

April 16, 1946.

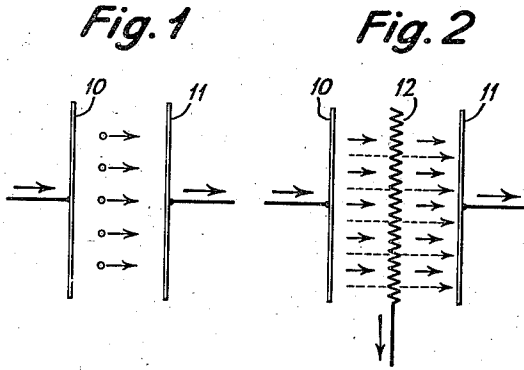
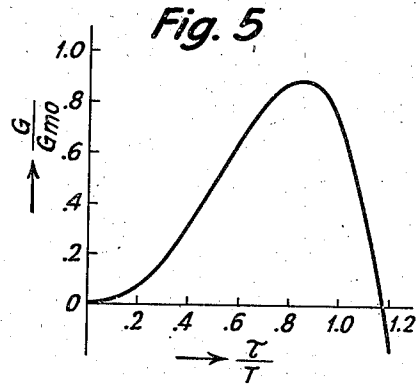
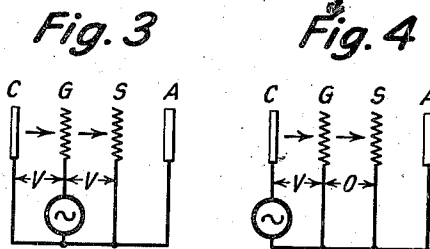
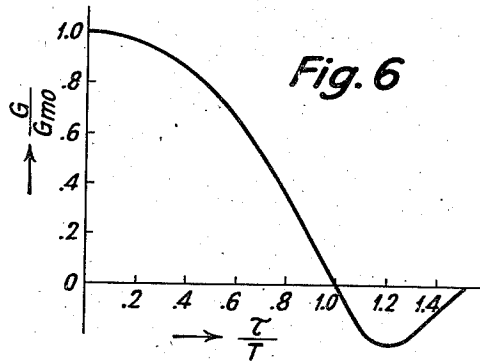
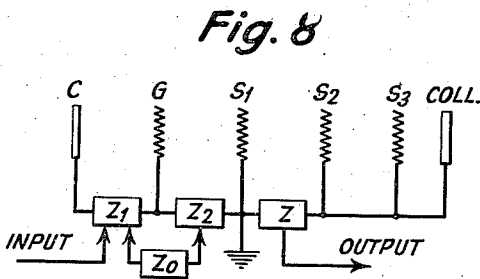
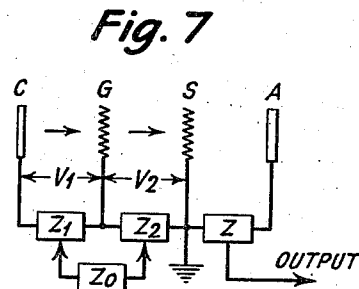
A. V. HAEFF

2,398,499

ELECTRON DISCHARGE DEVICE

Filed May 29, 1941

3 Sheets-Sheet 1



INVENTOR.
ANDREW V. HAEFF
BY *Charles McClair*
ATTORNEY.

