Nov. 12, 1940. H. M. WAGNER 2,221,743

MAGNETIC VOLUME CONTROL

Filed Sept. 30, 1939 3 Sheets-Sheet 1

Fig. 1

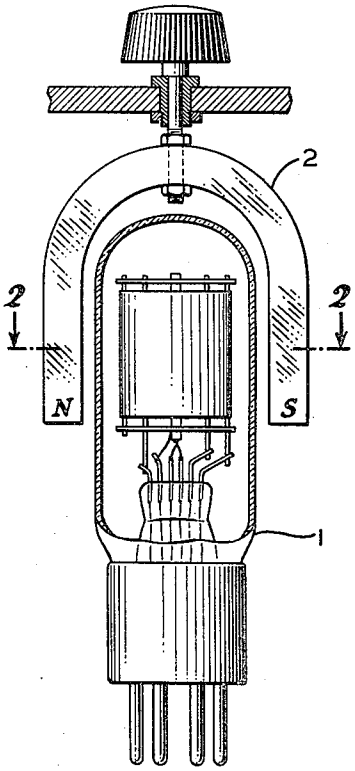


Fig. 2

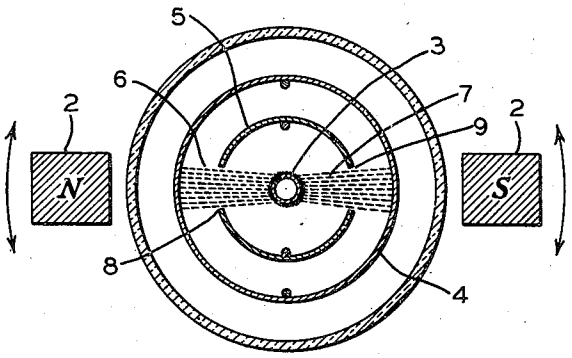


Fig. 3

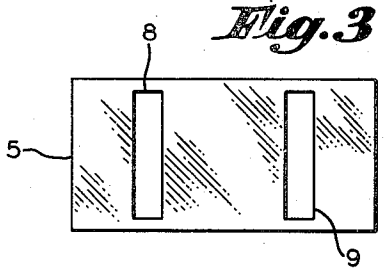


Fig. 4

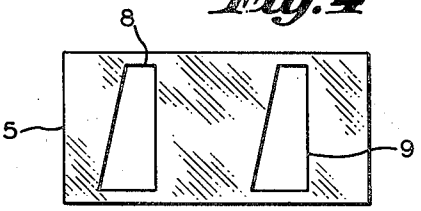


Fig. 6

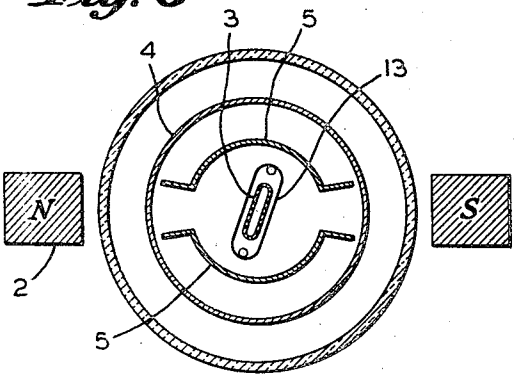
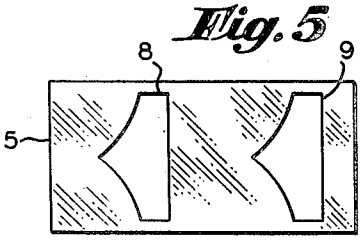


