Jan. 25, 1949. P. W. CHARTON 2,460,062

GRID CONTROLLED ELECTRON TUBE

Filed Nov. 23, 1945 2 Sheets-Sheet 1

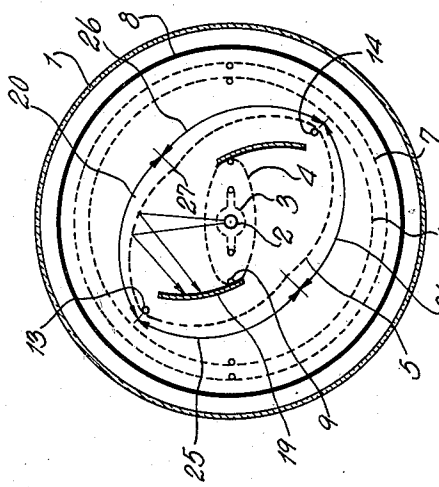


Fig. 3.

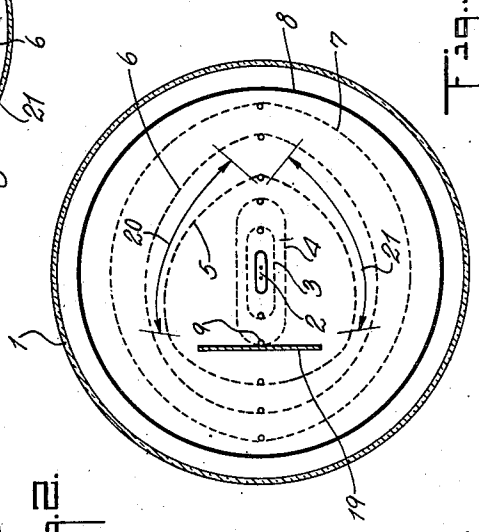


Fig. 5.

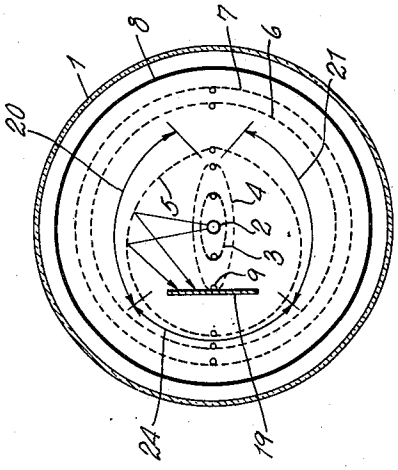


Fig. 2.

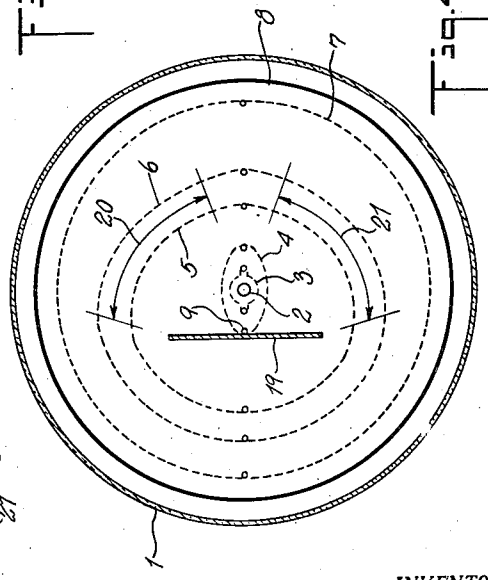


Fig. 4.

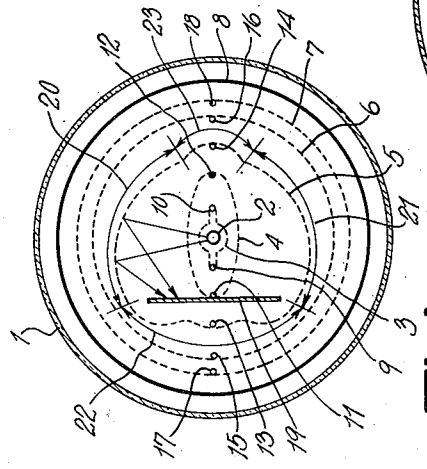


Fig. 1.

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Fig. 6.

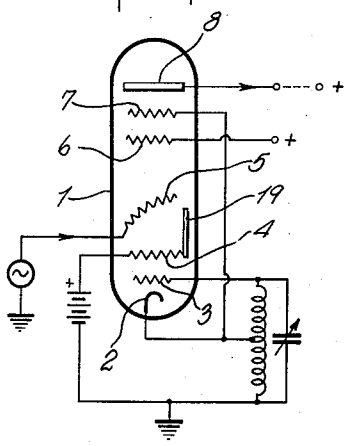


Fig. 7.

