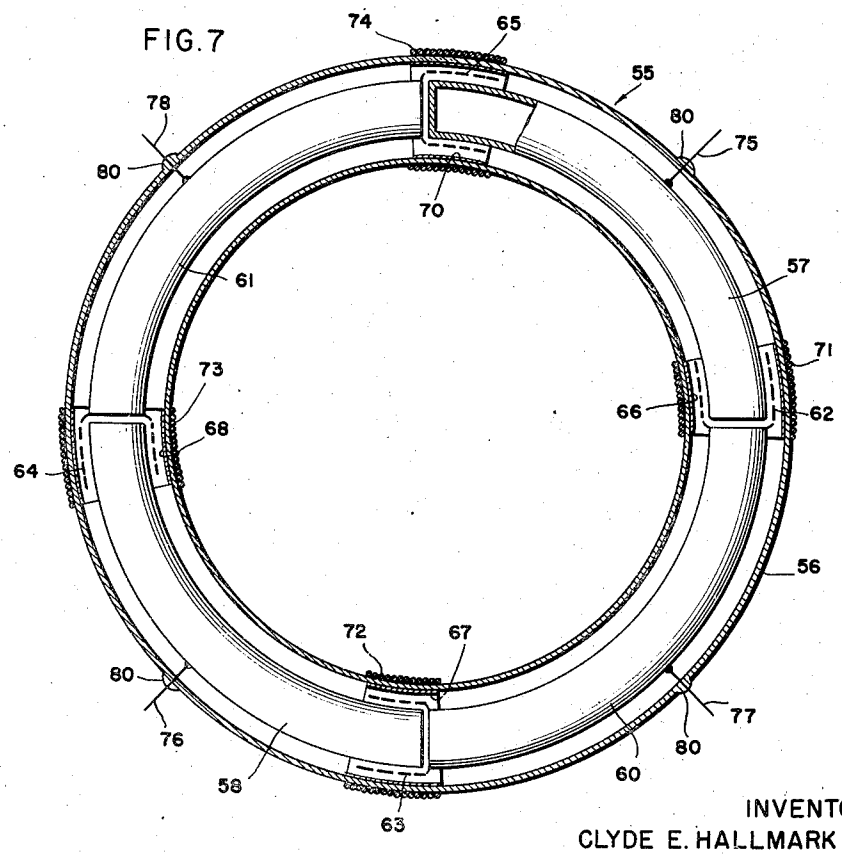


FIG. 7



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FIG. 8

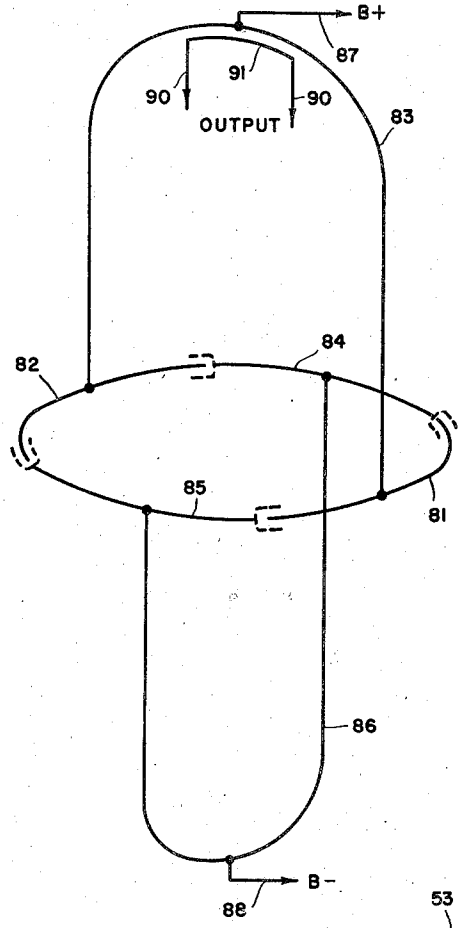


FIG. 6

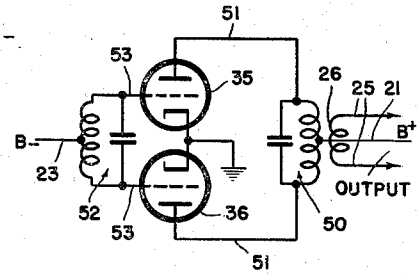
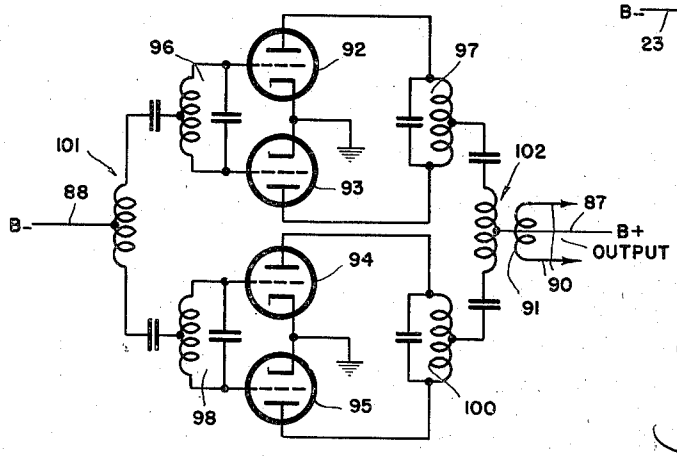


FIG. 9



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UNITED STATES PATENT OFFICE

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ULTRA HIGH FREQUENCY POWER OSCILLATOR

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Application December 29, 1944, Serial No. 570,256

16 Claims. (Cl. 250—27.5)

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This invention relates to electric discharge devices and particularly to an oscillator capable of generating ultra-high frequencies.

Numerous oscillators have heretofore been devised for generating high and ultra-high frequencies. In a well known system the oscillations generated by a regeneratively coupled amplifier are stabilized by a tuned circuit. Instead of a feedback amplifier an electron discharge tube having a negative resistance may be utilized for generating oscillations. The tuned circuits associated with a feedback amplifier or a negative resistance discharge device usually comprise lumped reactance elements such as capacitances and inductances, the values of which determine the resonant frequency. A tuned circuit of this type is quasi-stationary, that is, at any given instant the oscillating current intensity in the tuned circuit is the same at any point because the current oscillates back and forth between the capacitance element and the inductance element. However, in such an oscillator system the values of the component parts of the circuit place an upper limit on the frequencies that can be generated therein.

In order to increase the frequency which can be generated by an oscillator it has been suggested to employ resonant transmission lines as tuned circuits. Such a resonant transmission line is also known in the art as a Lecher wire system. A tuned circuit of this type is non-stationary, that is, the current intensity at a certain instant is different at different points of the tuned circuit. A tuned transmission line does not possess discontinuities such as lumped capacities and, therefore, standing waves are developed so that at a certain point of the line a voltage node is formed while other portions of the tuned circuit have voltage maxima or ventral segments. Oscillators associated with a tuned transmission line or Lecher wire system have considerable merit. They may be used for generating ultra-high frequencies, such for example as those of the order of three thousand megacycles. However, great difficulties have been experienced heretofore in order to devise oscillators of this type which have an appreciable power output at ultra-high frequencies.

