

Dec. 10, 1940.

W. T. HARRIS

2,224,649

ULTRA HIGH FREQUENCY CIRCUITS

Filed Nov. 10, 1938

3 Sheets-Sheet 1

FIG. 1.

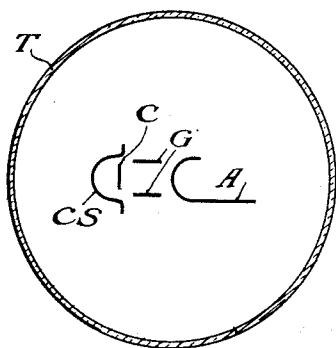


FIG. 2.

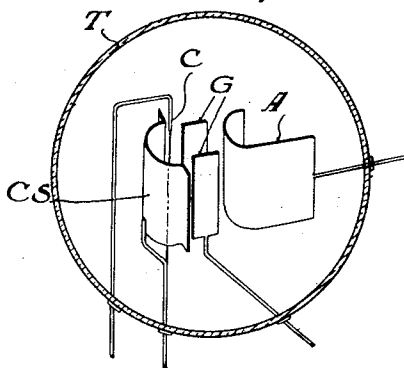


FIG. 3.

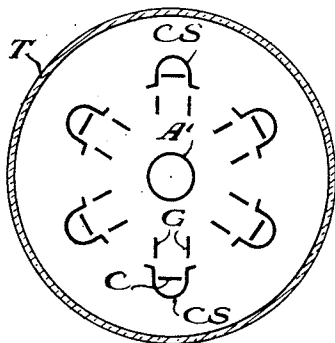


FIG. 4.

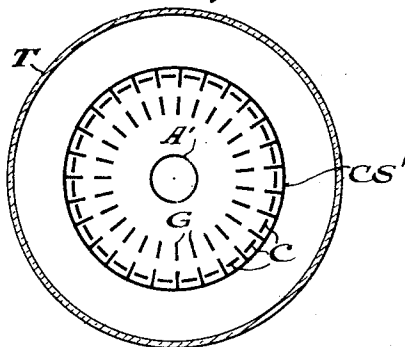
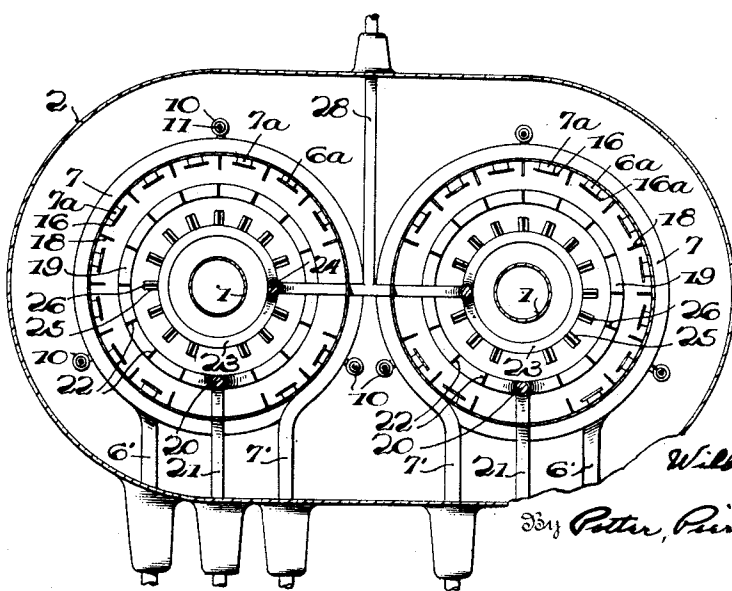


FIG. 5.



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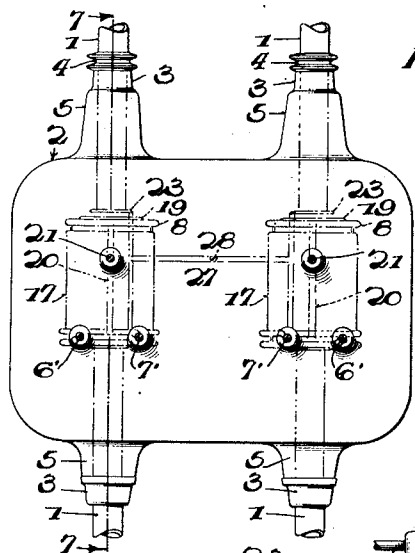


FIG. 6.