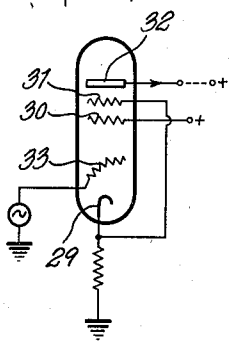


Fig. 8.

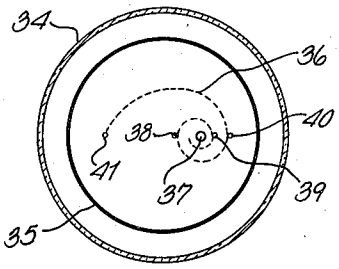


Fig. 9.

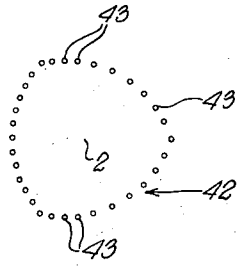
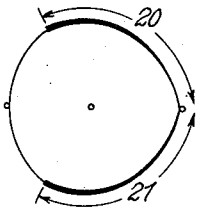


Fig. 11.



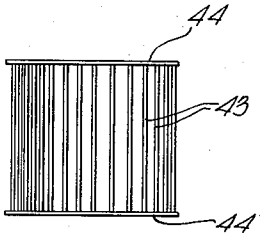


Fig. 10.

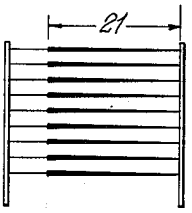


Fig. 12.

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UNITED STATES PATENT OFFICE

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GRID CONTROLLED ELECTRON TUBE

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Application November 23, 1945, Serial No. 630,320

18 Claims. (Cl. 250—27.5)

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This invention relates to grid-controlled electron tubes and more particularly it relates to the tubes of the multi-grid category.

A principal object of the invention is to provide a grid-controlled electron tube having a novel grid construction and arrangement for improving certain operating characteristics of the tube.

Another object is to provide a grid-controlled electron tube with improved plate current cutoff characteristics.

Another object is to provide a multi-grid arrangement having uniformity of potential along the effective control area of one of the control grids.

A feature of the invention relates to a multi-grid electron tube having a series of grids which are serially traversed by the emitted electrons, at least one of the grids having a special configuration and orientation with respect to the cathode so as to reduce the disturbing effects of electronic back-coupling between the grids.

In the great majority of grid-controlled electron tubes, because of the asymmetry of the various electrodes, the plate current cutoff is far from uniform and causes an objectionable trailing plate current-grid voltage characteristic. This is particularly true of those tubes with oval or elliptical grids, or flat grids with round plates, or flat grids with a round cathode, and the like.

Another feature relates to an electron tube having a novel grid construction such that the electrons from a suitably located cathode approach the grid wires at a substantially uniform angle. As a result, it is possible to design a tube so that it possesses substantially uniform plate current cutoff characteristic along the effective length of the grid wires.

A further feature relates to an electron tube having a cathode, an anode, and an auxiliary collector electrode, as well as a grid located between the cathode and anode and having its effective control area in the configuration of an arc of a logarithmic spiral whereby a substantial number of electrons which are reflected or repelled from the grid wires follow trajectories directed towards said auxiliary collector.

A further feature relates to the novel organization, arrangement and relative location of parts which cooperate to provide an improved frequency converter tube of the multi-grid type.

Other features and advantages not specifically enumerated will be apparent after a consideration of the following detailed descriptions and the appended claims.

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In the drawing which represents certain typical embodiments,

Fig. 1 is a diagrammatic plan view of a tube embodying the electrode arrangement according to the invention.

Figs. 2, 3, 4 and 5 are respective modifications of Fig. 1.

Fig. 6 is a composite schematic-wiring diagram showing one manner of using tubes of Figs. 1 to 5.

Fig. 7 is a composite schematic wiring diagram of a further modification of the invention.

Fig. 8 is a diagrammatic plan view of a still further modification.

Fig. 9 is a plan view of a modification of the grid structure according to the invention.

Fig. 10 is a front elevation of Fig. 9.

Fig. 11 represents a still further modification of the grid structure according to the invention.

Fig. 12 is a front elevation of Fig. 11.

While the inventive concept is capable of embodiment in a wide variety of tubes, it is particularly useful in so-called frequency converter or mixer tubes such as those of the electronically coupled oscillator type. It will be understood however, that the invention can be embodied in any tube construction where the problem of reflected or repelled electrons is present, which electrons if not suitably directed, will interfere with the desired operational characteristics of the tube. The invention is also useful in any tube where a substantially uniform plate current cutoff characteristic for a signal excited control grid is required. It will be understood therefore, in illustrating the invention in a frequency converter or mixer tube that this is done merely for purposes of explanation and not by way of limitation.