Another drawback of conventional oscillators associated with a tuned transmission line is that a discontinuity is introduced into the system at the junction of the oscillator tube and the transmission line. This drawback has led to the development of special tube forms to obviate or minimize such discontinuities.

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It is an object of the present invention, therefore, to provide an oscillator capable of generating ultra-high frequencies with a substantial power output.

A further object of this invention is to provide an oscillator where the frequency of oscillation is determined by the physical dimensions of the oscillator tube.

Another object of the invention is to provide an oscillator circuit which does not possess any discontinuities such as lumped capacities.

Still another object of the invention is to provide an oscillator tube structure which requires a minimum of electric leads that have to be sealed through the evacuated envelope of the tube.

In accordance with the present invention there is provided a high vacuum electron discharge device comprising an outer hollow member of conducting material. At least one pair of inner members of conducting material is provided. The inner members are insulated from each other and disposed within the outer member. The inner members have substantially equal length and one of each pair of inner members has a grid-like extension at each end thereof surrounding a portion of the other one of the pair of inner members. Means coextensive with the grid-like extensions are provided for emitting electrons. Each of the grid-like extensions and the portions of the outer and inner members coextensive therewith serve as a three-element vacuum tube, while the intermediate sections of the members serve as transmission lines. In this manner one or more pairs of three-element vacuum tubes are provided.

Preferably, the outer member is of toroidal shape and serves as a cathode. One of each pair of inner members serves as a grid, while the other one of each pair of inner members serves as an anode. The length of each of the inner members may be substantially equal to one-half the wave length of the waves to be generated.