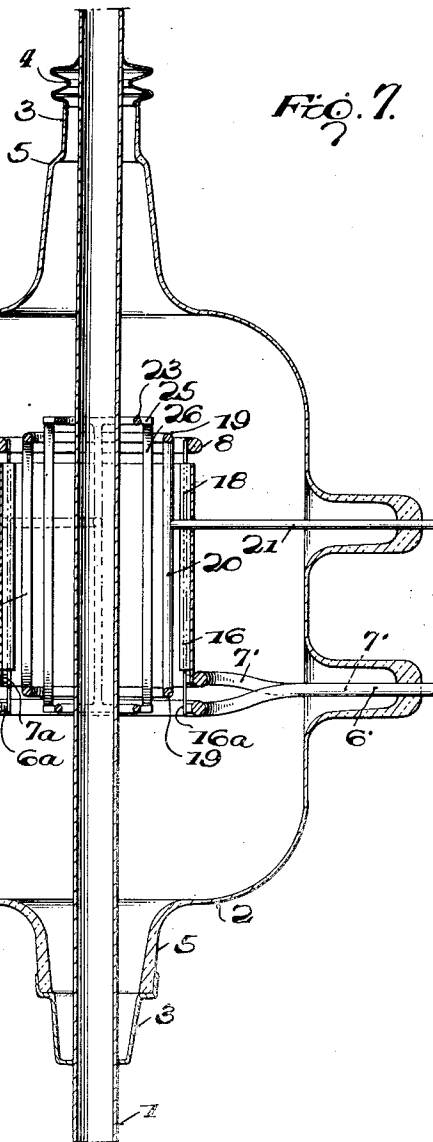


FIG. 7.

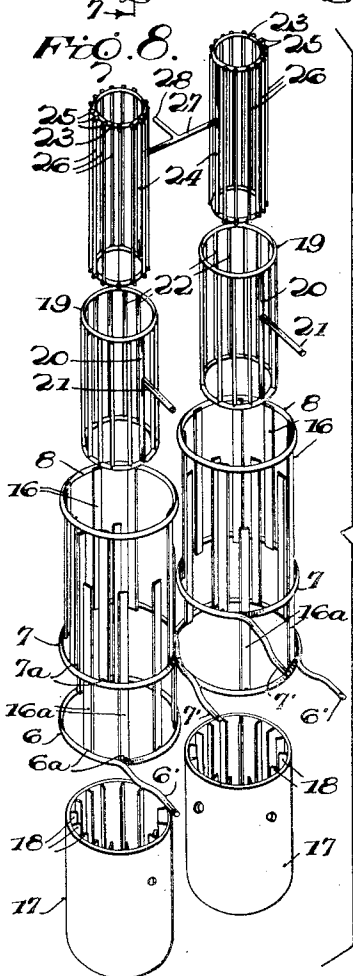


FIG. 8.

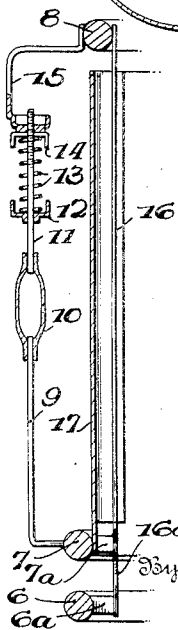


FIG. 9.

