

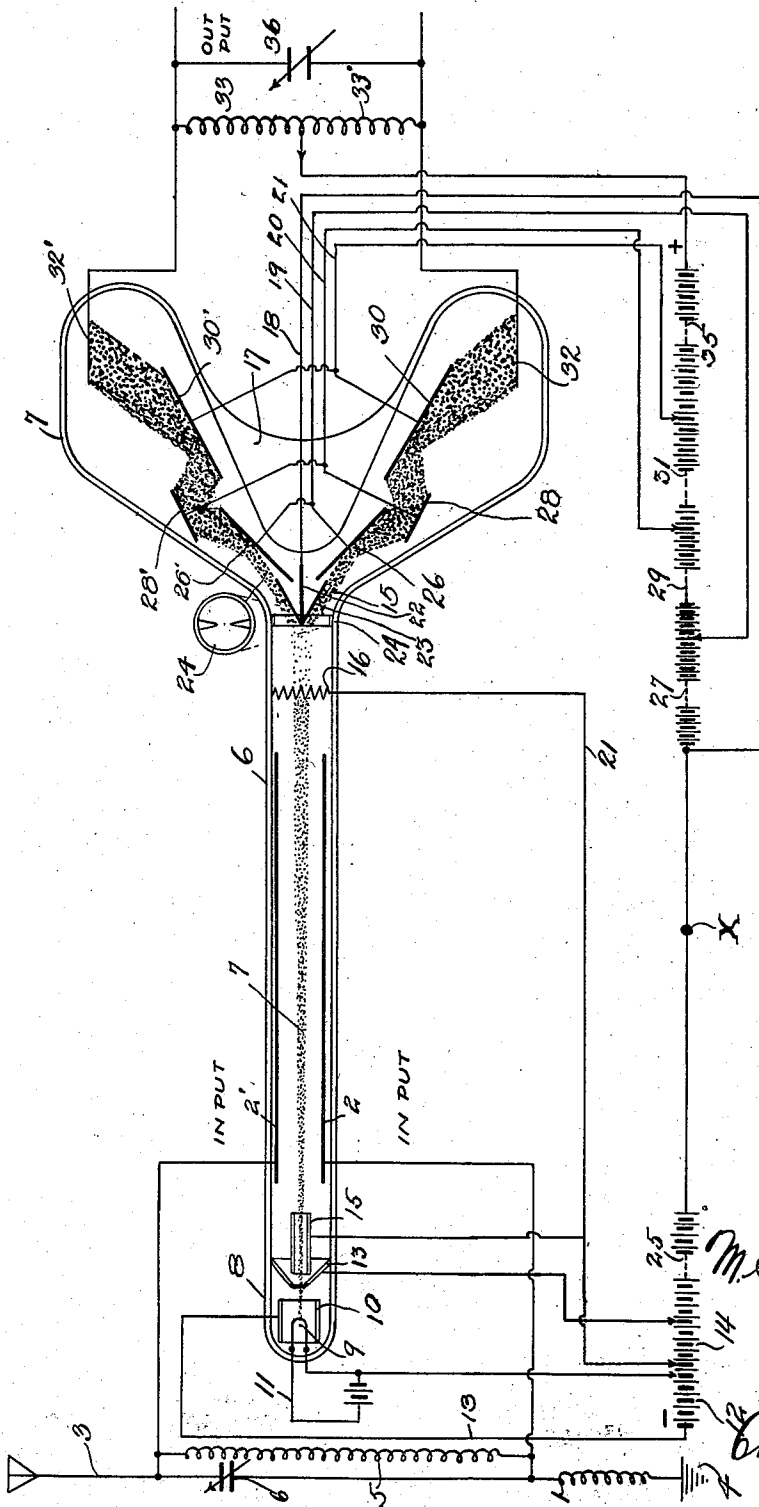
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AMPLIFICATION OF RADIANT ENERGY

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AMPLIFICATION OF RADIANT ENERGY

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This invention relates to improvements in the method and apparatus of the amplification of electrical energy. This result is obtained by producing a narrow beam of electrons and successively decelerating, guiding, accelerating and causing said beam to impinge alternately on two different receivers which may be the faces of two independent output electrodes or the faces of another electrode having two faces capable of emitting secondary electrons, where bombarded. These secondary electrons so emitted are attracted either to more secondary electron-emitting electrodes or alternately to one and then the other of a pair of final electrodes.