For a better understanding of the invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings:

Fig. 1 is a plan view, partly in section, of an electric discharge device embodying the present invention;

Fig. 2 is a cross-sectional view along line 2—2 of Fig. 1;

Fig. 3 is a cross-sectional view along line 3—3 of Fig. 1;

Fig. 4 is a plan view similar to Fig. 1 showing means for fluid cooling the anode structure of the discharge device;

Fig. 5 is an electric circuit diagram of the oscillator of Fig. 1 and its connections;

Fig. 6 is a diagram of the equivalent electric circuit of the oscillator of Fig. 1;

Fig. 7 is a plan view, partly in section, of a modified electric discharge tube in accordance with the invention containing two pairs of three-element vacuum tubes;

Fig. 8 is a schematic electric circuit diagram of the oscillator of Fig. 7; and

Fig. 9 is a diagram of the equivalent electric circuit of the oscillator of Fig. 7.

Referring more particularly to Figs. 1 to 3 of the drawings, there is provided a high vacuum electron discharge device 10 including an outer member 11 of toroidal shape which preferably serves as the cathode of the discharge device. Two inner members 12 and 13 are provided within cathode 11 extending substantially through the entire length of cathode 11. Inner member 12 preferably serves as the anode of electric discharge device 10, and member 13 serves as the grid thereof. Anode 12 is hollow and closed at both ends as clearly shown in Fig. 1. Grid 13 has two perforated or grid-like extensions 14 and 15 which surround a portion of each end of anode 12 and which may, for instance, consist of a wire screen. The inner surface of cathode member 10 is provided with electron emissive material at 16 and 17. Electron emissive surfaces 16 and 17 are coextensive with perforated or grid-like extensions 14 and 15, respectively. Heater windings 18 and 20 are arranged outside of cathode member 11 for heating electron emissive surfaces 16 and 17 in order to provide a copious electron flow.

Cathode member 11 may be made of glass and may have an inner surface of electrically conducting material such as a metal film. Alternatively, cathode member 11 may be made of metal. Anode member 12 and grid member 13 preferably consist of a metal of good electric conductivity such as copper or silver. Due to the skin effect, high frequency current is localized within a very thin surface layer of the conducting line. Hence, it is only necessary to plate the outer surface of inner members 12 and 13 and the inner surface of cathode member 11 with copper or silver for the purpose of reducing the electric resistance thereof. Lead 21 connected to the mid-portion of anode member 12 is sealed through cathode member 11 by means of insulating seal 22. Lead 23 is connected to the mid-portion of grid member 13 and sealed through cathode member 11 by insulating seal 24. Output leads 25, 25, sealed through cathode member 11 by insulating seals 27, 27, are connected to loop 26 inductively coupled to the mid-portion of anode member 12.

Referring now to Fig. 4, there is illustrated means for fluid cooling the electric discharge device shown in Fig. 1. For this purpose anode member 12 is provided with fluid inlets 30, 31 and a fluid outlet 32. The cooling fluid may be introduced through inlets 30, 31 and may be removed from outlet 32. It will be understood that anode member 12 is closed and fluidtight. Inlets 30, 31 and outlet 32 are connected to suitable pipes sealed through outer cathode member 11. The pipe connections between anode 12 and cathode member 13 should be electrically insulated.

Referring now to Fig. 5, there is shown a schematic electric circuit diagram illustrating the circuit connections of the oscillator structure shown in Figs. 1 to 4. Electric discharge device 10 of Figs. 1 to 4 is electrically equivalent to two three-element vacuum tubes 35 and 36. The plates of tubes 35 and 36 are connected by lead 37, the two grids are connected by lead 38 and the cathodes are connected by lead 40, grounded as shown. Lead 37 and the plates of vacuum tubes 35, 36 correspond to anode member 12 shown particularly in Fig. 1. Similarly, lead 38 and the grids of vacuum tubes 35, 36 correspond to grid member 13 and its extensions 14, 15; lead 40 and the two cathodes of tubes 35, 36 correspond to cathode member 11. For the purpose of applying positive operating potential to the plates of tubes 35, 36 lead 21 connects the mid-portion of lead 37 through resistor 41 to battery 42 having its negative terminal grounded. Bypass condenser 43 connects lead 21 to ground. For applying negative operating potential to the grids of tubes 35, 36 there is provided lead 23 connecting the mid-portion of grid lead 38 through resistor 44 to battery 45 having its positive terminal grounded. Bypass condenser 46 connects lead 23 to ground. Battery 42 supplies a positive potential to the plates of tubes 35, 36 which may be of the order of magnitude of 1000 volts, while battery 45 supplies a negative potential of the order of magnitude of 100 volts to the grids of tubes 35, 36.