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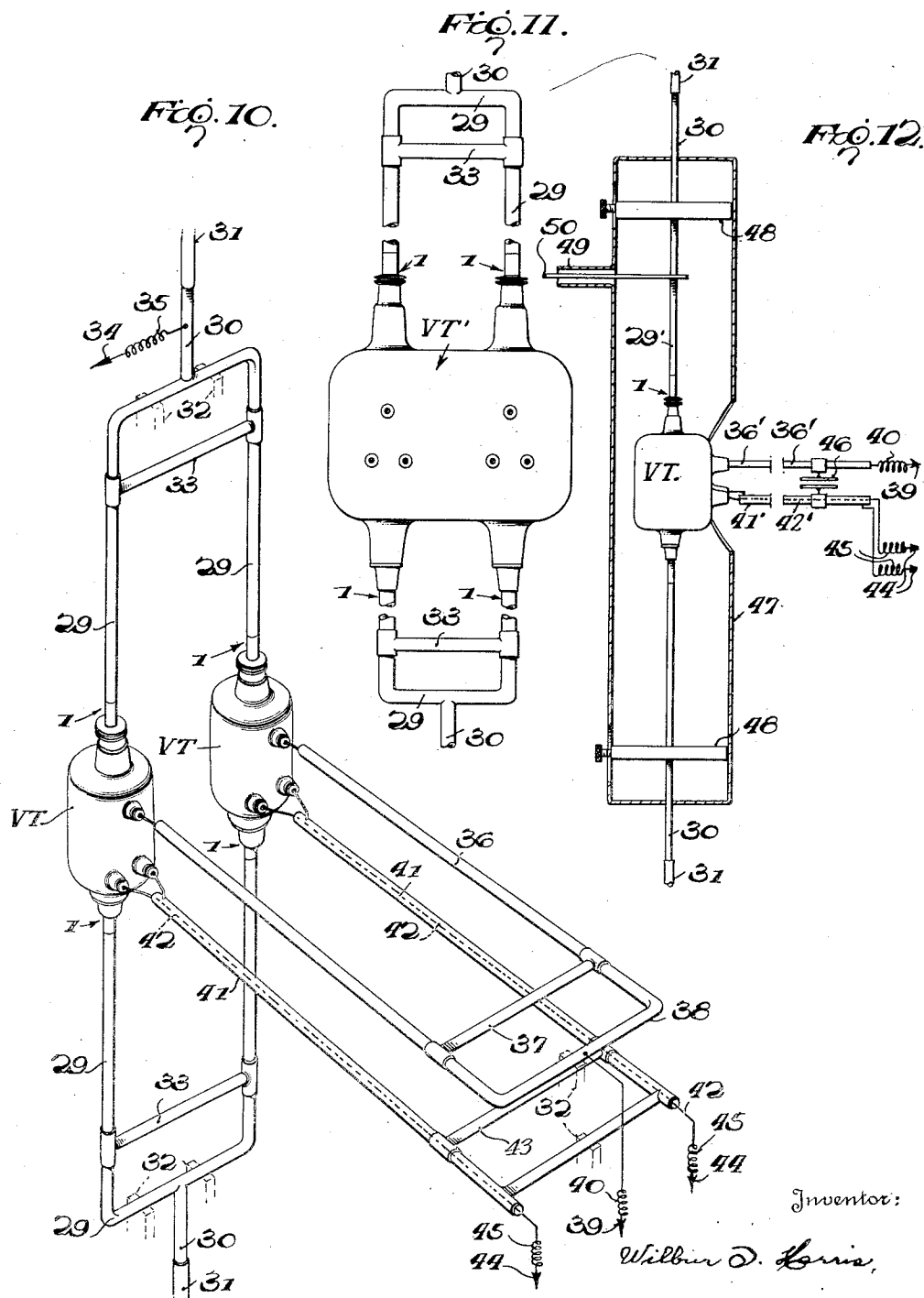
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ULTRA HIGH FREQUENCY CIRCUITS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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ULTRA HIGH FREQUENCY CIRCUITS

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Application November 10, 1938, Serial No. 239,885

14 Claims. (Cl. 250—27)

This invention relates to ultra high frequency circuit, and particularly to constructions in which certain tube elements are directly incorporated in the circuit.

5 The tubes now used in ultra high frequency circuits are of clumsy shapes and have poorly arranged leads which are responsible for substantial inductance and high frequency resistance in ultra high frequency circuits that are built
10 around the tubes. The output of the prior tubes has been limited by these faults and by the grid dissipation, i. e. grid currents due to electrons captured by the grid in their flow from cathode to plate. A recently produced ultra high frequency tube of the water cooled anode type exhibits a grid current of from one-fifth to one-half of the anode current when used as an oscillator. The output of this tube tends towards zero as the wave length is shortened to one meter.
20 Objects of the present invention are to provide tubes having grids of novel design that are not bombarded, and ultra high frequency circuits including such tubes. An object is to provide ultra high frequency circuits in which no leads are required between the tube elements and the oscillatory and water circuits. More specifically, objects are to provide ultra high frequency circuits and self-excited oscillations having a tuned output circuit of the Lecher type, the parallel conductors of the Lecher system being hollow water cooled tubes constituting the anodes of the tubes.

