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HIGH-FREQUENCY AMPLIFIER

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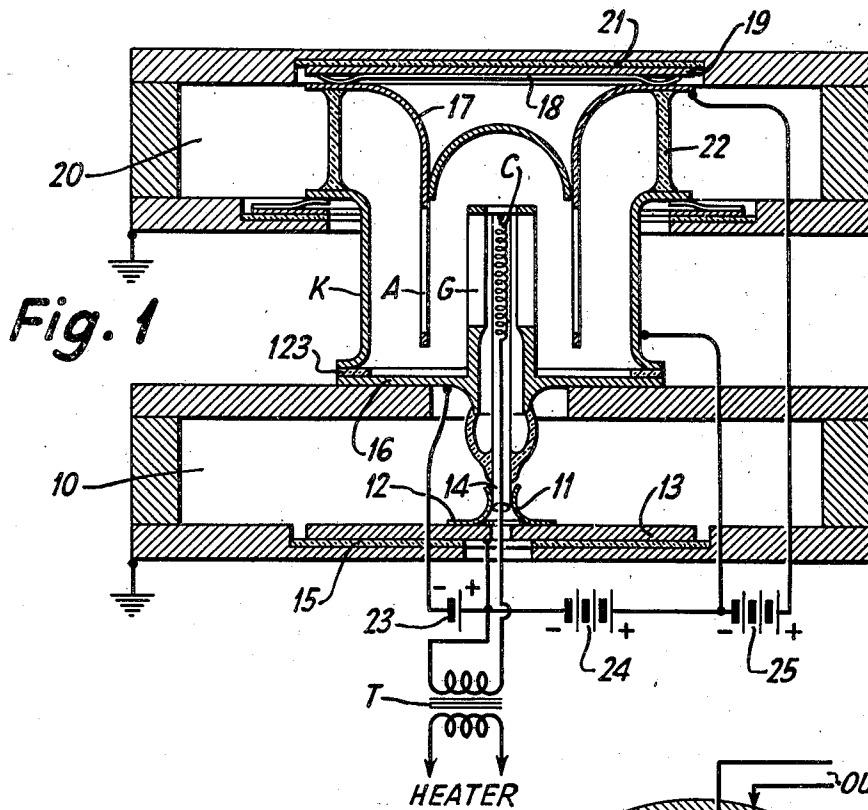


Fig. 2

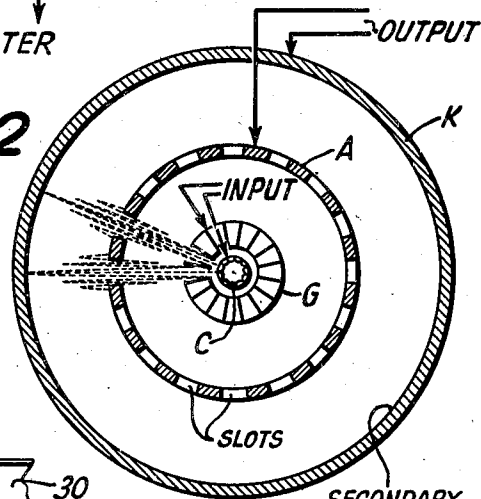
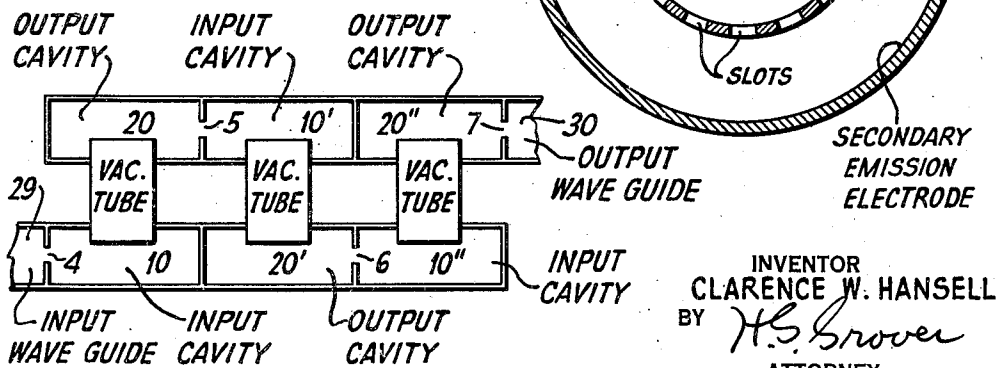


Fig. 3



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HIGH-FREQUENCY AMPLIFIER

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This invention relates to electron discharge device amplifiers and circuits therefor capable of passing a broad band of frequencies in the ultra high frequency region.