The operation of the oscillator of the invention will readily be understood with reference to Fig. 6 showing the equivalent circuit of the oscillator structure. The cathodes of tubes 35, 36 are grounded and the grids thereof are connected in phase opposition. Hence, tubes 35, 36 are arranged in push-pull. Tuned circuit 50 is connected by leads 51, 51 to the plates of tubes 35, 36. Another tuned circuit 52 is connected by leads 53, 53 to the grids of tubes 35, 36. Tuned circuit 50 corresponds to the tuned transmission line represented by anode member 12. The distributed capacitance and inductance of the tuned transmission line as well as the interelectrode grid-to-plate capacitances have been represented by the lumped capacitance element and inductance element of tuned circuit 50 in Fig. 6. Similarly, tuned circuit 52 corresponds to the tuned transmission line represented by grid member 13 and grid-like extensions 14, 15. The distributed capacitance and inductance of the tuned transmission line as well as the interelectrode cathode-to-grid capacitances have been shown in tuned circuit 52 of Fig. 6 as a condenser and coil. Lead 21 supplies positive operating potential from a battery indicated schematically at B+ to the mid-portion of the inductance coil of tuned circuit 50. Lead 23 supplies negative operating potential from a battery B— to the mid-portion of the inductance coil of tuned circuit 52. The ultra-high frequency output energy is derived from leads 25, 25 connected to loop 26 coupled, in turn, to the inductance coil of tuned circuit 50.

It will be seen that the oscillator circuit of Fig. 6 is a push-pull connected tuned-grid tuned-plate oscillator. In order to tune the transmission lines represented by tuned circuits 50 and 52, anode member 12 and grid member 13 each have ap-

proximately the same length corresponding to one-half the wave length of the oscillations to be generated. Accordingly, parallel resonant circuits 50 and 52 are tuned to approximately the same frequency.

The operation of a tuned-grid tuned-plate oscillator is well understood in the art, and will be explained here for an oscillator having one tube only. The coupling between the plate circuit and the grid circuit of the oscillator is effected through the tube. This electronic type of coupling can be explained in the following manner. If the frequency of the plate circuit is below its resonant frequency, the plate load is inductive. Hence, the grid-to-plate interelectrode capacitance results in a negative value of the effective conductance between the grid and the cathode. It can be shown that for an inductive load the grid conductance is negative, in other words, the circuit operates similar to a negative resistance device. Therefore, instead of dissipating power through the oscillator tube, power is supplied from the tube into the grid circuit as well as into the plate circuit.

It follows from the above explanation that the parallel resonant plate circuit of a tuned-grid tuned-plate oscillator should have a resonant frequency which is slightly higher than the resonant frequency of the parallel resonant grid circuit. Only when this condition is met, the effective conductance between the grid and the cathode has a negative value which is essential for the operation of the oscillator. Hence, the effective electrical length of anode member 12 should be slightly less than the effective electrical length of grid member 13. The effective length of grid member 13 should be calculated from the mid-portions of extensions 14 and 15. Therefore, it will be seen that, although the physical length of anode member 12 and grid member 13 may be substantially equal, the effective electrical length of anode member 12 is slightly less than that of grid member 13 due to the extensions 14 and 15 of anode 12, which is just what is required, because a shorter electrical length of anode member 12 will slightly increase the resonant frequency of the parallel resonant circuit in series with the anodes.

The operation of a push-pull connected tuned-grid tuned-plate oscillator will be obvious from the explanations given hereinabove. As clearly shown in Fig. 6 the grids of tubes 35 and 36 are connected in phase opposition. Therefore, when either tube 35 or tube 36 is conducting space current the other one is inoperative and vice versa. Therefore, voltage maxima or antinodes are developed at the end of portions of anode member 12 and grid member 13. The thus produced oscillations will develop standing waves along anode member 12 and grid member 13, and it is obvious that voltage nodes are formed at the mid-portions of anode member 12 and grid member 13. The standing voltage waves in turn creat standing oscillating current waves which have a 90 degrees phase shift in space with respect to the standing voltage waves. Accordingly, current maxima are developed at the mid-portions of anode member 12 and grid member 13. The direct current potentials are connected to those points of anode member 12 and grid member 13 where the alternating current waves have their maxima. Output loops 26 is arranged where the alternating current of anode member 12 has its maximum.