Fig. 5



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MAGNETIC VOLUME CONTROL

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Fig. 7

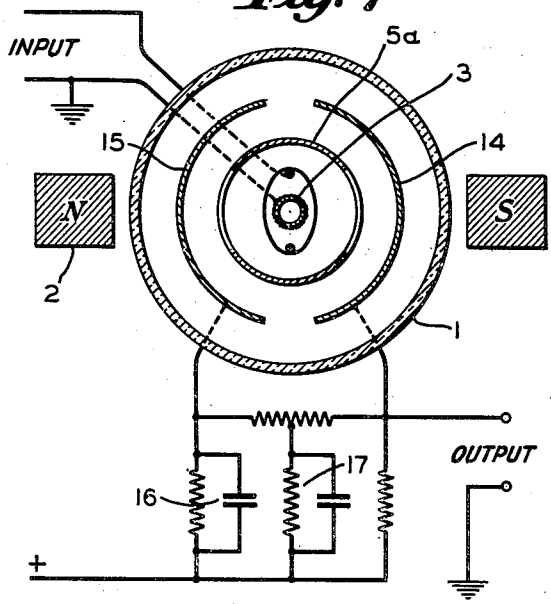


Fig. 7a

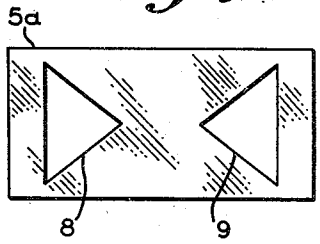


Fig. 11

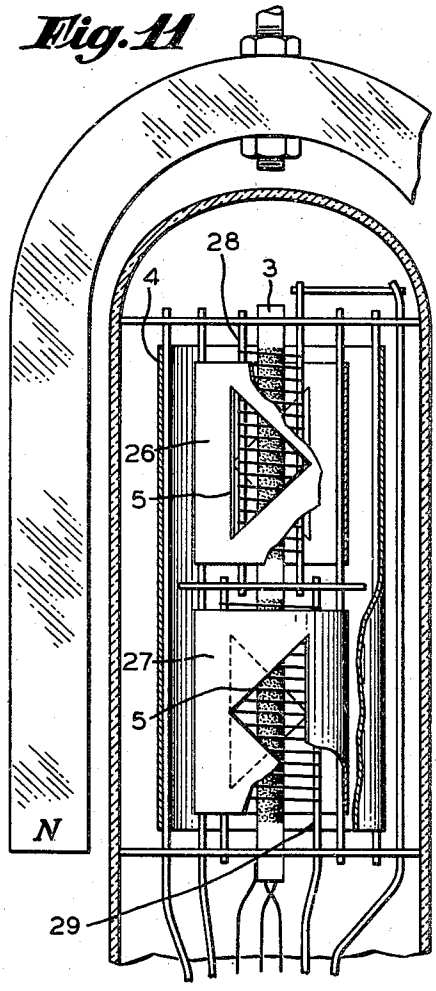
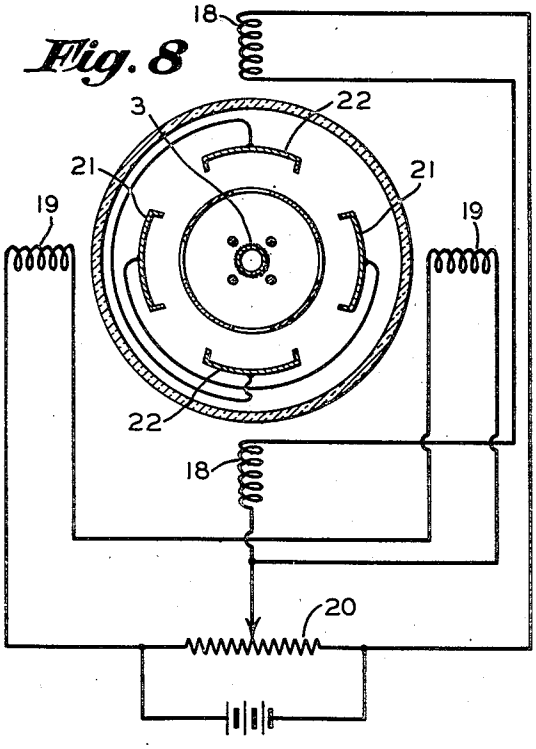