More particularly described, the method of amplification consists in sending a narrow beam of electrons between two or more input plates which are charged electrostatically by the input. At a distance from these input plates there is a screen or grid so placed and charged that it will protect the electrons in the vicinity of the input electrodes from the accelerating influence of the more highly electropositive field beyond the screen or grid. In addition a plane partition or other dividing means is placed behind the screen or grid normally in line with the electron beam in its neutral position with its plane perpendicular to the direction of the movement of the electron beam when the latter is deflected by changes of difference in potential of the input plates.

This partition terminates at its edge toward the input plates within an inverted V-shaped member which when bombarded by the electron beam will emit secondary electrons on one or another side of the member. These electrons in turn migrate to the more positively charged electrodes on each side of the said partition.

The secondary electrons at the positively charged electrodes may migrate and in turn generate further secondary electrons from another electrode beyond the one from which they are emitted. This further electrode is more positively charged than the preceding one. The final electrode in the series, which is determined by the degree of amplification desired, delivers its current to one end of a resistance or impedance, the other end being similarly connected to the final electrode of the opposite series. The resistance or impedance is tapped at the center for connection to a source of positive potential greater than that of the series of secondary electron-emitting electrodes. The output or load circuit may be shunted between the ends of this resistance or impedance.

The object of this invention is to make possible an electron valve in which any of the following characteristics which it may be desired to incorporate simultaneously may be incorporated simultaneously to practically any desired degree without sacrificing long life, durability or high efficiency; large amplification factor; small active control current; ability to give high voltage output, high current output, or both; no output background current; any desired mutual conductance curve and aperiodicity.

Other objects will be apparent in the following description.

In the drawing I have shown a system for periodic amplification of weak radio waves, and to avoid unnecessary illustration I have shown a special shield which would find most use in audio amplifiers or power amplifiers. This shield will be explained with the amplifier in the following description.

The shell 6 is a long glass cylinder enlarged at one end, 7. At the small end 8, is a filament 9, held at a positive potential with relation to concentrating cylinder 10 by potential source 12. Co-axially mounted in front of concentrating cylinder 10 is a cone-shaped accelerating shield 13 with its apex, which has a hole in it, pointing toward filament 9.

This accelerating shield is held at a positive potential with relation to filament 9 by potential source 14. Co-axially mounted with the accelerating shield 13 and extending into the interior of the large end of the said accelerating shield is a concentrating tube 15. This concentrating tube is held at a negative potential with relation to shield 13 by connecting it near filament 9.

In front of concentrating tube 15 is a pair of control electrodes 2 and 2'. Electrodes 2 and 2' are shunted by inductance 5 and capacitance 6. To avoid confusion the effect of inductance 5 and capacitance 6 will be ignored until they are further mentioned.

Electrode 2' is connected to antenna 3 and electrode 2 is connected to ground 4 through inductance 1. In front of control electrodes 2 and 2' is a screen or grid 16, which is held at a potential similar to that of the concentrating cylinder 15 by conductively connecting it thereto. In place of the electrodes 2 and 2' I may use the customary helices for deflecting the beam.

The enlarged end of the tube contains a press 17 which is in axial line with electrodes 2 and 2'. The press 17 serves as a point of entry for conductors 18, 19, 20 and 21 and also, together

with a plane metallic partition 22, which is symmetrically mounted in the same axial line, to divide the enlarged end 7, of the shell 6, into two similar compartments.

- 5 A metallic member 23, having an inverted V-shaped cross-section is so conductively mounted on the electrode 22 that its apex is parallel with the plane of metallic partition or electrode 22 and its two arms point away from screen 16.
- 10 Conductively mounted on the apex of the inverted V-shaped member 23, is a shield 24, having two V-shaped apertures with their apices pointing in line and almost meeting at the center of the shield.

- 15 Electrode 22 is held at a positive potential with relation to the screen or grid 16 by potential source 25. Electrodes 26 and 26' are symmetrically placed, one on each side of partition 22 and behind the inverted V-shaped member 23.
- 20 Electrodes 26 and 26' are connected to conductor 19 and held at a relatively high positive potential with respect to electrode 22 by potential source 27.

- 25 Electrodes 28 and 28' are connected to conductor 20 and held at a high electropositive potential with respect to electrodes 26 and 26' by potential source 29. Electrodes 30 and 30' are placed one on each side of partition 22 and behind electrodes 28 and 28'.

- 30 Electrodes 30 and 30' are connected to conductor 21 and held at a high electropositive potential with relation to electrodes 28 and 28' by potential source 31.

- 35 It is to be understood that the above electrodes 23; 26; 26'; 28; 28'; 30 and 30' are to be coated with some form of an alkali earth metal.