The physical length of anode member 12 and grid member 13, therefore, determines the frequency of the oscillator circuit. Hence, it is feasible to generate micro-waves down to a wave length of one decimeter corresponding to a frequency of up to 3000 megacycles. The lower limit of the frequency to be generated or, in other words, the upper limit of the wave length depends upon the physical dimensions of the discharge device and may be of the order of magnitude of one meter corresponding to 300 megacycles.

The power output obtainable with the oscillator of the invention is high even at a low wave length of about 10 to 15 centimeters. Anode member 12 and grid member 13 are in the form of a transmission line and, therefore, they can be made with a high Q, that is, with a high ratio of reactance to resistance and, hence, the losses in the circuit are very low. Furthermore, the oscillator of the invention has a high symmetry and the transmission lines are arranged in such a manner that no discontinuities are introduced. These factors coupled with the comparatively great heat dissipating power of anode member 12 and cathode member 10 all contribute to a high power output of the oscillator.

When the frequency to be generated by the oscillator of the invention becomes very high or the wave length very short, the dimensions of the tube become very small. In this case it may be advantageous to employ more than the equivalent of one pair of three-element vacuum tubes.

Such a structure has been illustrated in Fig. 7. As shown in Fig. 7, there is provided a high vacuum electron discharge tube 55 having an outer member 56 of toroidal shape which preferably serves as a cathode. Within cathode member 56 there are disposed two anode members 57 and 58 and two grid members 60 and 61. Grid member 60 is provided with two grid-like extensions 62 and 63 of wire mesh which surround adjacent end portions of anode members 57 and 58, respectively. Grid member 61 also has two grid-like exensions 64 and 65 surrounding the other end portions of anode members 58 and 57, respectively. Electron emissive materials 66, 67, 68 and 70, arranged on the inner surface of cathode member 56, are provided coextensive with each grid-like extension 62, 63, 64 and 65. For the purpose of heating electron emissive surfaces 66, 67, 68 and 70, heater windings 71, 72, 73 and 74 are arranged about cathode members 56.

Leads 75 and 76 are connected to the mid-portions of anode members 57 and 58, while leads 77 and 78 are connected to the mid-portions of grid members 60 and 61, respectively. Leads 75, 76, 77 and 78 are sealed through cathode member 56 by insulating seals 80. Cathode member 56 may either be of glass with an inner metal film such as copper or silver or it may consist of metal. Anode members 57, 58 and grid members 60, 61 preferably consist of metal which may be copper or silver plated as explained in connection with Fig. 1. If desired, anode members 57 and 58 may be fluid cooled in the manner shown in Fig. 4.

The electrical connections of electron discharge device 55 of Fig. 7 are illustrated in Fig. 8. Anode members 81, 82, shown schematically in Fig. 8, have their mid-portions connected to anode transmission line 83, while grid members 84 and 85 have their mid-portions connected to grid transmission line 86. Positive operating potential is supplied through lead 87 to the mid-portion of anode transmission line 83, and negative potential is supplied through lead 88 to the mid-portion of grid transmission line 86. Anodes 81,

82 and grids 84, 85 have approximately the same length corresponding to one-half the wave length of the waves to be generated. As explained hereinabove in connection with Figs. 1 to 6, the equivalent electrical length of anode members 57 and 58 as shown in Fig. 7 should be slightly shorter than that of grid members 60 and 61. Actually, the physical length of anode members 57 and 58 could be made equal to the physical length of grid members 60 and 61 because the equivalent electrical length of grid members 60 and 61 will be higher in view of their extensions 62, 63, 64 and 65.

The effective length of anode transmission line 83 from either anode 81 or anode 82 to lead 87 is equal to one-half the wave length of the waves to be generated or a multiple thereof. Grid transmission line 86 preferably has the same length as anode transmission line 83 so that its effective length from either grid 84 or grid 85 to lead 88 is equal to one-half the wave length of the oscillations or a multiple thereof.