Fig. 8



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MAGNETIC VOLUME CONTROL

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Fig. 9

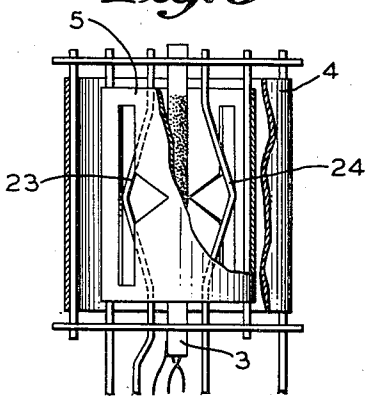


Fig. 10

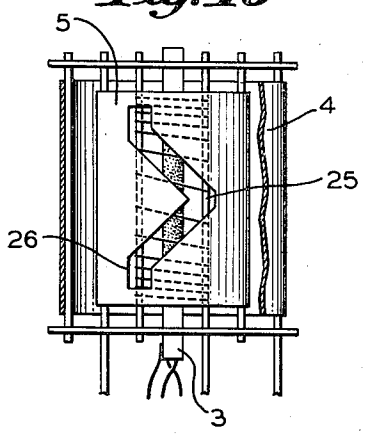


Fig. 12

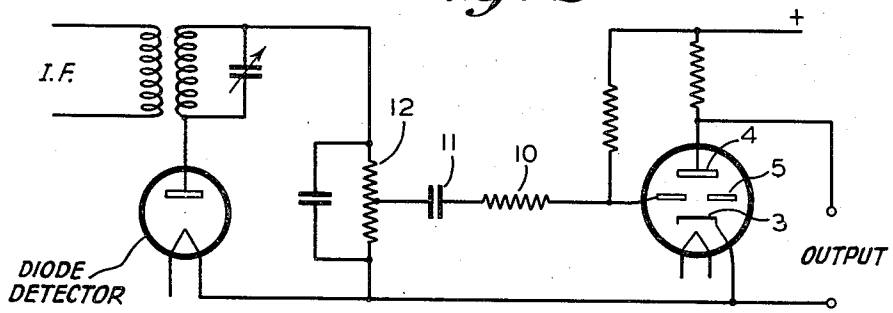
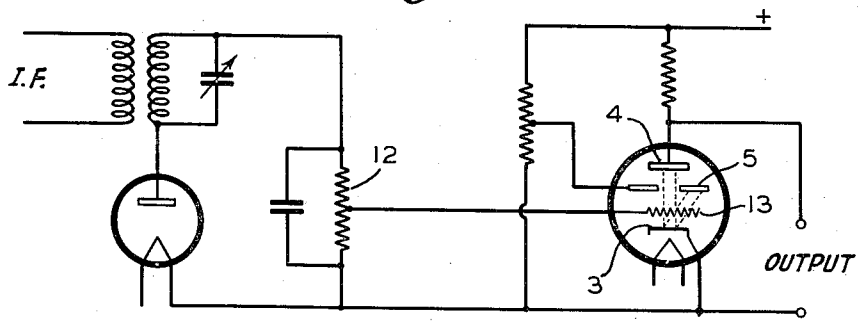


Fig. 13



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2,221,743

UNITED STATES PATENT OFFICE

2,221,743

MAGNETIC VOLUME CONTROL

Herbert M. Wagner, Kearny, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application September 30, 1939, Serial No. 297,281

13 Claims. (Cl. 250—27.5)

My invention relates to amplification or volume control devices, particularly volume control tubes for signaling systems such as radio frequency or audio frequency amplifiers.

Manual amplification control is usually obtained by an adjustable resistor, such as a potentiometer. The sliding contacts and moving parts of adjustable resistors wear with use and become defective, and the contact resistance between the sliding contact and the face of a resistor, such as a carbon rod or a wire wound resistor, becomes erratic.