Referring to Fig. 1, there is shown in diagrammatic plan view a tube embodying certain features of the invention, and wherein the numeral 1 represents any suitable evacuated enclosing bulb or envelope within which the various electrodes are suitably mounted and held in proper spaced relation by any of the expedients well-known in the electron tube art. For simplicity of explanation, each of the grid electrodes is shown schematically in the drawing by a dotted line which, however, is intended to represent any well-known foraminous grid structure comprising for example, one or more parallel side rods or uprights for each grid, and between which extend the so-called spaced laterals or grid wires. The grids may be formed by helically winding the fine wire laterals around a pair of side rods to which the helical turns are suitably fastened,

although other methods of forming the grids may be employed.

The electrode arrangement includes an electron-emitting cathode 2, which may be of any well-known type preferably, although not necessarily, a linear cathode as represented by the usual indirectly heated cathode. This type of cathode comprises a tubular metal sleeve exteriorly coated with electron-emissive material and provided internally with an insulated heater. It will be understood however, that cathode 2 may be in the form of a substantially straight coated filament.

Successively surrounding the cathode 2 are grids 3, 4, 5, 6 and 7, and an anode or plate 8. The respective grids 3 to 7 have corresponding pairs of side rods 9—10, 11—12, 13—14, 15—16, 17—18; the anode or plate 8 is provided with suitable supports (not shown). All the electrodes may be mounted on a common header or stem which is sealed vacuum-tight into the envelope 1, it being understood that suitable lead-in wires connect to the respective electrodes in the well-known manner.

When the tube of Fig. 1 is to be used as a frequency converter or mixer tube, the electrodes 2, 3 and 4 are connected as shown for example in Fig. 6 to function as a local feed-back oscillator, wherein grid 3 acts as the oscillator control grid and the anode-grid 4 acts as the oscillator plate electrode. The grid 5 acts as the second control or modulating grid, while a grid 6 acts as a shield grid, and grid 7 acts as a suppressor grid. In the well-known manner, the electrons from the actual cathode 2 which emerge through the openings of grid 4 fall in a retarding field and may form a potential minimum or even sometimes a virtual cathode between grids 4 and 5. On the one hand some of these electrons will travel between the grid laterals of grid 5 and thence between the grid laterals of grids 6 and 7 to the plate 8, the number of electrons reaching plate 8 being controlled by the signal potentials applied to grid 5. On the other hand and provided grid 5 is not effectively negative, some of the electrons which emerge through grid 4 will strike the laterals of grid 5. Conversely when the potential of grid 5 swings towards the negative direction, it also causes a certain number of approaching electrons to change their trajectories. With the usual oval or circular construction of grid 5, a considerable number of these electrons which approach the grid laterals of grid 5 will be reflected or repelled back over practically the same trajectories as their trajectories of approach. Consequently, a percentage of these electrons may return through the openings of grid 4 and reach the control grid 3. This results in undesirable electronic back-coupling between the control grids 3 and 5. This phenomenon is accentuated if the frequency of the signals applied to grid 5 are so high that their periodicity is comparatively low in relation to the transit time of the electrons returning from grid 5. In order to reduce to a small percentage the number of these reflected or repelled electrons from arriving at grid 3, the grid 5 according to the invention is curved so that its effective control area that is traversed by the electron streams from cathode 2, is in the configuration of an arc of a logarithmic spiral. With such a configuration of grid 5, the electrons which are radially emitted from cathode 2 all approach the laterals of grid 5 at a substantially uniform angle which however is materially different from 90 degrees. Consequently, the majority of these electrons will be reflected from grid 5 over different trajectories from their approach trajectories. Therefore, by suitable spacing of grids 4 and 5, these reflected or repelled electrons can be directed towards a region which is outside the boundary of grid 4. Two typical reflected electron trajectories are shown in Fig. 1. In order to prevent these electrons eventually reaching the control grid 3, a baffle plate, collector plate or shield 19 can be mounted adjacent one end of grid 4 and connected to a suitable positive potential. If desired, the baffle 19 can be attached to the side rod 11 of grid 4.

In order that the grid 5 may surround the cathode 2 and be symmetrical over its effective area, the grid laterals may be wound to a somewhat cardioidal shape wherein the effective control portions 20 and 21 are each in the configuration substantially of a logarithmic spiral arc. In order that the side rods 13, 14, may be symmetrical on each side of the cathode, the left-hand portion 22 of the grid laterals can be formed to any suitable shape to meet, and to be fastened to the side rod 13. Likewise, the right-hand sections 23 can be formed so as to be attachable to the side rod 14.