30 These and other objects and advantages of the mutually adapted tubes and circuits will be apparent from the following specification when taken with the accompanying drawings in which:

Fig. 1 is a schematic transverse section through a tube embodying the invention;

Fig. 2 is a perspective view of the same;

40 Figs. 3 and 4 are schematic diagrams of multiple element water-cooled tubes;

Fig. 5 is a transverse sectional view through a double screen grid tube;

45 Fig. 6 is a side elevation of the same;

Fig. 7 is a sectional view substantially on line 7—7 of Fig. 5;

Fig. 8 is an exploded view of the cathode and grid electrodes of the double tube;

50 Fig. 9 is an enlarged detail view of the cathode and cathode shield elements;

Fig. 10 is a perspective view of an ultra high frequency oscillator including triode tubes such as shown in Fig. 4;

55 Fig. 11 is a fragmentary front elevation of a

similar oscillator including a double assembly tube of the Fig. 5 type; and

Fig. 12 is a side elevation, with parts in section, of a single tube triode oscillator.

Certain features of the invention as applied to tubes for use at ultra high frequencies may be incorporated in simpler tube constructions, as shown in Figs. 1 and 2, which may be operated at radio and lower frequencies with efficiencies not obtainable with prior tubes. The tube elements comprise an anode A having a semi-cylindrical section which merges into a flat heat-radiating flange, a filamentary cathode C, preferably a flat strip or ribbon extending parallel to the axis of the semi-cylindrical plate section, a cathode shield CS at the side of the filament opposite the anode, and a grid G in the form of a pair of parallel ribbons extending along opposite sides of the space between the cathode and anode. The elements are supported within an evacuated envelope T in the usual manner by their leads, the cathode shield CS being connected to one of the cathode leads.

This electrode assembly has the general form, as viewed in cross-section, of an electron gun and the control grid lies outside of the electron stream and is not bombarded during use of the tube as an oscillator. Tubes of this design have been operated at ultra high frequencies with grid currents reduced to the order of one one-thousandth of the plate current, thus substantially eliminating overheating of the grid as a factor limiting efficiency and/or the highest frequency of operation. With an anode A of tantalum and a construction of substantially the dimensions of the patent drawings, the tubes of Figs. 1 and 2 have converted about 75 watts of power at ultra high frequencies. This is equivalent to the performance of prior small ultra high frequency tubes of more complex or expensive construction and operating without cooled anodes.

Tubes of higher power output may be constructed, as shown in Fig. 3, by a multiple assembly of a plurality of "electron gun" units about a central tubular anode A' through which water may flow to cool the anode. An assembly of six units, as shown in Fig. 3, has been operated with high efficiency at wave lengths of the order of one meter; the six filaments being of tungsten 0.050" wide, 0.001" thick and 1" long, with the filaments equally spaced to define a cylindrical surface of about 0.75" diameter. Amplification constants between 30 and 50 were obtained, and the tube exhibited very linear plate characteristics that intersect the zero current axis smooth-

ly, i. e. they exhibit sharp cut off characteristics. For operating conditions leading to maximum power output, the grid current remained vanishingly small; of the order of $\frac{1}{1000}$ of plate current.

Increasing the cathode surface will give greater power converting capacities, and such increase in the cathode surface may be obtained through the use of more and/or of longer cathode ribbons. Exceedingly compact constructions may be obtained with the electrode geometry shown schematically, and on a larger scale, in Fig. 4. The cathode shield CS' takes the form of a cylinder having radial ribs that define compartments in which the cathode ribbons C are located, the grid G' being formed by ribbons or strips in radial alignment with the ribs of the cathode shield.

Screen grids may be desirable to simplify neutralization problems when modulating over an extended frequency band, as in television transmission, and the screen grid will comprise ribbons or strips in alignment with the control grid ribbons. The incorporation of two sets of electrode assemblies in one envelope is especially advantageous in screen grid tube constructions as this simplifies a connection of the two screen grids by a low impedance conductor. An appropriate design, as shown in Fig. 5, comprises two electrode assemblies that each include the elements shown in Fig. 4 and, in addition, an inner set of grid ribbons constituting a screen grid. The electrode assemblies may be in close proximity since each is within its cathode shield cylinder and the bar connecting the screen grids may therefore be quite short.