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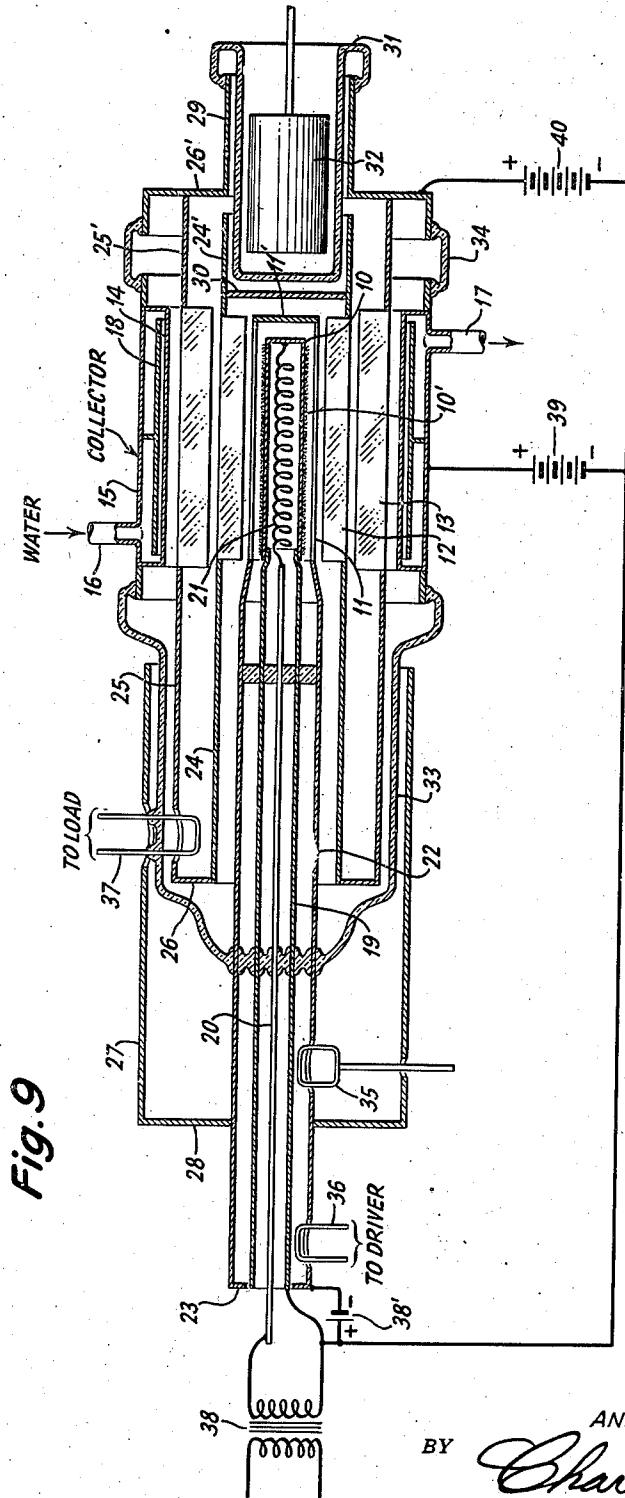
A. V. HAEFF

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ELECTRON DISCHARGE DEVICE

Filed May 29, 1941

3 Sheets-Sheet 2



INVENTOR.
ANDREW V. HAEFF

BY

Charles McClain
ATTORNEY.

April 16, 1946.