An object of the invention is to provide a high frequency electron discharge device amplifier which avoids concentrations of current in leads, or other causes of sharp or extreme wave discontinuity.

A further object is to provide an electron discharge device structure which has grid and cathode electrodes so constructed and arranged as to form continuous surfaces mounted on cylindrical or flange type seals suitable for resonant cavity or resonant line input or output circuits.

Briefly stated, the invention comprises a vacuum tube having a thermionic cathode, a surrounding grid structure having a plurality of vanes extending radially from the cathode, a slotted anode spaced from and surrounding the grid vanes, and an outer surrounding secondary emissive electrode forming an integral part of the envelope of the tube. The thermionic cathode is preferably fluted to cause concentrations of electrons in the spaces between the grid vanes, thus reducing the flow of electrons to the grid. The vane-like construction of the grid provides a relatively high amplification constant or ratio of change of electron current to change of grid-cathode potential and greatly reduces the effect of anode-cathode potential variations in opposing the variation of electron current through the grid in response to grid-cathode potential variations. By making the secondary emissive electrode an integral part of the outer envelope of the metal tube, I am able to prevent excessive rise of the temperature of the secondary emitter through the use of cooling fluid, such as air, on that part of the envelope. Further, it is possible to keep the secondary emitter surface at a lower temperature than the temperature of any other surface exposed to the vacuum, thus tending to reactivate the secondary emissive surface continuously by a process of sublimation, in those cases where surface activation is utilized to increase the ratio of secondary emission to impinging electron current.

A more detailed description of the invention follows in conjunction with the drawing, therein:

Fig. 1 diagrammatically illustrates the mechanical construction of an electron discharge device constructed in accordance with the present invention. This figure shows the input and output resonant cavities and the circuit connec-

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tions for supplying suitable potentials to the vacuum tube electrodes.

Fig. 2 is a horizontal cross section through the center of the vacuum tube of Fig. 1.

Fig. 3 diagrammatically illustrates the use of the several electron discharge devices of Fig. 1 in cascade.

Referring to Figs. 1 and 2, the vacuum tube comprises a thermionic cathode C, a surrounding grid G having a plurality of radially arranged and spaced vanes, a slotted anode A, and a secondary emission electrode or second cathode K. The cathode C is fluted in the space between the vanes in order to reduce the flow of electrons to the grid or control electrode G. This fluted construction causes the electrons to concentrate as a beam and pass through the openings between the vanes. This fluted arrangement causes the electrons to leave the thermionic cathode at right angles to the surface and thus, after some curvature in their paths, to pass through the grid openings. The thermionic cathode, as noted, is an indirectly heated type having a filament or heater coil through the center which is supplied with suitable low frequency heating current through iron core transformer T. The anode comprises a metal structure having a plurality of slots arranged longitudinally of the tube with the slot openings in the same straight line as the spaces between the vanes, in order to enable the electrons from the thermionic cathode to pass freely through the slots of the anode. The secondary emissive electrode which may have the surface which faces the anode and thermionic cathode coated with secondary emissive material, forms the outer envelope of the tube, thus enabling the temperature of this electrode to be lower than that of other parts exposed to the vacuum. It is preferred that cooling fluid, such as air, be blown on the outer surface of the secondary emissive electrode in order to lower its temperature during the operation of the vacuum tube.

An input cavity resonator or wave grid 10 is connected between the grid G and the thermionic cathode C. The connection between the cathode C and the wave guide is accomplished by means of a circular contact arrangement having a plurality of spring contacts which are soldered at 12 to the plate 13 of the input cavity resonator 10 and which make firm contact with the metallic extension 14 of the cathode. Plate 13 is mounted on a thin dielectric spacer 15 which is located between this plate and the bottom wall portion of the input cavity resonator 10. Plate 13 and condenser 15 thus form part of a by-pass condenser

which has very low impedance to energy of the operating frequency. It should be noted that the grid G has its vanes directly connected to the upper part of the input wave guide 10 by means of the metallic flange 16. Since the input wave guide normally is grounded, it will be evident that the grid normally is also grounded.