As shown in Figs. 5 to 9, the hollow anode of the vacuum tube is an oxygen free high conductivity copper tube 1 that extends centrally through a glass envelope 2 that is preferably of the type designated 707DG by the Corning Glass Company. The opposite ends of copper tube 1 extend through and are silver soldered respectively to a rigid sleeve 3 and to a syphon bellows 4 which, in turn, is soldered to a sleeve 3. These sleeves are "Kovar" (a glass sealing alloy) and they are connected to the main body 2 of the envelope by intermediate sections 5 of 704AJ glass manufactured by the Corning Glass Company. The different coefficients of expansion of the copper and glass necessitate the syphon bellows or expansion joint at one anode seal.

The cathode ribbons are connected between rings 6, 7 at the bottom of the assembly and an upper ring 8 that is yieldingly supported from the ring 7 by telescoping connections that each comprise a wire 9 connected by a hollow glass bead 10 to a wire 11 having a cupped washer 12 secured thereto to carry a light tungsten spring 13 that bears against a washer 14, the wire 11 extending freely through washer 14 and the looped end of a wire 15 that is attached to the ring 8. The rings 6, 7 are preferably formed as loops in the ends of relatively long wires, thus leaving projecting ends 6', 7', respectively, that extend through the envelope 2 to serve as the cathode terminals and to support the cathode assembly. Alternate cathode elements 16, 16a extend between ring 8 and rings 6, 7, respectively, the ring 8 being of somewhat smaller diameter than rings 6 and 7, and short studs 6a, 7a being spot welded to rings 6, 7, respectively, to make connection to the lower ends of the cathode elements. The cathode screen comprises the cylinder 17 and

radial ribs 18 which are carried by the ring 7 and terminate short of the upper cathode ring 8.

The control grid assembly comprises upper and lower rings 19 that are connected by a wire support 20 to which the grid lead 21 is attached. The grid elements 22 are secured to the rings 19 in radial alignment with the shield ribs 18. Similarly, the screen grid assembly includes upper and lower rings 23 that are spaced by a wire 24 and carry short studs 25 between which the screen grid ribbons 26 are connected. In a double assembly tube, the relatively rigid wires 24 of the screen grids are connected by a shorting bar 27 to which the terminal 28 is secured. The cathode shield cylinder 17 is apertured to pass the terminals 21 and 28 that support the control grid and screen grid, respectively.

A typical ultra high frequency oscillator employing triode tubes is shown in Fig. 10. The copper tube anodes 1 of two vacuum tubes VT, of the design shown schematically in Fig. 4, are arranged vertically and connected above and below the vacuum tubes VT by U-shaped copper tubes 29 having branches 30 that are connected to the water-circulating rubber or glass tubes 31.

Soldered connections are employed between the anode tubes 1 and the tubing 29 of the anode and water circuit and junctions other than those indicated may be at any desired points in the anode circuit. This copper tubing constitutes a substantially rigid structure and insulating members 32 engage the cross-bars of the U-shaped tube members 29 to provide the mechanical support for the vacuum tubes.

The perimeter of the rectangular structure formed by the anode tubes 1 and connecting tubes 29 is somewhat in excess of the longest electromagnetic waves that are to be generated and shorting bars 33 are adjustably mounted on the parallel anode tubes 29 to tune this external anode circuit to the desired frequency. It is to be noted that the bars 33 are not necessarily placed symmetrically with respect to the vacuum tubes, but may be so adjusted that the tube impedance matches the anode circuit impedance. The plate voltage lead 34 is connected to a pipe 30 and is illustrated as including a choke 35 but this and other illustrated chokes are perhaps not necessary when the voltage supply leads are connected, as shown, at voltage node points.

The grid circuit comprises the conventional quarter-wave circuit provided by the parallel conductors 36 and adjustable shorting bar 37, the conductors 36 being connected by a bar 38 to which the grid biasing source may be connected through lead 39 and choke 40. The cathode or filaments of the tubes are supplied in series by a coaxial conductor system comprising a U-frame 41 of copper tubing which is connected to one terminal of each filament and insulated wires 42 which extend through the legs of the frame 41 and are connected to the other filament terminals. A shorting bar 43 is adjustable along the frame 41 to tune the filament circuit to the quarter-wave length of the generated oscillations. The heating circuit leads 44 are connected through chokes 45 to the outer tube 41 and the internal wire 42', respectively. The grid and filament circuits are rigid assemblies that are supported from insulating members 32' at the centers of the cross-members of these U-shaped circuit elements.