A. V. HAEFF

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ELECTRON DISCHARGE DEVICE

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3 Sheets-Sheet 3

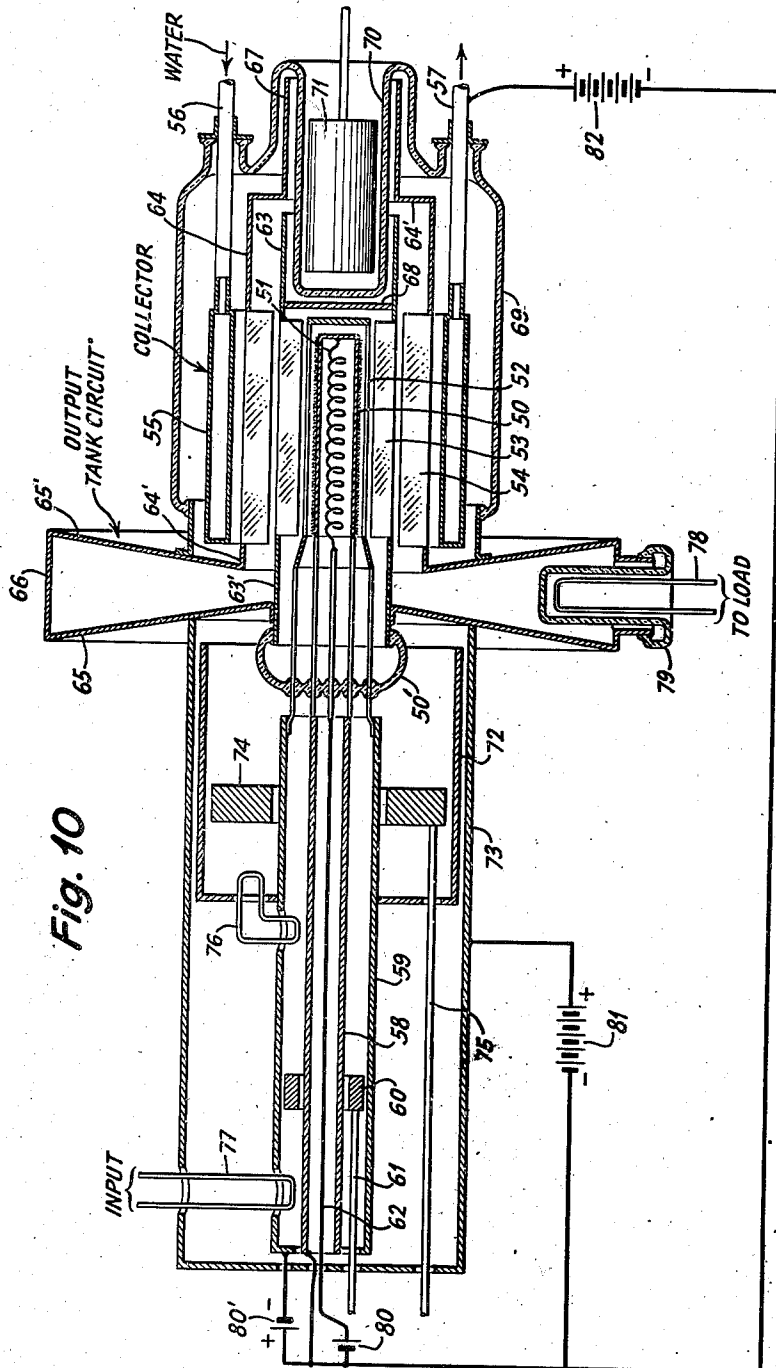


Fig. 10

INVENTOR.
ANDREW V. HAEFF
BY *Charles McClellan*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,398,499

ELECTRON DISCHARGE DEVICE

Andrew V. Haeff, Washington, D. C., assignor to
Radio Corporation of America, a corporation
of Delaware

Application May 29, 1941, Serial No. 395,709

13 Claims. (Cl. 250—27.5)

My invention relates to electron discharge devices and associated circuits having improved operating characteristics and particularly suitable for use at ultra-high frequencies.

The present application is a continuation in part of my copending application, Serial No. 375,029 filed January 18, 1941, and assigned to the same assignee as the present application.

It has been demonstrated that tubes utilizing conventional grids for controlling current are well adapted for operation at ultra-high frequencies and retain their characteristic advantage of possessing high transconductance. However, one of the difficulties encountered in operating amplifying tubes at ultra-high frequencies is the presence of considerable loading in the input circuit which results in an excessive amount of power being required to drive the tube. This decreases the effective power gain of the tube when operated as an amplifier.

The fundamental causes of high input loading are (1) ohmic and radiation resistance losses due to high circulating currents in electrodes and leads; (2) electron loading which results from the interaction of the electron stream with the circuit, including degenerative or regenerative effects caused by lead impedance.

In order to reduce ohmic resistance losses it is necessary to use internal leads and external conductors made of high conductivity material and having large peripheries. In addition inter-electrode capacitances must be reduced as much as possible in order to minimize circulating currents. To reduce radiation losses a thoroughly shielded circuit of conventional design or closed type "cavity" resonators must be used.

The principal object of my invention is to provide an electron discharge device and associated circuit having means for substantially reducing or completely neutralizing electron loading when the device is used at ultra-high frequencies.

It is also an object of my invention to provide an electron discharge device having means for minimizing ohmic and radiation resistance losses when the device is used at ultra-high frequencies.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawings in which Figures 1 and 2 are diagrammatic representations of electrodes and the movement of electrons between the electrodes; Figures 3 and 4 are diagrammatic representations of conventional tubes and methods of operating the same; Figures 5 and 6 are curves representing the relationship of the electron loading (conductance) and the transit time of the electrons of the tubes in Fig-

ures 3 and 4; Figures 7 and 8 are diagrammatic representations of tubes and circuits made according to my invention for practicing my invention; Figure 9 is a longitudinal section of an electron discharge device made according to my invention and Figure 10 is a longitudinal section of a modification of an electron discharge device made according to my invention.

In order to understand better the effect of electron loading, the mechanism of interaction between the electron stream and the electrodes to which circuits may be connected will be reviewed. Consider a system of two electrodes 10 and 11 as shown in Figure 1. Assume that electrons travel from the electrode 10, which may be a cathode, to the electrode 11, which may be an anode. During electron transit an image charge appears on the electrodes equal in magnitude to the total charge present at any moment within the interelectrode space. The division of the image charge between the two electrodes depends, in general, upon the instantaneous distribution of charges moving within the interelectrode space and upon the configuration of the electrodes. The current induced in an electrode due to motion of a charge is equal to the rate of time variation of the induced image charge on the electrode due to the moving charge. The total instantaneous current induced in the electrode by the electron stream will be found by summing the individual currents induced by all charges moving within the interelectrode space. If a voltage exists between electrodes 10 and 11 the displacement current due to the interelectrode capacitance must be also taken into account.