The slotted anode A is connected by means of an arcuate or conical metallic flange 17 and metallic spring contacts 18 to a metallic plate 19 of the output wave guide or cavity resonator 20. Plate 18 of the output wave guide is separated by means of a dielectric spacer 21, from a direct current standpoint, from the remaining portion of the output cavity. In effect, plate 19 and spacer 21 form a by-pass condenser which is a path of very low impedance to energy of the operating frequency for any currents flowing over the anode supporting flange 17. An insulating cylinder 22 forming a portion of the outer envelope of the vacuum tube supports the flange 17 and is positioned between this flange and an extension of the secondary emissive electrode or second cathode K, as shown.

It should be noted that the secondary emissive electrode K is connected by spring contacts and a bypass condenser for high frequency currents, but not for direct currents, at its upper end to the bottom wall of the output cavity resonator 20 and is separated by insulation 123 from the grid flange 16. Insulation 123 also serves as a radio frequency bypass condenser. A radio frequency by-passing condenser thus exists between the secondary emissive cathode K and the input and output cavity resonators.

The vacuum within the tube envelope is maintained by virtue of the seal created by the grid flange 16, the anode flange 17, the secondary emissive electrode, and the cylinder of insulation 22, as well as insulation 23, which cooperate to produce an air-tight structure. Both the input and output wave guides or cavity resonators 10 and 20 respectively are grounded, as shown. The grid is maintained at a suitable potential relative to the cathode by means of a battery 23 or other source. Depending on detail design of the tube this potential may be a small positive or negative value, or zero. The secondary emissive electrode K is maintained at a positive potential relative to the cathode by means of a power source 24, while the slotted anode A is maintained at a still higher positive potential relative to the cathode by means of a power source 25. By way of illustration only, the secondary emissive electrode K may be maintained at a positive potential of 100 to 300 volts relative to the cathode, while the slotted anode A may be maintained at a positive potential of the order of 1000 volts relative to the cathode. Obviously, these values of potential may be changed to suit different conditions encountered during use and different constructions of tubes.

In the operation of the system of Figs. 1 and 2, electrons leaving the thermionic cathode C pass through the vanes of grid G and the openings of slotted anode A and impinge on the secondary emissive electrode K, thus releasing secondary electrons from K at a ratio greater than unity. The alternating current input from the cavity resonator or input wave guide 10 causes variations in the number and velocity of electrons from the thermionic cathode C and produces variations in the number of initial electrons or the value of electron current flowing through the slotted anode to the secondary emissive electrode.

It should be noted that this alternating current input from the cavity comprises the incoming signal of radio frequency energy to be amplified by the vacuum tube system of the invention.

The passage of primary electrons from the cathode C and through the slotted anode A to the secondary emissive electrode K is intended to set up electron currents between A and K which are one-half cycle in time earlier than the electron currents set up by the secondary electrons returning in the opposite direction and passing through the slotted anode A toward the thermionic cathode C. The secondary electrons which pass through slotted anode A going toward the thermionic cathode C are stopped and reflected by the electric field between the slotted anode A and the control electrode or grid G. These reversed or reflected electrons pass back through the anode A toward the secondary emissive cathode K at such time as to add to the output oscillations set up in the output cavity resonator or wave guide 20 which is coupled between A and K. In practice the electrode potentials are to be adjusted to make the a. c. electron currents between electrodes A and K synchronous with the output electric field set up in cavity 20.

By making the electrons oscillate back and forth through the slotted anode A, the total electron current contributing to the oscillations in the output cavity resonator 20 is made to be much greater than the electron current coming from the thermionic cathode C and also much greater than that which corresponds to the initial secondary emission current. The potentials applied to the electrodes and the spacing of the electrodes are so correlated as to achieve this result. Because each electron passes in and out of the space between the slotted anode A and the secondary emissive cathode K several times, the potentials developed between these two electrodes A and K by the output cavity resonator 20 can be relatively small for any given power conversion efficiency. Stated in other words, for a certain overall power gain in the vacuum tube, the output circuit can be more heavily loaded and therefore pass a broader band of frequencies having more or less equal amplification throughout the band compared to what could be obtained for the same conversion efficiency and same gain if each electron delivered energy to the output circuit for only a single passage therethrough. Another way of stating this result is that as a consequence of the multiple use of electrons, it is possible to convert their direct current energy into alternating current energy with a much lower alternating current inter-electrode potential, as a consequence of which the resistive component of output impedance can be much lower for any given value of conversion efficiency, which will permit a large increase of frequency band width, or give more gain at any particular band width.