When oscillations are generated by the oscillator shown in Figs. 7 and 8, standing waves are generated along anodes 81, 82 and grids 84, 85. Due to the fact that anodes 81, 82 and grids 84, 85 have an effective length approximately equal to one-half of the wave length to be generated, voltage nodes are developed at the mid-portions of anodes 81, 82 and grids 84, 85. Similarly, the free ends of anodes 81, 82 and grids 84, 85 have voltage maxima or antinodes. The standing waves of the current developed by the standing voltage waves have a phase displacement of 90 degrees in space with respect to the standing voltage waves, and, therefore, current maxima are developed at the mid-portions of anodes 81, 82 and grids 84, 85. The mid-portions of transmission lines 83 and 86 correspond electrically to the mid-portions of anodes 81, 82 and grids 84, 85, respectively. Hence, the direct current is supplied to those points of transmission lines 83 and 86 where the alternating current has a maximum. The oscillating output energy is derived from output terminals 99, 90 connected to loop 91 which is coupled to the mid-portion of anode transmission line 83.

The equivalent electric circuit of the oscillator of Figs. 7 and 8 is illustrated in Fig. 9. The circuit includes four three-element vacuum tubes 92, 93, 94 and 95. Vacuum tubes 92 and 93 arranged in push-pull with their cathodes grounded have a tuned-grid circuit 96 and tuned-plate circuit 97. Vacuum tubes 94, 95 also arranged in push-pull with their cathodes grounded have a tuned-grid circuit 98 and a tuned-plate circuit 100. As explained in connection with Figs. 1 to 6, tuned circuits 96, 97, 98 and 100 represent the distributed capacitances and inductances of anode members 57, 58 and grid members 60, 61 as well as the interelectrode capacitances of the four vacuum tubes. Tuned grid circuits 96 and 98 have the mid-portions of their inductances coupled by tuned circuit 101 corresponding to grid transmission line 86. The negative potential from a battery indicated at B— is supplied to the grids of the four tubes by lead 88. Since tuned circuit 101 corresponds to transmission line 86 there is actually a conductive connection between the battery B— and the grids of the four tubes, although in Fig. 9 series condensers have been shown in tuned circuit 101.

Similarly, tuned circuit 102 corresponding to anode transmission line 83 interconnects the mid-portions of the inductances of tuned circuits 97 and 100. Lead 87 supplies positive voltage from battery B+ to the mid-portion of the inductance of tuned circuit 102. As explained hereinabove, there is a conductive connection from battery B+ to the anodes of the four tubes, although series condensers are shown in tuned circuit 102. The oscillating output energy is obtained through leads 90, 99 connected to loop 91, which in turn is coupled to the inductance of tuned circuit 102. This circuit operates similarly to the circuit shown in Fig. 6 and, therefore, no further explanation is needed here.

The discharge device shown in Fig. 1 comprises only four wires which have to be sealed through cathode member 11. Also, in the discharge device shown in Fig. 7 only four wires have to be sealed in which greatly simplifies the glass work.

Outer toroidal member 11 of the oscillator of Figs. 1 to 4 and outer member 56 of the discharge device of Fig. 7, preferably, are used as the cathode of the discharge device. This has the advantage that since the cathode is grounded, the discharge device is at ground potential. Another advantage is that the heater windings or the equivalent of the filament heater system may be arranged outside of toroidal member 11 or 56 and, hence, need not be sealed through the outer member of the discharge device. Furthermore, by using the outer toroidal member 11 or 56 as the cathode the cathode emission is increased. However, for the operation of the oscillator of the invention it is entirely immaterial whether the outer member is the cathode or the anode. If outer member 11 of Figs. 1 to 3 is used as the anode, inner member 12 should be used as the cathode.

It is also feasible to utilize the electron discharge device of the invention as a push-pull amplifier in the ultra-high frequency field. For this purpose it is necessary to neutralize the interelectrode capacitances of the two discharge paths of the device shown in Figs. 1 to 4 or of the four discharge paths of the discharge device of Figs. 7 and 8 so that self-oscillation is prevented. This can be done, for instance, by cross-connecting the grid of each tube structure to the plate of the other tube structure through a condenser which will neutralize the interelectrode capacitances of the discharge paths. The operation of a push-pull neutralizing circuit of this type is well understood in the art and, hence, no further explanation is required here.