Consider now a three-electrode system formed, for example, by a cathode 10, a control grid 12 and the plate 11 of a triode. Two spaces have to be considered. The total current induced in the intermediate electrode 12 (Figure 2) is contributed by moving charges in both spaces, 10—12 and 12—11, and the total current is equal to the vector sum of the two currents. The power generated or absorbed by the electron stream within the spaces 10—12 and 12—11 depends upon the respective current, voltage and the phase angle between the current and voltage in each space. Thus the power generated or absorbed within the spaces 10—12 and 12—11, will be:

$$W_{10-12} = i_{10-12} V_{10-12} \cos \phi_{10-12}$$

$$W_{12-11} = i_{12-11} V_{12-11} \cos \phi_{12-11}$$

In a more general case, such as a low- μ triode, when there may exist considerable penetration of the electric fields from space 12—11 into space 10—12, one must also consider direct interaction between electrodes 11—10, so that a power $W_{10-11} = i_{10-11} V_{10-11} \cos \phi_{10-11}$ also must be taken into account.

In order to reduce the electron loading the

total power must be reduced to a minimum. This can be accomplished by choosing currents, voltages and their respective phases in such a way that for the general case the total power

$$W = W_{1-2} + W_{2-3} + W_{3-1} + \dots$$

is a minimum.

In a conventional negative grid tetrode operated at low frequencies the input electrode loading will be negligibly small if the driving voltage is applied in a conventional manner between the grid and the cathode so that the voltage also appears between the control grid G and the screen S. (See Figure 3.) The R.-F. electronic current passing in the G—S space is very nearly equal and opposite in phase to the current in the C—G space so that the total driving power is very nearly zero

$$(W = iV_{C-G} - iV_{G-S} \approx 0)$$

However, in a circuit shown in Figure 4 where the driving voltage is applied between the grid and the cathode only, but does not appear between the grid and the screen, the loading will be very severe at low frequencies. This loading is due to the fact that even though a current, equal to C—G space current, flows in the G—S space, no voltage is present in this region and hence no negative power is developed in the G—S space to balance the power absorbed in the C—G space.

As the driving frequency is increased the circuit of Figure 3 will exhibit electron loading which initially will increase with the frequency. This loading is due to the fact that with increasing electron transit time compared to a period of the applied voltage frequency the amplitudes and phases of currents in the C—G and G—S spaces change in such a manner that the amounts of power absorbed and generated in the two spaces no longer balance each other. For the case of a high- μ control grid when the spacings and D.-C. voltages are such that the G—S electron transit time is negligible compared to C—G transit time an analysis shows that the electron loading (conductance) will vary with transit time as shown in Figure 5. Here the ordinates of the curve represent the ratio G/G_m where G =conductance of the grid G due to electron motions and G_m =transconductance of the Grid G at very low or zero frequency, that is when the transit time of the electron is negligible in comparison to the time of one cycle of the frequency of the applied voltage. The abscissae represent the ratio τ/T that is the ratio of the transit time of the electron to the period of oscillation of the applied alternating voltage. The electron loading increases rapidly with transit time, reaches a maximum at the value of transit time τ equal to 0.85 of the oscillation period T and then, under ideal conditions, passes through zero and becomes negative. In the case of circuit shown in Figure 4 the variation of electron loading with transit time will be as shown in Figure 6. Starting with its maximum value at low frequency the loading decreases with increasing frequency.

These curves indicate that for certain values of electron transit angle, that is for certain values of the ratio of

$$\frac{\tau}{T} = \frac{\text{transit time}}{\text{period of oscillation}}$$

the loading will be small even for conventional input circuits. However, the values of frequency and operating voltages for these optimum condi-

tions frequently lie outside the useful operating range of the tube. The tubes could be designed for this optimum condition but, in general, this may necessitate a compromise, so that high transconductance may be partly sacrificed. The present invention provides means for neutralizing electron loading for a wide range of frequencies and operating voltages without any sacrifice of the useful characteristics of the tube, such as high transconductance.

A general scheme is that in addition to the driving voltage applied between the cathode and grid, a voltage is developed between the control grid and the screen of such a magnitude and phase as to generate power in the grid-screen space and this power is fed back into the cathode-grid circuit, so that it will balance the power absorbed in the cathode-grid space.