The object of my invention is an amplification or volume control device that is smooth in operation, mechanically simple, free from noise-producing sliding contacts and resistors, and will withstand long and hard use.

In accordance with my invention the discharge from a thermionic cathode is formed into an electron beam which may be rotated about the cathode as a pivot by a magnetic field of substantially uniform intensity which extends lengthwise of and directs the beam and is bodily rotated about the axis of the cathode as a center, and which may, for example, be produced by rotatable permanent magnets of the horseshoe type with poles of the magnet on opposite sides of the electrode assembly. By rotation of the magnet the electron beam may be rotated about the cathode to bring it into registery with windows or openings in an electrode so arranged that the angle of rotation of the magnetic field controls the space current to the anode.

In one modification of my invention the anode is tubular and surrounds the cathode, and a tubular masking electrode comprising a cylinder of sheet metal is interposed between the cathode and anode, the cylinder having windows or openings on opposite sides of the cathode. The beam of electrons may conveniently be modulated with signal voltages impressed upon either or both the masking electrode and grid placed between the cathode and anode. Such a tube has many circuit applications including the control of amplitude of signals, mixing signals and tone control.

The characteristic features of my invention are defined with particularity in the appended claims and the preferred embodiments of my invention are described in the following specification and shown in the accompanying drawings in which:

Figure 1 shows my novel amplification control device including a tube made in accordance with my invention and a magnet;

Figure 2 is a transverse sectional view along the line 2—2 of Figure 1;

Figures 3, 4 and 5 show masking electrodes of my novel tube developed or laid out flat to better show the windows or openings in the electrode;

Figure 6 shows my novel tube with a separate control grid around the cathode;

Figure 7 shows one embodiment of my novel tube with circuit connections for combined volume and tone control;

Figure 7*a* shows the developed masking electrode of Figure 7;

Figure 8 shows a tube embodying my invention with electrical means for rotating the magnetic field;

Figures 9 and 10 show partly sectional tubes embodying my invention with means for varying the transconductance and amplification constant of the tubes;

Figure 11 shows a tube embodying my invention with means for insuring a constant anode current and means for varying the transconductance of the tube;

Figures 12 and 13 show representative circuit applications of my novel amplification control device.

Figure 1 shows my novel volume control device mounted on the panel of amplifier apparatus and comprises a tube 1 of conventional envelope and basing construction with its longitudinal axis coincident with the center of rotation of a magnet 2 of the horseshoe type, the poles of the magnet being positioned on opposite sides of the tube. Rotation of the magnet as hereinafter described varies the volume of the signal passed by the tube from minimum to a maximum. The magnet described here is, for convenience, shown as the permanent type although an electromagnet may be used.

One preferred embodiment of my novel tube, shown in section in Figure 2, comprises a cathode 3, preferably of the indirectly heated type, coaxial with a cylindrical anode 4. Between the anode and cathode and coaxial therewith is a cylindrical masking electrode 5 of sheet metal coaxial with the cathode and anode. The field produced by the poles of the magnet lying in a plane through the cathode and anode draws the electrons into two relatively flat beams 6 and 7, each beam extending the length of the cathode. The boundaries of the beams are quite well defined with a strong magnetic field and the plane of the beams lies in a plane through the poles so that rotation of the poles rotates the beams about the cathode as an axis. Windows or openings 8

and 9 in the masking electrode are provided on opposite sides of the cathode so that the two beams may be simultaneously rotated into registry with the windows. The degree of coverage of the windows by the beams determines the anode-cathode space current and signal level in the anode circuit of the tube.

Masking electrodes with preferred shapes of openings are shown in Figures 3, 4 and 5 where the tubular masking electrode 5 is developed or laid out flat to better show the windows. The sides of the slotted openings may be straight and parallel as shown in Figure 3, or tapered as shown in Figures 4 or 5 to give a more gradual change of anode current with magnet rotation. Any desired relation of magnet rotation and volume level may be obtained by curving the edges of the slot as shown in Figure 5 where volume may be made an exponential function of magnet rotation.