While there has been described what are at present considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A high vacuum electron discharge device comprising an outer hollow member of conducting material, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length, one of said inner members having an electron controlling extension at each end thereof surrounding a portion of the other one of said pair of inner members, and electron emitting means coextensive with said extensions, each of said extensions and the portions of said members coex-

tensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

2. A high vacuum electron discharge device comprising an outer hollow and closed member of conducting material serving as a cathode, two inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length, one of said inner members serving as a grid and the other one as an anode, each one of said grid members having a grid-like extension at each end thereof surrounding a portion of the adjacent anode member, and electron emitting means along the inner surface of said cathode and coextensive with said grid-like extensions, each of said extensions and the portions of the adjacent anode member and said cathode member coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

3. A high vacuum electron discharge device comprising an outer member of conducting material having a toroidal shape and serving as a cathode, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length, one of said inner members serving as a grid and the other one as an anode, each one of said grid members having a grid-like extension at each end thereof surrounding a portion of the adjacent anode member, each of said anode members being closed at its ends to form a fluid tight structure, means extending through said cathode member for circulating a cooling fluid through said anode member, and electron emitting means extending along said grid-like extensions, each of said extensions and the portions of the adjacent anode member and said cathode member coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

4. A high vacuum electron discharge device comprising an outer member of conducting material having a toroidal shape and serving as a cathode, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length and forming together substantially a torus, one of said inner members serving as a grid and the other one as an anode, each one of said grid members having a grid-like extension at each end thereof surrounding a portion of the adjacent anode member, electron emissive surfaces extending on the inner surface of said cathode member along said grid-like extensions, and means outside of said cathode member for heating said electron emissive surfaces, each of said extensions and the portions of the adjacent anode member and said cathode member coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

5. A high vacuum electron discharge device comprising an outer member of conducting material having a toroidal shape and serving as a cathode, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length and extending substantially through the entire

inner length of said outer member, one of said inner members serving as a grid and the other one as an anode, each one of said grid members having a grid-like extension at each end thereof surrounding a portion of the adjacent anode member, electron emissive surfaces extending on the inner surface of said cathode member along said grid-like extensions, and heater windings outside of said cathode members for heating said electron emissive surfaces, each of said extensions and the portions of the adjacent anode member and said cathode member coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

6. A high vacuum electron discharge device comprising an outer hollow member of conducting material, two inner members of conducting material insulated from each other and disposed within said outer member, said two inner members having substantially equal length, one of said inner members having a perforated extension at each end thereof surrounding a portion of the other one of said inner members, and electron emitting means extending along said extensions, each of said extensions and the portions of said members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

7. A high vacuum electron discharge device comprising an outer hollow and closed member of conducting material serving as a cathode, two inner members of conducting material insulated from each other and disposed within said outer member, said two inner members having substantially equal length, one of said inner members serving as a grid and the other one as an anode, said grid member having a grid-like extension at each end thereof surrounding a portion of said anode member, and electron emitting means along the inner surface of said cathode member and coextensive with said grid-like extensions, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

8. A high vacuum electron discharge device comprising an outer member of conducting material having a toroidal shape and serving as a cathode, two inner members of conducting material insulated from each other and disposed within said outer member, said two inner members having substantially equal length, each of said two inner members extending substantially through a semicircle, one of said inner members serving as a grid and the other one as an anode, said grid member having a grid-like extension at each end thereof surrounding a portion of said anode member, said anode member being closed at its ends to form a fluid tight structure, means extending through said cathode member for circulating a cooling fluid through said anode member, and electron emitting means extending along said grid-like extensions, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

9. A high vacuum electron discharge device comprising an outer member of conducting material having a toroidal shape and serving as a cathode, two inner members of conducting ma-

terial insulated from each other and disposed within said outer member, said two inner members facing each other and having substantially equal length, one of said inner members serving as a grid and the other one as an anode, said grid member having a grid-like extension at each end thereof surrounding a portion of said anode member, electron emissive surfaces extending on the inner surface of said cathode member along said grid-like extensions, and means outside of said cathode member for heating said electron emissive surfaces, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

10. A high vacuum electron discharge device comprising an outer member of conducting material having a toroidal shape and serving as a cathode, two inner members of conducting material insulated from each other and disposed within said outer member, said two inner members having substantially equal length and extending substantially through the entire inner length of said outer member, one of said inner members serving as a grid and the other one as an anode, said grid member having a grid-like extension at each end thereof surrounding a portion of said anode member, electron emissive surfaces extending on the inner surface of said cathode member along said grid-like extensions, and heater windings outside of said cathode member for heating said electron emissive surfaces, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting transmission lines.