A schematic diagram of such a circuit is represented in Figure 7. An impedance Z_2 is introduced between the screen S and the grid G of such magnitude and phase angle that the current i_{G-S} will produce a voltage V_2 across this impedance. The power $W_2 = i_{G-S} V_2 \cos(i_{G-S} V_2)$ generated in the G—S space is then fed to the grid-cathode circuit Z_1 by means of a coupling circuit Z_0 . The impedances Z_1 and Z_2 usually take the form of tuned circuits and the coupling impedance Z_0 may be the inter-electrode capacitance or an auxiliary coupling element.

Figure 8 shows schematically the input loading neutralization circuit in combination with an inductive type output circuit. Here the output circuit Z is connected between the two screening electrodes S_1 and S_2 . The suppressor and current collecting electrodes, represented respectively by S_3 and $coll.$, are also shown. In the above circuit diagrams only the essential R.-F. circuits are indicated. Blocking, grounding and by-passing condensers which are used for providing isolation of electrodes for D. C., so that different D. C. voltages can be applied to different electrodes, are not shown.

One practical embodiment of my invention incorporated in a so-called "inductive output tube" is shown in detail in Figure 9. "Inductive output tubes" and their operation are described more fully in my Patent 2,237,878 issued April 8, 1941 and assigned to the same assignee as the present application. Briefly this tube comprises a cathode for supplying a beam of electrons and a collector for receiving the electrons. A modulating grid is placed adjacent the cathode for modulating the beam of electrons which passes to the collector. Surrounding the beam path is a resonant cavity circuit comprising a hollow member having a passageway extending therethrough through which the beam passes. The passageway is provided with a gap lying in a plane transverse to the beam path. As the modulated beam of electrons passes across this gap, energy is transferred from the beam to the resonant cavity circuit which provides the output circuit for the tube and which can be coupled to a radiator or to an amplifier.

Referring to Figure 9, the electron discharge device includes the elongated tubular cathode 10 provided with an emitting coating 10' and surrounded successively by concentric electrodes including the control grid 11 consisting of longitudinally extending parallel rods secured to a disc 11', the first screen electrode 12 comprising a plurality of radially positioned slat-like electrode elements and a second screen electrode 13 consisting of radially positioned slat-like elec-

trode elements aligned with the elements of the grid 12 followed in turn by the water-cooled collector 14 having a water jacket 15 and an intake 16 and an outlet 17, a baffle 18 being provided for insuring circulation of the water throughout the water jacket.

The cathode is an indirectly heated cathode and is provided with a coil heater 21 having one end connected to the lead-in and support 20, the other lead being provided by the tubular member 19 supporting the cathode and surrounding the lead 20. The tubular member 19 is surrounded in turn by the tubular member 22 supporting the grid, the tubular members being capacitatively closed at their free end by means of ring-like member 23 to form a concentric line tank circuit. This concentric line arrangement serves as the input tank circuit between the cathode 10 and the control grid 11.

The output tank circuit is of the resonant cavity type. Extending from the opposite ends of the slat-like screen electrodes are the tubular members 24, 24' and 25, 25'. These concentric and coaxial tubular members are electrically closed at their ends by ring-like members 26 and 26' for providing an output tank circuit.

The control grid-screen grid resonant cavity tank circuit is provided by means of concentric tubular member 27 capacitively coupled with member 25 and closed at the end by ring-like member 28. The other end of the resonant cavity tank circuit connected to the screen grid electrodes is provided with extension 29 between which and member 24' there is a gap, the extension 24' being closed by the transverse disc 30 to form a cup-shaped cavity, the open end of extension 29 being closed by re-entrant insulating portion 31 which also serves as a seal. A tuning condenser in the form of a plunger 32 is provided which can be moved longitudinally of the tubular members 24, 24' across the gap for tuning the output tank circuit. The collector electrode 14 is insulatingly supported with respect to the other electrodes by means of the cup-shaped closure member 33 connected between the water jacket of the collector and the leads for the other electrodes and by the collar 34 sealing the water jacket of the collector and the closure member 26' so that the space occupied by the electrodes may be evacuated to provide an evacuated envelope for these electrodes.

Coupling between the cathode-control grid circuit (Z_1) and control grid-screen grid tank (Z_2) may be controlled by means of the coupling loop 35 (Z_0). The input is coupled to the cathode grid space by coupling loop 36 and the load coupled to resonant cavity output tank circuit between the screen grid electrodes by means of coupling loop 37.

The cathode heater voltage is supplied by transformer 38 and grid bias by voltage 38', the positive voltage for the collector 15 being supplied by voltage source 39 and for the tank circuit by voltage source 40.