Figure 12 shows a simple amplifier circuit for the tube of Figure 2 in which the masking electrode is coupled into the input circuit of the tube through coupling resistor 10 and condenser 11 to the conventional detector load circuit 12 of a radio receiver. In operation as the anode current is reduced by rotating the magnet the signal applied to the masking electrode is reduced because of the increased voltage drop in the series coupling resistor.

A control grid around the cathode may be employed to obtain higher transconductance and greater beam modulation. As shown in Figure 6 a conventional wire wound grid 13 on side rods is telescoped over the cathode with the plane of the side rods transverse to the plane through the center of the windows. The sides of the cathode may be flattened to obtain higher emission and increased transconductance and the side rods of the grid should be placed at the edges of the cathode. The flattened sides of the cathode and control grid should be inclined to the plane through the center of the windows. The side rods cause undesired defocusing and "fringing" of the electrons at the sides of the beam and inclination of the plane of the cathode and rods is necessary to get complete cut-off of the anode current when the magnet is rotated to the extreme clockwise position in Figure 6.

Good results have been obtained with my tube connected as an amplifier with the grid 13 coupled, as shown in Figure 13, to the load circuit 12 of a diode rectifier and the masking electrode connected to a steady positive potential. Low distortion throughout the entire range of signal amplification was obtained with my tube in the circuit of Figure 13 with a standard oxide coated cathode .050" in diameter and about 1" long placed coaxial with a masking electrode .50" in diameter and an anode .75" in diameter, and with an anode voltage of 250 volts and a masking electrode voltage of 30 volts. While my tube is shown in Figures 12 and 13 connected for signal voltage amplification, it could of course be connected to amplify direct current or radio or intermediate frequency currents, modulated or unmodulated.

The electrons in the two oppositely directed beams may conveniently be collected on electrically independent sections of the anode. As shown in Figure 7 a separate anode is placed opposite each of the two windows in the masking electrode and is provided with separate lead-in conductors. The two anodes 14 and 15 may then be connected to different output circuits such as different loud speaker amplifiers. When provided with the masking electrode 5a of Figure 7a the tube is useful in tone control circuits, the windows in the masking electrode being tapered in opposite directions so that as rotation of the magnet moves one beam toward the narrow portion of one window the other beam is moved toward the wider portion of the other window. A loud speaker with a good high frequency response may be coupled to one anode and another speaker with good low frequency response may be connected to the other anode, and by rotation of the magnet the ratio of signal to the two speakers may be easily adjusted. Alternatively, the two anodes may be connected to the two points in a frequency discriminating circuit comprising for purposes of illustration circuits 16 and 17. More or less bass compensation, for example, may be introduced into the output load circuit merely by shifting the proportion of current to the two anodes.

A mechanically pivoted magnet of the horseshoe type has been described for rotating the electron beams about the cathode as a pivot. Rotation of the magnetic field may, if desired, be obtained electrically by two pairs of coils 18 and 19 with their axes placed at right angles, as shown in Figure 8. Direct current for energizing the coils may be supplied through potentiometer 20 for adjusting the relative field strengths of the two pairs of coils and for adjusting the angular position of the resultant magnetic field. With the sliding contact on the potentiometer on the extreme left end of the resistor, coils 19—19 are deenergized and coils 18—18 receive full energization and the magnetic field and electron beams are then vertical. By moving the contact to the other end of the resistor the other pair of coils is energized and the magnetic field and beams are rotated 90° Any intermediate position of the beam may be easily obtained by adjustment of the potentiometer and is particularly useful for remote control of the volume control tube. The anode and masking electrode arrangement of Figures 2 or 7 may be used, but to obtain control of separate output circuits with minimum rotation, a masking electrode with four windows and two anodes 21 and 22, each with a segment in registry with opposite windows are used. The input signal may easily be switched from one output circuit to the other and the amplitude of signal in either output controlled by the position of the magnet.