The multiple use of the electrons requires a coordination of the electron to-and-fro transit time with the operating frequency, which, of itself introduces some frequency selectivity. As an illustration, at a band width of let us say 40 megacycles, in order to accommodate modulation frequencies up to 20 megacycles at say a carrier frequency of 2000 megacycles, there will be 100 cycles of carrier current per cycle of highest modulation frequency. In this case, if each electron is used over again for let us say ten times (equivalent to about five whole round trips through the slotted anode A), there will not be introduced

any substantial limit on the band width due to the transit time selectivity.

The amplifier of the invention can be used anywhere in a range between 100 and 10,000 megacycles, depending upon the dimensions of the vacuum tubes and the resonant cavities and the potentials supplied to the electrodes of the tube. Such an amplifier should be very useful for the relaying of radio signals, for example in a television or multiplex communications relaying system.

Fig. 3 diagrammatically illustrates several amplifier tubes of the type shown in Fig. 1 arranged in cascade, in which each vacuum tube is used as an amplifying coupling element between an input and an output resonant cavity circuit or wave guide. Fig. 3 shows three amplifier sections. The first amplifier section, from left to right in this figure, has an aperture 4 in its input cavity 10 through which input signals are supplied from an input wave guide 29. The output cavity 20 for this amplifier section is provided with aperture 5 for supplying energy to the input cavity resonator 10' of the second amplifier section. Similarly, the output cavity resonator 20' of the second amplifier section is provided with an aperture 6 for supplying energy to the input cavity resonator 10'' of the third amplifier section. The output cavity resonator 20'' of the third amplifier section is provided with an aperture 7 for supplying energy to the output wave guide 30.

The apertures 4, 5, 6 and 7 are each preferably in the form of an adjustable slot or iris. These adjustable slots or irises enable impedance adjustments to be made, and are so positioned as to make the cavity resonators resonate at the operating frequency. The size and shape of the openings, in combination with cavity dimensions, are such that they present a resistive loading to the end of the input wave guide 29 and output wave guide 30 immediately adjacent their cavity resonators to bring about an impedance match. In other words, the position, size and shape of the opening or iris provides an impedance matching circuit in combination with the associated cavity resonator. The signal input circuit supplying the alternating current signal to the wave guide 29 looks into a resistive load, and the output wave guide 30 which derives the amplified signal may also look into a resistive load facing back into the amplifier system although the impedance match at this point is not essential. It is only at the input to the amplifier that it is nearly essential that the resistive load matches the characteristic impedance of the connecting wave guide.

The features of the invention are: (1) Elimination of the use of wires or leads which ordinarily would produce concentrations of current and thus cause sharp or extreme wave discontinuities; (2) the use of a secondary emitter electrode forming an integral part of the outer envelope of the metallic vacuum tube, thus preventing any possibility of excessive rise in temperature which would spoil the secondary emissive properties and enabling this secondary emitter electrode, by means of suitable cooling fluid, to be maintained at a lower temperature than all other surfaces exposed to the vacuum; (3) the construction of the anode circuit which avoids wave discontinuities which would ordinarily result in complication of the response characteristics of the output circuit; (4) the method of operation and construction which enables electrons produced by secondary emission to make multiple trips in and

out of the slotted anode in a manner to increase the electron current so that a substantially lower output load resistance may be used which will provide wider band width without loss of efficiency; (5) the construction which enables the use of wave guides or cavity resonators (resonant chambers) exclusively; (6) the grounded grid type of input arrangement which aids in eliminating the need for circuit neutralization, thus providing a low impedance input circuit for matching the wave guide input without too much loss of gain or loss of band width, due to the impedance transformation at the input, and providing a degree of negative feed-back useful in reducing noise and distortions; and (7) a grid or control electrode made with vanes instead of wires, and a relatively large grid to anode spacing which, up to a point, reduce the effect of anode potential upon the electrons pulled through the grid in a manner to permit larger gain and use of a low negative zero or low positive grid potential. The cathode to secondary emission electron transit time need not be small compared with a cycle so that considerable depth of the vanes is permissible. In fact, a relatively large spacing can be an aid to electron grouping or bunching, in response to velocity variations produced by grid to cathode high frequency potentials, in the electron stream reaching the secondary emissive electrode.