In operation the electrons emitted by the cathode pass through the control grid where they are modulated and formed into radial beams after which they enter into the space between the screen electrodes where the modulated electrons are subjected to the high frequency field of the output tank circuit connected to the screen electrodes in such phase that energy is extracted from the modulated beams to excite the tank circuit before they are collected by the collector. Coupling exists between the control grid 11 and

first screen electrode 12 so that energy from the screen electrode-control grid space is fed back into the control grid-cathode space, the amount of feedback being controlled by means of the coupling loop 35, which couples the field within the cathode-control grid space and the field in the control grid-screen electrode space. Tuning of the output tank circuit can be accomplished by means of tuning condenser 32. By means of the arrangement disclosed the desirable characteristics sought are obtained.

It will thus be apparent that by means of the construction shown in Figure 9 that losses due to the electron loading effects in the input circuit are reduced to a minimum by my invention. Ohmic and resistance losses due to high circulating current in electrodes and leads are reduced to a minimum due to the fact that concentric lines and resonant cavities used are of high conductivity material and large diameter and due to the effective by-passing of the radio frequency currents. Radiation losses are reduced to a minimum because of the shielded circuits. Thus all three objects contemplated by my invention are practiced to provide a tube particularly suitable for use at ultra-high frequencies at high efficiencies.

In Figure 10 is shown a modification of the device shown in Figure 9. The indirectly heated cathode 50 is provided with the heater coil 51 and is surrounded in turn by control grid 52, first screen electrode 53, second screen electrode 54 and collector 55, the electrodes being of substantially the same construction as that shown in Figure 9 except for the collector which is of different form and is provided with the in-take member 56, and outlet member 57 for permitting circulation of the cooling medium through the collector. The cathode heater and grid electrodes are supplied with leads extending through and sealed into a cup-shaped member 50' and electrically connected to the tubular extensions 58 and 59 which form together a coaxial line input tank circuit, this tank circuit being tuned by tuning condenser 60 in the form of a collar surrounding hollow conducting member 58 and movable by means of rod 61 longitudinally of the coaxial line tank circuit. One of the heater leads and conductor 62 lie within the tubular member 58. The screen and accelerating electrodes are provided with tubular extensions 63 and 64, which are concentric and coaxial and are electrically closed by ring shaped member 64'. The other ends of the screen and accelerating electrodes are provided with hollow like extensions 63' and 64', to which side walls 65 and 65' having a resonant cavity tank circuit are connected. The resonant cavity tank circuit is closed at the outer peripheries of the wall by ring shaped member 66. Thus the screen electrodes and associated elements provide the output resonant cavity for the tube. Tuning of this resonant cavity is accomplished in substantially the same manner as in the tube shown in Figure 9. An extension 67 is provided spaced by means of a gap from tubular member 63 closed by means of the transverse disc-like member 68. Extending within the tubular members 67 and 63 is re-entrant portion 70 of the closure and sealing member 69. To provide a screen electrode-control grid resonant cavity a cup-shaped member 72 is supported on the tubular members 59 and surrounds and is coaxial with the tubular member 59, capacitive coupling existing between this member and shielding member 73 electrically connected to the

wall 65 of the resonant cavity. The control grid-first screen grid tank circuit then comprises tubular member 59, cup-shaped member 72, shielding member 73 and wall 65 of the tank circuit and collar 63' electrically connected to the screen grid. Tuning of this resonant cavity is accomplished by member 74 slidable longitudinally of the circuit by means of rod 75. Input coupling is provided by means of loop 77 and output is obtained from the tank circuit by means of coupling loop 78 mounted within re-entrant insulating seal 79. Heating potentials are applied from voltage source 80 and biasing potentials for the grid by source 80'. Potentials for the tank circuit are obtained from voltage source 81 and for the collector from voltage source 82.

The tube operates in substantially the same manner as the tube shown in Figure 9, coupling between the control grid-cathode circuit and the control grid-screen grid circuit being had by means of coupling loop 76.

It will be apparent from the above discussion and description that I have provided an electron discharge device particularly suitable for use at ultra-high frequencies since both ohmic and radiation resistance losses due to high radio frequency circulating currents in electrodes and leads have been substantially eliminated, and because electron loading, which results from interaction of the electron stream and the circuit, including regenerative or degenerative effects caused by lead impedance, has also been substantially neutralized. This is accomplished by means of leads and external conductors of highly conducting material and large diameter. The radiation losses are reduced to a minimum by thoroughly shielded circuits comprising closed type cavity resonators.