- 40 Electrodes 32 and 32' are placed one on each side of the press 17, and at a good distance behind electrodes 30 and 30'. Electrodes 32 and 32' are connected one to arm 33 and the other to arm 33' of center-tapped resistance 33; 33' respectively. Electrodes 32 and 32' are held at a high electropositive potential with respect to electrodes 30 and 30' by connecting the center-tap 34 to potential source 35.

- 45 As a means for tuning the output I have shown condenser 36.

- 50 In the tube, electrons are emitted from filament 9 and concentrated by the repulsion of cylinder 10 and attracted by the accelerating shield 13. Of the electrons approaching shield 13 some strike it and others pass through the hole in it. Those which pass through the hole are decelerated and concentrated by tube 15 and pass between the control plates 2 and 2'.

- 55 The electrons can be decelerated to any desired degree by increasing the negativity of concentrating tube 15.

- 60 Input plates 2 and 2' act as a condenser which, with inductance 1 forms a series-resonant circuit. When an alternating electromotive force of the same frequency as the resonant frequency of the series-resonant circuit is set up between the ground 4, and antenna 3, a current will flow through the said series-resonant circuit. This current will be limited chiefly by the resistance of inductance 1. This current will set up an E. M. F. between electrodes 2 and 2' whose magnitude will vary directly with the current and inversely with the effective capacitance between electrodes 2 and 2'. The current, which can be drawn by the resonant circuit from the antenna 3 will be limited, no matter how low the resistance of inductance 1. Therefore a method for obtaining a radical potential step-up cannot be had by

decreasing the resistance of the inductance 1 but by decreasing the effective capacitance between plates 2 and 2' and neutralizing the increased capacitive reactance by increasing the inductance 1, without increasing its resistance.

Since decreasing the size of or the distance between electrodes 2 and 2' would decrease the sensitivity of the tube their effective mutual capacitance may not be decreased in this manner.

To avoid a limiting condition at this point I have conceived a method which I believe to be new and novel for neutralizing the effective capacitance between input electrodes. This consists in shunting the input electrodes 2 and 2' with inductance 5. The smaller the resistance and inductance of inductance 5, the less will be the effective mutual capacitance between electrodes 2 and 2', but the resistance of inductance 5 will tend to increase the power loss and thus decrease the potential between electrodes 2 and 2'. (It is here assumed that the inductance 5 has an inductance relatively high to its resistance.) By increasing inductance 1 and properly proportioning inductance 5 while keeping the effective resistance of the network low, practically any degree of potential step-up may be obtained for any given frequency. However, since it would be difficult to build a very high grade inductance that is variable I choose to shunt a small variable condenser 6, across the input electrode as a means for varying the point of resonance.

As the electrons pass between electrodes 2 and 2' they will be attracted toward either electrode 2 or 2' at any given point between electrodes 2 and 2' according to the potential difference between the said plates at that particular point at that particular time. (It is here assumed that the distance between the control electrodes is much less than a wave length.)

From this rule it can be seen that the electron stream emerging from tube 15 will be deflected the most when the active length of the electrodes is equal to one half the product of the wave length of the E. M. F. being amplified and the distance travelled by an electron in the beam during one cycle of the E. M. F. divided by the difference between the wave length of the E. M. F. and the distance travelled by an electron in the beam during one cycle of the E. M. F.

Thus it will be seen that if the velocity of the electrons were made equal to the velocity of the radio waves it would be possible to increase the length of the electrodes 2 and 2' almost indefinitely. It is, however, practically impossible to make the electrons travel as fast as the radio waves and there must, therefore, be a compromise between the length of the control electrode and the velocity of the electrons.

Since to have long electrodes would entail an increase in the bulk of the tube I choose to have comparatively short electrodes and a very low electron velocity. Using only one pair of control electrodes a limit would be reached to the angle to which the beam could be deflected for a given potential difference between control electrodes.

A method for overcoming this limit will be mentioned later but is not employed in the tube in the diagram.

The screen or grid 16 prevents the highly electropositive field of the electrodes in the enlarged end of the tube from accelerating the electrons while they are in the vicinity of electrodes 2 and 2'. After the electrons have passed from between electrodes 2 and 2' they pass through grid 16 and are highly accelerated by the highly electro-

positive field of the shield 24. Those passing electrode 2 when and where it was positively charged will some strike shield 24 and others pass through it. The number passing through it will be determined by the size of the opening in the shield 24 at the point where the beam approaches it and therefore, the degree to which the electrons of the beam were attracted toward electrode 2.