What is claimed is:

1. An electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, means electrically connected to said control electrode for substantially grounding said control electrode, and means for maintaining said anode at a positive potential and said secondary emissive electrode at an appreciably higher positive potential relative to said cathode said last named means comprising a voltage source connected to said cathode and secondary emissive electrode.

2. An electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary emissive electrode forming an integral part of the envelope of said device, means electrically connected to said control electrode for maintaining the same at a negative potential relative to said thermionic cathode, and means electrically connected to said anode and said secondary emitting electrode for maintaining said anode at a positive potential and said secondary emissive electrode at an appreciably higher positive potential relative to said cathode.

3. An electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, said cathode being fluted at those portions located along radial lines between said vanes, whereby electrons are concentrated into beams for passage between said vanes, an anode having spaced slots located on the same radial lines as the fluted portions of said cathode, and an electrode surrounding said anode and coated with secondary emissive material on its surface facing said anode, said electrode which

surrounds said anode forming an integral part of the envelope of said device.

4. An electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary emissive electrode forming an integral part of the envelope of said device, a cavity resonator coupled between the control electrode and cathode, and a cavity resonator coupled between the anode and secondary emissive electrode.

5. A wide frequency band vacuum tube amplifier comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary emissive electrode being coated on its interior surface with secondary emissive material and forming an integral part of the envelope of said tube, means for substantially grounding said control electrode comprising a voltage source connected thereto, means comprising a voltage source for maintaining said anode at a lower potential than said secondary emissive electrode relative to said cathode, an input cavity resonator coupled between said cathode and control electrode, an output cavity resonator coupled between said anode and secondary emissive electrode, and means including a wave guide for supplying radio frequency energy to be amplified to said input cavity resonator.

6. An electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary electron emissive electrode forming an integral part of the envelope of said device, whereby a surface of said last mentioned electrode is exposed to the exterior of said envelope for heat dissipation.

7. A multi-stage amplifier having a first electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary emissive electrode forming an integral part of the envelope of said device, a cavity resonator coupled between the control electrode and cathode, and a cavity resonator coupled between the anode and secondary emissive electrode, and a second similar electron discharge device with associated cavity resonators, the cavity resonator coupled between the control electrode and cathode of the second discharge device being closely adjacent the cavity resonator coupled between the anode and secondary emissive electrode of the first discharge device, said last two cavity resonators being coupled together by virtue of apertures therein which register in position.

8. A multi-stage amplifier having a first electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary emissive electrode forming an integral part of the envelope of said device, a cavity resonator coupled between the control electrode and cathode, and a cavity resonator coupled between the anode and secondary emissive electrode, and a second similar electron discharge device with similarly coupled cavity resonators, the cavity resonator coupled between the control electrode and cathode of the second discharge device being closely adjacent the cavity resonator coupled between the anode and secondary emissive electrode of the first discharge device, said last two cavity resonators being coupled together by virtue of registering apertures therein, and a wave guide coupled to the other cavity resonator of said first device through an aperture in said last cavity resonator, said last aperture being adjustable in size, said wave guide being adapted to have input signals applied thereto.

9. A multi-stage amplifier having a first electron discharge device comprising a thermionic cathode, a control electrode comprising a plurality of radially extending vanes surrounding said cathode, an apertured anode surrounding said control electrode, and a secondary electron emissive electrode surrounding said anode, said secondary emissive electrode forming an integral part of the envelope of said device, a cavity resonator coupled between the control electrode and cathode, and a cavity resonator coupled between the anode and secondary emissive electrode, and a second similar electron discharge device with associated cavity resonators, the resonant chamber coupled between the control electrode and cathode of the second discharge device being closely adjacent the cavity resonator coupled between the anode and secondary emissive electrode of the first discharge device, said last two cavity resonators being coupled together by virtue of registering apertures therein, means including a wave guide for supplying alternating current energy to the other cavity resonator of said first device, and a wave guide coupled to the other cavity resonator of said second device through an aperture in said last cavity resonator, said last aperture being adjustable in size.

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