11. An oscillator for generating ultra-short waves comprising an outer hollow member of conducting material, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length corresponding to substantially one-half the wave length of the waves to be generated, one of said inner members having a grid-like extension at each end thereof surrounding a portion of the adjacent inner member, and electron emitting means extending along said grid-like extensions, each of said extensions and the portions of said members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting resonant transmission lines.

12. An oscillator for generating ultra-short waves comprising an outer member of conducting material having a toroidal shape and serving as a cathode, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, one of said inner members serving as an anode and the other inner member serving as a grid, said inner members having substantially equal length corresponding to substantially one-half the wave length of the waves to be generated, each of said grid members having a grid-like extension at each end thereof surrounding a portion of the adjacent anode member, electron emitting means along the inner surface of said cathode member and coextensive with said grid-like extensions, said cathode member being connected to ground, and means for supplying suitable potentials coupled to the mid-portions of said grid members and of said

anode members, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting resonant transmission lines whereby said mid-connection points become voltage nodes and the end portions of said anode and grid members voltage maxima.

13. An oscillator for generating ultra-short waves comprising an outer member of conducting material having a toroidal shape and serving as a cathode, at least one pair of inner members of conducting material insulated from each other and disposed within said outer member, one of said inner members serving as an anode and the other inner member serving as a grid, said inner members facing each other and having substantially equal length corresponding to substantially one-half the wave length of the waves to be generated, each of said grid members having a grid-like extension at each end thereof surrounding a portion of the adjacent anode member, electron emissive surfaces along the inner surface of said cathode member and coextensive with said grid-like extensions, heater windings outside of said cathode member for heating said emissive surfaces, said cathode member being connected to ground, means for supplying suitable potentials coupled to the mid-portions of said grid members and of said anode members, and means coupled to said anode member for deriving oscillating output energy of a wave length determined by the length of said inner members, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting resonant transmission lines, said mid-connection points becoming voltage nodes and the end portions of said grid and anode members voltage maxima, thereby to provide a push-pull connected tuned-grid tuned-plate oscillator.

14. An oscillator for generating ultra-short waves comprising an outer hollow and closed member of conducting material, two inner members of conducting material insulated from each other and disposed within said outer member, said inner members having substantially equal length corresponding to substantially one-half the wave length of the waves to be generated, one of said inner members having a grid-like extension at each end thereof surrounding a portion of the other one of said inner members, and electron emitting means extending along said grid-like extensions, each of said extensions and the portions of said members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting resonant transmission lines.

15. An oscillator for generating ultra-short waves comprising an outer member of conducting material having a toroidal shape and serving as a cathode, two inner members of conducting material insulated from each other and disposed within said outer member, one of said inner members serving as an anode and the other one as a grid, said inner members forming together substantially a torus and having substantially equal length corresponding to substantially one-half the wave length of the waves to be generated, said grid member having a grid-like extension at each end thereof surrounding a portion of said anode member, electron emitting means along the inner surface of said cathode member and coextensive with said grid-like extensions, said cathode mem-

ber being connected to ground, and means for supplying suitable potentials coupled to the mid-portions of said grid member and of said anode member, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting resonant transmission lines whereby said mid-connection points become voltage nodes and the end portions of said grid and anode members voltage maxima.

16. An oscillator for generating ultra-short waves comprising an outer member of conducting material having a toroidal shape and serving as a cathode, two inner members of conducting material insulated from each other and disposed within said outer member, one of said inner members serving as an anode and the other one as a grid, said inner members extending substantially through the entire inner length of said outer member and having substantially equal length corresponding to substantially one-half the wave length of the waves to be generated, said grid member having a grid-like extension at each end thereof surrounding a portion of said anode member, electron emitting means along the inner surface of said cathode member and coextensive with

said grid-like extensions, said cathode member being connected to ground, means for supplying suitable potentials coupled to the mid-portions of said grid member and of said anode member, each of said extensions and the portions of said anode and cathode members coextensive with said extensions constituting a three-element vacuum tube with the intermediate sections of said members constituting resonant transmission lines, whereby said mid-connection points become voltage nodes and the end portions of said anode and grid member voltage maxima, and a loop at the node of said anode for deriving oscillating output energy of a wave length determined by the length of said inner member, thereby to provide a push-pull connected tuned-grid tuned-plate oscillator.

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