The illustrated circuit functions as an oscillator as the grid-plate capacities of the tubes provide sufficient power for driving the system at

the selected frequency. Power may be transmitted from the oscillator to a load circuit along a Lecher system or a coaxial line. The transfer can be accomplished inductively through a loop placed near the anode circuit or by connecting the line conductors to the two sides of the anode circuit. The latter system has the advantage that the line impedance may be matched by attaching the line terminals at the proper distance from one of the shorting bars 33. The anode circuit is thus flexible and permits a balancing with both the line and the tube impedances. The illustrated circuit has been operated at high efficiency at wave lengths between 0.75 and 2 meters, and is of course operable outside those limits. Modulation voltages may be applied between the cathodes and anodes or, preferably, in view of the high amplification, between the cathodes and control grids. The substantial elimination of grid currents that is characteristic of the new tubes permits highly efficient grid circuit modulation.

The mechanical design is somewhat simpler when a double unit tube VT' is used in place of the separate tubes VT of the Fig. 10 circuit. The assembly of a double tube VT' and a tuned anode circuit is shown in Fig. 11, and the parts of the anode circuit are identified by the same reference numerals as in Fig. 10, but will not be described in detail. The grid and filament circuits may be substantially as shown in Fig. 10.

A preferred oscillator circuit for extremely short waves is shown in Fig. 12, which illustrates the correct design for a single tube analogue of the described push-pull oscillator. Tube VT is of the described construction having a hollow anode 1 that is soldered to tube sections 29' that are connected to the cooling water circuit provided by insulating tubes 31. The grid lead 36' and the coaxial filament circuit lead 41' are parallel and connected by an adjustable capacitive shorting bar 46 to form a quarter-wave Lecher system. The main Lecher system comprises the anode tube 1 and an outer copper shell 47 that is closed except for the necessary openings for the grid and filament leads to the tube and the slots for the adjustment of shorting disks 48 that tune the anode circuit. A coaxial transmission line comprising an outer conductor 49 and internal conductor 50 is connected to the shell 47 and anode 1 at one side of the oscillator tube VT. This oscillator is self-shielding and non-radiating as the high frequency electric and magnetic fields are confined to the interior of the shell 47, except at the specified openings and these, if desired, may be provided with auxiliary shielding.

Amplifier and oscillator circuits using the new tubes operate at high efficiency as the grids are not bombarded and the tube anodes are directly incorporated in the tuned circuits. The ultimate high frequency limit of an oscillator is determined by circuit neatness and the time required for an electron to travel from the cathode to anode. The time of flight of the electrons may be shortened by increasing the applied voltages as the tube grids are not bombarded and therefore do not impose a limit on the applied voltages. The grids previously employed did set such a limit due to the heating of the grids to emitting temperature by bombardment.

Claims to the tube constructions herein disclosed are presented in my copending application Serial No. 247,933, filed Dec. 27, 1938, Patent No. 2,204,306, dated June 11, 1940, "Vacuum tubes."

It is to be understood that the circuits and tubes herein described are illustrative of the invention and that various modifications that may be developed by those skilled in the art fall within the spirit of my invention as set forth in the following claims.

I claim:

1. In a high frequency circuit, a Lecher system including two parallel conductors and adjustable shorting members connecting said conductors near the outer ends thereof, an evacuated envelope surrounding the intermediate portion of one of said conductors, cathode and grid elements within said envelope cooperating with said enclosed intermediate portion of the conductor to form a vacuum tube, and means for impressing potentials between said cathode element and respectively said grid elements and said enclosed conductor.

2. In a high frequency circuit, the invention as claimed in claim 1, wherein said enclosed conductor is tubular, in combination with insulated connection means for passing a cooling fluid through said tubular conductor.