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 having a cathode electrode for supplying a stream of electrons and a collector electrode for collecting said electrons and surrounding said cathode, a control electrode surrounding said cathode and intermediate said cathode electrode and said collector electrode and a screen electrode surrounding said cathode and control electrodes and intermediate said control electrode and collector electrode, a first impedance including a hollow body forming a resonant cavity tank circuit connected between said cathode and control electrode, and a second impedance including a hollow member forming a second hollow resonant cavity tank circuit coupled between the control electrode and screen electrode, said electron discharge device having means electrically coupling said tank circuits together.

2. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode for collecting said electrons, a control electrode intermediate said cathode electrode and said collector electrode and surrounding said cathode, and a screen electrode surrounding said

cathode and control electrodes and intermediate said control electrode and collector electrode, a first impedance including a concentric line tank circuit connected between said cathode and control electrode, and a second impedance including a hollow conducting member forming a resonant cavity tank circuit connected between the control electrode and screen electrode, and means electrically coupling said impedances together, and a second resonant cavity tank circuit intermediate said screen electrode and said collector electrode for inductively extracting energy from the electron stream as it moves from said cathode to said collector.

3. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode for collecting said electrons, a control electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode for modulating said stream of electrons and a pair of successively positioned screen electrodes surrounding said cathode and control electrodes and intermediate said control electrode and collector electrode, a concentric line tank circuit connected between said cathode and control electrode, and a hollow conducting member electrically coupled between the control electrode and one of said screen electrodes and forming a resonant cavity tank circuit, said electron discharge device having means electrically coupling said tank circuits, and a resonant cavity tank circuit electrically coupled between said pair of successively positioned screen electrodes and surrounding the path of said electron stream between the control electrode and the collector electrode for inductively abstracting energy from said electron stream during operation of said electron discharge device.

4. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting said electrons, a control electrode intermediate said cathode electrode and said collector electrode and surrounding said cathode electrode, and a screen electrode surrounding said cathode electrode and control electrodes intermediate said control electrode and collector electrode, a tubular member electrically coupled to said cathode electrode, a first conducting member electrically coupled to said control electrode and coupled to said tubular member and forming with said tubular member a tank circuit, a second conducting member electrically coupled to said screen electrode and coupled to said first conducting member and providing with said first conducting member a second tank circuit, and coupling means coupling said tank circuits together.

5. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting said electrons, a control electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode, and a pair of successively positioned screen electrodes intermediate said control electrode and collector electrode, a tubular member electrically coupled to said cathode electrode, a second tubular member surrounding said first tubular member and electrically coupled to said control electrode and forming with the first tubular member a first tank circuit, a third tubular member surrounding and electrically coupled to said second tubular mem-

ber and one of said screen electrodes and providing with said second tubular member a second tank circuit, and means coupling said tank circuits together, and a hollow resonant cavity tank circuit electrically connected between said screen electrodes.

6. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting said electrons, a grid electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode, and a pair of successively positioned screen electrodes intermediate said grid and collector electrodes, a first tubular conducting member electrically coupled to said cathode electrode, a second tubular conducting member electrically coupled to said grid and surrounding said first tubular conducting member and forming therewith a tank circuit, a third conducting member electrically coupled to one of said screen electrodes and surrounding said second tubular conducting member and providing therewith a second tank circuit, and coupling means coupling said tank circuits together, and concentric tubular members extending from opposite ends of said screen electrodes and electrically closed at their free ends providing an output resonant cavity for inductively extracting energy from said electron stream as it passes between said cathode and said collector electrode.

7. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting said electrons, a control electrode intermediate said cathode electrode and said collector electrode and surrounding said cathode electrode, and a screen electrode surrounding said cathode electrode and control electrode and intermediate said control electrode and collector electrode, a first impedance including a concentric line tank circuit connected between said cathode electrode and control electrode, and a second impedance comprising a hollow conducting member forming a resonant cavity tank circuit connected between the control electrode and screen electrode, and means electrically coupling said impedances together, and an output circuit connected to said electron discharge device.

8. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode for collecting said electrons, a control electrode surrounding said cathode and intermediate said cathode electrode and collector electrode, a pair of successively positioned screen electrodes surrounding said cathode and control electrode and intermediate said control electrode and collector electrode, and an electrically resonant hollow body connected between said cathode and control electrode and providing an input circuit and a hollow conducting member electrically coupled between the control electrode and one of said screen electrodes and forming a resonant cavity tank circuit, said electron discharge device having means electrically coupling said electrically resonant hollow body and said tank circuit together, and a resonant cavity tank circuit electrically coupled between said pair of successively positioned screen electrodes for inductively abstracting energy from said electron stream during operation of said electron discharge device.