Those striking the inverted V-shaped member 23 cause it to emit secondary electrons. These secondary electrons are in turn violently attracted by electrode 26 and strike it with sufficient force to cause it to emit secondary electrons. The secondary electrons emitted by electrode 26 in turn are violently attracted to electrode 28, thus causing it to emit secondary electrons. The electrons from electrode 28 are violently drawn against electrode 30, thus causing it to emit secondary electrons. These electrons from electrode 30 are attracted by electrode 32. However, since no more positive electrode is adjacent to electrode 32 any secondary electron emitted therefrom returns thereto. Therefore, an electron current will flow from electrode 32 into arm 33 of center-tap inductance 33; 33'. When electrode 2 is most positive, electrons travel through the other aperture in shield 24 and strike the other side of the inverted V-shaped member causing it to emit electrons which in turn ultimately cause a current to flow into arm 33' of center-tapped inductance 33; 33'.

The apertures in the shield 24 need not be exactly V-shaped but can be shaped in any desired way according to the desired mutual conductance curve or any lack of linearity in the secondary emission. If the distance between the apices of the apertures in this shield is properly adjusted electrons will never pass through both apertures simultaneously and therefore, secondary emission will not take place on both sides of the partition simultaneously and there will, therefore, be no uncontrolled current in the output provided the electrodes are kept sufficiently cool to prevent thermo-emission. The tube will therefore, be highly efficient.

Since the tube can be operated with a hard vacuum there is almost no limit to the voltage which can be had between the last pair of secondary electron emitting electrodes and the final electrodes. Therefore, tubes of this type can be built for virtually any output voltage.

Since any number of stages of secondary emission can be built into the tube the current output with which a tube can be built is practically unlimited. Both current output and voltage output can be increased almost indefinitely regardless of the input because one aids an increase of the other and because the sensitivity of the tube is independent of its output.

The sensitivity of the tube can be increased almost indefinitely because the velocity of the electron beam can be decreased almost indefinitely. A limit need not be reached when the electrons are decelerated to such an extent that the differences in velocity due to the differences in the amount of thermal energy imparted to the electrons while leaving the filament because they can be sent through an aperture and then filtered for differences in velocities by spreading them into a spectrum with an electrostatic or electromagnetic field.

Changes in the quantity of electrons having a given velocity as they leave the filament and therefore in the number which bombard the inverted V-shaped member 23 for a given potential

difference between control electrodes 2 and 2' can be compensated by placing an appropriate resistance at the point marked by the "X" which is next to potential source 25; or if necessary, by replacing the potential source 25 with an appropriate network of resistances and potential sources.

The tube may be made aperiodic as desired without sacrificing efficiency because both the capacitance between input electrodes and that between output electrodes can be increased indefinitely. By connecting an appropriate resistance with the input electrodes and shunting this series circuit with an equal resistance connected in series with an appropriate inductance the power factor and equivalent resistance of the input circuit can be kept constant regardless of frequency.

Since the filament emits only a very small portion of the electrons in the tube it can be made small and operated at an unusually low potential, thus increasing the life of the tube.

I do not wish to confine the scope of my claims to apparatus of the exact form described, for I realize that such things are possible as the use, in place of the hard vacuum and lean beam, a soft vacuum and a dense beam and a lower operating voltage, and the use of screens or grids in place of plates for control electrodes and the use of a photo-electric surface in place of a filament as an initial source of electrons.

What I claim is:—

1. The combination in an electronic valve, of an electron beam and a pair of control electrodes so located that a change in potential difference between said electrodes will sway the beam means to produce from the beam an intermittent stream of electrons and one or more other electrodes receiving said intermittent stream of electrons and amplifying this stream in the form of emitted secondary electrons.

2. The combination within an electronic tube valve, of an electron beam, a pair of control electrodes so placed that a potential difference between said electrodes will sway the said electron beam, a partition or other separating means held at a negative bias with respect to the output circuit of the valve, at the end of the tube so placed that when the beam is swayed by either of said control means it will pass from one side of said partition or separating means to the other and a pair of collecting electrodes positively charged with relation to source of said electron beam, said electrodes being connected to opposite terminals of an output circuit, one of said collecting electrodes being placed on either side of said partition or separating means.