To increase the range of input signal variation of my novel magnetic volume control device, I have found it desirable to make the grid of the variable mu type. A grid is placed unsymmetrically with the emitting surface of the cathode to give a different amplification factor or transconductance for different parts of the emitting surface. One variable mu grid for my novel tube shown in Figure 9 comprises two bent rods 23 and 24 on opposite sides of the cathode and in a common plane through the cathode. The rods are bent outwardly at their centers, the bends lying in said plane, the plane in Figure 9 being coincident with the plane of the paper. With the magnet so positioned that the beams of electrons from the cathode are inclined to the plane of the paper, Figure 9, and the active portions of the beams reaching the anode are mainly under the full controlling influence of those portions of the rods near the cathode which provide a high amplification and transconductance. As the beams are rotated towards the narrow portions of the windows, nearer the perpendicular to the paper,

Figure 9, only those portions of the beams under the influence of the widely spaced and low amplification portions of the rods are admitted through the windows to the anode and the percent of modulation of the beam by the grid is reduced.

Alternatively, in an increased range of transconductance may be obtained by the variable mu grid of **25**, Figure 10, in which a variable pitch grid is placed between the cathode and a V-shaped slotted window **26** in the masking electrode. With the beam rotated so that electrons are admitted through the upper and lower ends of the slot the electrons pass through the closely spaced turns of the control grid, giving the tube a characteristic of high transconductance. As the beam is rotated to admit electrons through the center of the slot, the electrons reaching the anode are under the controlling action only of the widely spaced grid wires. In Figures 9 and 10 the transconductance of the tube increases or decreases rapidly and in approximately direct proportion to the increase or decrease of anode current.

Should it be desired that the anode current remain constant as the transconductance and percent of signal in the output circuit is varied, one beam may be modulated by the signal while the other beam remains unmodulated by the signal but is varied in amplitude inversely with the first beam. The two masking electrodes **26** and **27** shown in Figure 11 have windows with tapered sides pointing in opposite directions so that rotation of the magnet may increase the current through one window as current to the anode through the other window is decreased. The two masking electrodes may conveniently be placed end-to-end and coaxial about the cathode with the anode **4** surrounding the two masking electrodes. A control grid **28** upon which signal voltages may be applied is mounted in concentric relation with the cathode and inside the upper masking electrode. Rotation of the magnet increases the modulated space current through the window of the upper masking electrode and is accompanied by a corresponding decrease in direct current through the window of the other masking electrode so that the direct current component of the anode current may remain substantially constant while the signal component may be varied at will. To adjust the direct current components through the two masking electrodes to a substantially equal value, a grid **29** may be placed inside the lower masking electrode and connected to an adjustable biasing source to adjust the two currents to equal values.

An amplification control device constructed according to my invention comprising a tubular anode coaxial with and surrounding the cathode with a tubular masking electrode is smooth in operation, mechanically simple, free of mechanical difficulties of the usual volume control resistors and will withstand long and hard use.

I claim:

1. A cathode, an anode, means for producing a magnetic field with lines of force parallel to a plane through the cathode and the electron collecting surface of the anode comprising a magnet with poles in said plane, said cathode and anode being between said poles, a sheet-like electrode transverse to said plane and between the cathode and anode, said electrode having a window, the magnet being rotatable to rotate the beam of electrons formed by said field into or out of registry with said window.

2. A cathode, an anode, means for producing a magnetic field with lines of force parallel to a plane through the cathode and the electron collecting surface of the anode comprising a magnet with poles in said plane, said cathode and anode being between said poles, a sheet-like electrode transverse to said plane and between the cathode and anode, said electrode having a window, the magnet being rotatable with respect to the anode and cathode to rotate the beam of electrons formed by said field into or out of registry with said window, and means for impressing a signal on said beam.