9. An electron discharge device having a cathode electrode for supplying a stream of electrons

and a collector electrode surrounding said cathode electrode for collecting said electrons, a control electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode, and a pair of successively positioned screen electrodes, each of said screen electrodes comprising a plurality of radially positioned slot-like grid elements, the elements of one of the screen electrodes being aligned with the elements of the other screen electrode, said screen electrodes being intermediate said control electrode and collector electrode, a first tubular member electrically coupled to said cathode electrode, a second tubular member surrounding said first tubular member and electrically coupled to said control electrode and forming with said first tubular member a tank circuit, a third tubular member surrounding and electrically coupled to said second tubular member and one of said screen electrodes and providing with said second tubular member a second tank circuit, means coupling said tank circuits together, and a hollow resonant cavity tank circuit electrically coupled between said screen electrodes.

10. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting the electrons, a grid electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode for modulating said electron stream, and a pair of successively positioned screen electrodes intermediate said grid electrode and collector electrode, a first tubular conducting member electrically coupled to said cathode electrode, a second tubular conducting member electrically coupled to said grid electrode and surrounding said first tubular conducting member and forming therewith a tank circuit, a third conducting member electrically coupled to said screen electrodes and surrounding said second tubular conducting member and providing therewith a second tank circuit and coupling means coupling said tank circuits together, and concentric tubular members extending from opposite ends of said screen electrodes and electrically closed at their free ends for providing an output tank circuit for inductively abstracting energy from the modulated electron stream as it passes between the cathode and said collector electrode, one of said screen electrodes being provided with a cup-shaped element at one end thereof and a tubular extension connected to the other screen electrode registering with said cup-shaped member and separated therefrom by means of a gap, and a tuning plunger movable longitudinally between the cup-shaped member and the tubular extension for tuning the output tank circuit.

11. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting the electrons, a grid electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode for modulating said electron stream, and a pair of successively positioned screen electrodes intermediate said grid electrode and collector electrode, a first tubular conducting member electrically coupled to said cathode electrode, a second tubular conducting member electrically coupled to said grid electrode and surrounding said first tubular conducting member and forming therewith a tank circuit, a third conducting member electrically coupled to said screen electrode and surrounding said second tubular

conducting member and providing therewith a second tank circuit and coupling means coupling said tank circuits together, one of said screen electrodes being provided with a cup-shaped element at one end thereof and a tubular extension on the other screen electrode registering with said cup-shaped member and separated therefrom by means of a gap, and a tuning plunger movable longitudinally between the cup-shaped member and the tubular extension, and a radially positioned cavity resonator at the other end of said screen electrodes and having one wall electrically connected to one of said screen electrodes and having another wall electrically connected to the other screen electrode.

12. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting electrons, a grid electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode, and a pair of successively positioned screen electrodes intermediate said grid electrode and collector electrode, a first conducting member electrically coupled to said cathode electrode, a tubular conducting member electrically coupled to said grid electrode and surrounding said first conducting member and forming therewith a tank circuit, concentric tubular members extending from opposite ends of said screen electrodes and electrically closed at their free ends for providing an output tank circuit for inductively abstracting energy from the electron stream as it passes between the cathode and said collector

electrode, and a cup-shaped member electrically coupled to one of said screen electrodes and to the grid electrode providing a cavity resonator between the screen electrodes and the grid electrode, and a coupling loop coupling said last resonant cavity with the tank circuit electrically coupled between the grid electrode and the cathode electrode.

13. An electron discharge device having a cathode electrode for supplying a stream of electrons and a collector electrode surrounding said cathode electrode for collecting the electrons, a grid electrode surrounding said cathode electrode and intermediate said cathode electrode and said collector electrode for modulating said electron stream, and a pair of successively positioned screen electrodes intermediate said grid electrode and collector electrode, a first tubular conducting member electrically coupled to said cathode electrode, a second tubular conducting member electrically coupled to said grid electrode and surrounding said first tubular conducting member and forming therewith a tank circuit, a third tubular member electrically coupled to one of said screen electrodes and surrounding said second tubular member and providing therewith a second tank circuit, and coupling means coupling said tank circuits, and a radially positioned cavity resonator at one end of said screen electrodes and having one wall electrically connected to said one screen electrode and the other wall electrically connected to the other screen electrode.

ANDREW V. HAEFF.