3. The combination within an electronic tube valve, of an electron beam, a pair of electrodes so placed that a change in potential difference of said electrodes will sway said electron beam, a partition or other separating means so placed at the end of the tube opposite the source of the said electron beam, such that when said electron beam is swayed by said control means its point of impingement will pass from one side of said partition or other separating means to the other side thereof, a grid placed between said control means and said partition or other separating means and so charged that it will shield the electrons between it and the vicinity of the control plates from the highly accelerating positive field of the partition or other separating means and the electrodes surrounding it, and a pair of output electrodes, one of which electrodes is placed on each side of

the said partition or other separating means and both of which are held at a positive potential with relation to said partition and to all other electrodes in the tube.

5 4. The combination within an electronic tube valve, of an electron beam, a pair of control electrodes so placed that a change of potential difference of said electrodes will sway said beam, and one or more electrodes so placed and charged
10 that in the operation of the tube they will intermittently emit secondary electrons, and one or more electrodes positively charged with relation to all other electrodes in the tube, for absorbing said secondary emitted electrons.

15 5. The combination within an electronic valve, of a source of electrons, one or more secondary-electron-emitting electrodes held at a positive potential with relation to said source of electrons, a control electrode, and a grid between
20 said source of electrons and said secondary-electron-emitting electrodes held at such an electronegative potential with relation to said secondary-electron-emitting electrodes that it will shield the electrons in the vicinity of said control
25 electrodes from the strong electropositive field of said secondary-electron-emitting electrodes, and an electrode more electropositively charged than any others in the tube and placed behind the most electropositively charged secondary-electron-emitting electrode in the tube.

30 6. The combination within an electronic tube valve, of an electron beam, a pair of electrodes so placed on opposite sides of the beam normally that a change of potential difference between
35 said electrodes will sway said beam, one or more secondary-electron-emitting electrodes held at a distinctly positive potential with relation to the source of said electron beam, a pair of electrodes held at a more electropositive potential than all
40 the other electrodes and also placed on opposite sides of the normal position of said beam so that the one of the pair of most positively charged electrodes which is on the same side of the tube as the input electrode at that instant deflecting
45 the beam, will receive the greatest bombardment of secondary electrons from the secondary-electron-emitting electrode and a grid placed between said pair of input electrodes and the secondary-electron-emitting electrode and negatively
50 charged with relation to said secondary-electron-emitting electrode.

7. The combination in an electrical amplifying system of an electronic tube valve, having within it an electron beam, a pair of control
55 electrodes so placed on opposite sides of the normal position of said beam that a change of potential difference of said electrodes will sway

said electron beam, one or more secondary-electron-emitting electrodes at least one of which is struck by the said electron beam and all of which are held at a distinctly electropositive potential with relation to the electron beam source, a pair
80 of electrodes held at a more positive potential than all the other electrodes and so placed on opposite sides of the normal position of said beam that the one of the pair of most positively charged electrodes which is on the same side of the tube as the control plate at that instant deflecting the beam will receive the greatest bombardment of secondary electrons from the secondary-electron-emitting electrode, a grid placed
90 between said pair of control electrodes and the secondary-electron-emitting electrode and negatively charged with relation to said secondary-electron-emitting electrode, and a center-tapped resistance or impedance whose extremities are connected each to one of the most positively
95 charged electrodes in the tube and whose center-tap is given a potential in excess of that of any of the above electrodes.

8. The combination in a vacuum tube electronic valve of one or more secondary-electron-emitting electrodes, separate means receiving said secondary emissions, an electron beam, a pair of input electrodes so placed that a change in potential difference of said input electrodes will sway said electron beam, and a shield so
105 placed and charged that the number of secondary electrons emitted from the first named electrodes is varied by the position of the electron beam with respect to the shield.

9. In combination with an inductance, a vacuum tube having spaced electrodes connected in series with said inductance and forming therewith a series resonant circuit, and a second inductance shunted across the said electrodes for decreasing the effective capacitance between the
115 said electrodes.

10. The combination in an amplifier, of means to produce an electron beam, means for utilizing variations in the input to cause said beam to sway, and means cooperating with said beam
120 to produce intermittently therefrom a stream of secondary electrons.

11. Means for amplifying a pulsating electron stream, comprising locating one or more members in the path of said stream for emitting
125 secondary electrons and means located beyond said members for collecting said secondary electrons, with means for maintaining said members relatively positive with respect to the electron source and means for maintaining said collecting means relatively positive to said members.

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DISCLAIMER

1,920,863.—*Matthew S. Hopkins, Jr.*, Washington, D. C. AMPLIFICATION OF RADIANT ENERGY. Patent dated August 1, 1933. Disclaimer filed March 25, 1936, by the patentee.

Hereby enters this disclaimer to claim 11 in said specification.
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