3. In a high frequency circuit, a Lecher system including two parallel conductors and adjustable shorting members connecting said conductors near the outer ends thereof, an evacuated envelope surrounding the intermediate portion of one of said conductors, cathode and grid elements within said envelope cooperating with the enclosed conductor to form a vacuum tube, and means for impressing potentials between said cathode element and respectively said grid elements and said enclosed conductor, said cathode element comprising a plurality of members arranged in cylindrical symmetry about the conductor, and said grid elements being disposed longitudinally at each side of the space between each cathode member and said conductor.

4. In a high frequency circuit, a plurality of conductive members constituting a Lecher system, one of said members being a tubular conductor, an evacuated envelope surrounding an intermediate portion of said conductor, and cathode and control grid elements cooperating with said conductor to form a vacuum tube, said conductor constituting the anode of the vacuum tube and extending beyond the opposite ends thereof.

5. In a high frequency circuit, the invention as claimed in claim 4 wherein said elements comprise a plurality of spaced cathode members arranged in a cylindrical surface coaxial with said conductor, and grid members longitudinally disposed at each side of the space between each cathode member and the conductor.

6. In a high frequency circuit, the invention as claimed in claim 4 wherein said elements comprise a plurality of spaced cathode members arranged in a cylindrical surface coaxial with said conductor, cathode shield means extending in spaced relation along the outer surface and the sides of each cathode member, and grid members longitudinally disposed at each side of the space between each cathode member and the conductor.

7. In a high frequency circuit, a Lecher system including a tubular conductor, an evacuated envelope surrounding an intermediate portion of said conductor, the enclosed portion of said conductor constituting the anode of a vacuum tube, a cathode comprising a plurality of flat ribbons lying substantially in a cylindrical surface coaxial with said anode conductor, said cathode ribbons being spaced circumferentially, a grid

comprising flat ribbons extending longitudinally of the anode conductor and disposed radially in alignment with spaces between adjacent cathode ribbons.

- 5 8. In a high frequency circuit, a Lecher system comprising parallel tubular conductors and adjustable shorting members connecting the same adjacent the opposite ends thereof, an evacuated envelope surrounding an intermediate portion of
10 each conductor, cathode and grid elements within each envelope cooperating with the enclosed conductor section to form a vacuum tube, and means for impressing energizing potentials between the cathode and the grid elements of each tube and
15 between the cathode elements and the Lecher system.

9. In a high frequency circuit, the invention as claimed in claim 8, wherein said means includes a quarter-wave Lecher system between the grid elements of the respective tubes, and coaxial conductors for supplying heater current to the cathode elements of the tubes in series, said coaxial conductors being arranged as a quarter-wave Lecher system.

- 25 10. In a high frequency circuit, a Lecher system comprising concentric tubular conductors and adjustable shorting members electrically connecting the same adjacent the opposite ends thereof, an evacuated envelope within the outer
30 conductor and surrounding an intermediate portion of the inner conductor, cathode and grid elements within said envelope and cooperating with the enclosed section of the inner conductor to constitute a vacuum tube, and means for impressing energizing potentials between the cathode and
35 grid elements of the tube and between the interior conductor and said cathode element.

11. In a high frequency circuit, the invention

as claimed in claim 10, in combination with insulated connection means for circulating a cooling fluid through said interior conductor.

12. In a high frequency circuit, a primary Lecher system comprising a central conductor and coaxial tubular conductor, with adjustable shorting members connecting the end portions of said conductors, an evacuated envelope within the tubular conductor and surrounding an intermediate portion of the central conductor, and cathode and grid elements within said envelope cooperating with said central conductor to form a vacuum tube, a coaxial conductor system for supplying heating current to the cathode element, a conductor parallel to said coaxial conductor system constituting a grid lead, a capacitive shorting connection between said coaxial conductor and said grid lead conductor to tune the same as a Lecher system, and means for impressing a positive potential on the central conductor of said primary Lecher system.

13. In a high frequency circuit, the invention as claimed in claim 12, wherein said cathode element comprises a plurality of filamentary conductors lying in a cylindrical surface coaxial with the enclosed central conductor, and said grid element comprises radially disposed members at each side of the space between said cathode ribbon and the central conductor.

14. In a high frequency circuit, the invention as claimed in claim 12, wherein said cathode element comprises a plurality of spaced flat ribbons lying in a cylindrical surface coaxial with the enclosed central conductor, and said grid element comprises radially disposed flat ribbons at each side of the space between each cathode ribbon and the central conductor.

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