3. A volume control device comprising a cathode, a grid surrounding said cathode, a masking electrode surrounding said grid, said masking electrode comprising a metal cylinder and having a window, an anode surrounding said masking electrode, and a movable magnet with poles on opposite sides of said anode.

4. A cathode, a control grid for modulating the electron current from the cathode, a magnet with poles on opposite sides of said cathode to form the electrons from said cathode into two oppositely directed beams, the magnet being rotatable to rotate said beams about the cathode as a pivot, a grid for modulating said beams, an apertured masking electrode in the path of said beams, and electron collecting electrodes in registry with the apertures.

5. In combination, an electron discharge device comprising a cathode, an anode with electron collecting surfaces on opposite sides of said cathode, a tubular masking electrode with windows in said electrode on said opposite sides of the cathode, a magnet with the poles of the magnet on opposite sides of the cathode, the magnet being rotatably mounted to rotate oppositely directed electron beams into and out of registry with said masking electrode windows.

6. In combination, a cathode, an anode and a masking electrode between the anode and cathode, a control grid electrode between one portion of said cathode and the anode, said masking electrode having spaced openings, one of the openings being opposite said one portion of the cathode, and a rotatable magnet with its poles on opposite sides of the cathode.

7. In combination, an electrode assembly including a cathode, a tubular anode coaxial with and surrounding said cathode, a tubular masking electrode comprising a cylinder of sheet metal coaxial with said cathode and between the cathode and anode, said cylinder having windows on opposite sides of the cathode, and a rotatable magnet with poles on opposite sides of the electrode assembly.

8. A cathode with an elongated electron emissive surface, a tubular anode coaxial and coextensive with said emissive surface, a masking electrode with a window, said window being irregular in shape and exposing along radial lines through the cathode different portions of the electron collecting surface of the anode to different portions of the cathode emissive surface, a control grid between the electron collecting and electron emissive surfaces, the grid being unsymmetrical with the cathode to give a different transconductance amplification factor for different parts of said emitting surface.

9. A cathode with an elongated electron emissive surface, a tubular anode coaxial with said emissive surface, a masking electrode with a window, said window being irregular in shape and exposing, along radial lines through the

cathode, different portions of the electron collecting surface to different portions of the cathode emissive surface, a control grid between the electron collecting and electron emissive surfaces, the grid being unsymmetrical with the cathode to give a different electrostatic influence upon different portions of the cathode, and a rotatable magnet with poles on opposite sides of the anode.

10. In combination an electrode assembly comprising an elongated cathode with two electron emitting surfaces spaced along the length of said cathode, an anode coaxial with and surrounding said two emitting surfaces, a grid and masking electrode around one emitting surface and a grid and a masking electrode around the other electron emitting surface, and a magnet with the poles of the magnet on opposite sides of the anode and parallel to the cathode.

11. In combination a cathode with two emitting surfaces, an anode with two spaced electron collecting surfaces in cooperative relation with said two emitting surfaces, a sheet electrode with a window between each of said emitting surfaces and its cooperating anode collecting surface, means for forming an electron beam from each emitting surface, said means being movable to rotate one beam into registry with one window and to rotate the other beam out of registry with the other window, and a signal control grid between one emitting surface and its window.

12. A cathode and anode, means for forming two separate beams of electrons from said cathode to the anode, means for changing the current in one beam to the anode and for simultaneously changing the current in the other beam to the anode, the sum of said current remaining substantially constant, a control grid in the path of one beam, and another grid in the path of the other beam.

13. In combination a cathode, an anode with an electron collecting surface opposite each of two electron emitting sections of said cathode, a sheet electrode with a window between each emitting section of the cathode and the anode, a signal control grid opposite one emitting section, a magnet with its poles disposed on opposite sides of said cathode, the poles of the magnet being movable to shift the beams formed by the magnet into and out of registry with the windows in said sheet electrode.

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