Fig. 2 shows an arrangement similar to that of Fig. 1 but with a slightly different configuration of grid 5. The parts of Fig. 2 which are functionally the same as those of Fig. 1 bear the same designation numerals. In Fig. 2 the effective control portions 20 and 21 of grid 5 are each respectively in the configuration of arcs of logarithmic spirals, whereas the portion 24 may be substantially a circular arc.

The constructions shown in Figs. 1 and 2 provide an arrangement wherein all the grid side rods can be mounted in the same plane but the windings of grid 5 are unsymmetrical with relation to the surrounding circular electrodes 6, 7 and 8. Fig. 3 shows a construction wherein the grid windings of grid 5 are symmetrical both with respect to cathode 2 and to the remaining electrodes. In this embodiment, the grid sections 20 and 21 are curved to the shape of arcs of logarithmic spirals, while the sections 25 and 26 are of different shape. The sections 25 and 26 may also be of logarithmic spiral arc configuration having a curvature so that the points 27, 28, are symmetrical with respect to cathode 2. In general, the grid 5 (Fig. 3) is somewhat in the configuration of an irregular oval but with the effective control portions 20, 21, having the curvature substantially of a logarithmic spiral arc. In this embodiment the grid side rods 13 and 14 are located in a plane which is roughly 45 degrees with respect to the plane of the remaining grid side rods.

In addition to reducing the number of electrons which tend to be reflected from grid 5 to grid 3, the logarithmic spiral arc grid has the important added advantage of providing a more uniform plate-current cutoff characteristic for the control grid 5. In many cases it is highly desirable to make sure that the effective potential around the periphery of grid 5 be substantially uniform, at least at one value of the grid 5 potential such as, for example, the plate current cutoff potential. One manner of achieving this result is shown in Fig. 4, wherein the parts which are similar to those of Fig. 1 bear the same designation numeral. In this embodiment, the grid 5 is of substantially the same configuration as grid 5, so

that it is substantially equidistant from grid 5, at least along the corresponding effective control areas 20 and 21. If the elements 2, 3 and 4 are of sufficiently small peripheral size as compared with grid 5, the equi-distancing of grids 5 and 6 results in a close approximation of uniform effective potential on the cathode side of grid 5. In order to increase further this uniformity, one or more of the remaining electrodes 6, 7, 8, can be equally spaced from 5. In any event, by well-known theory, and by appropriate shaping and spacing of grid 6 with respect to grid 5, the effective potential of grid 6 can be made to insure a substantially uniform equivalent potential along the periphery of grid 5. Thus, as shown in Fig. 5, the grid 6 is unequally spaced from grid 5 and this spacing is designed so that the potentials of grid 6 and grid 5 result in the desired uniform equivalent potential along grid 5. In general, the grid 6 will approximate a logarithmic spiral arc in the effective regions 20, 21, although the origins of the spiral arc curvature of sections 20, 21, of grid 6, may be displaced laterally with respect to the origins of the spiral arc curvatures of the corresponding sections of grid 5.

This uniform equivalent potential characteristic of the logarithmic arc spiral grid is not limited to a frequency converter or mixer tube. For example, there is shown schematically in Fig. 7, a tube of the pentode type wherein the cathode 29, shield grid 30, suppressor grid 31 and anode 32 may be of conventional design. However, the control grid 33 has its effective control area in the form of one or more arcs of a logarithmic spiral. Fig. 7 is of course structurally schematic and the electrodes 30, 31, 32 and 33, may surround the cathode 29 as shown in any of the embodiments of Figs. 1 to 5.

While the greatest advantages are achieved when the control grid of Figs. 1 to 7 is in the actual form of a logarithmic spiral arc the curvature of which is defined by the equation $r=Ae^{\theta \tan \phi}$ where "r" is the distance from the center of the spiral, coincident with the center of the cathode, and ϕ is the angle of incidence of the approaching electrons on the grid laterals, that is, the angle between their trajectories and the normal to the lateral wires. It will be understood, of course, that this curvature need not be precisely in accordance with the above formula providing that the angle of incidence is substantially uniform for the greater part of the radially emitted electrons. It is within the purview of the present invention therefore to provide a grid which has a substantially cardioidal configuration or any similar configuration, so that the radial electron trajectories from the cathode intercept or approach the grid laterals at a substantially uniform angle.

Fig. 8 represents a further modification wherein the invention is embodied in a triode. The evacuated enclosing envelope 34 encloses an output anode 35, a control grid 36 having a configuration in plan view in the form of a logarithmic spiral of two 360° turns, and with an elongated emitting cathode 37 wound in cross-section and at the center or origin of the logarithmic spiral. The grid turns can be supported on side rods 38, 39, 40 and 41.

The invention is not limited to a grid structure wherein the grid is formed of a fine wire helically wound around one or more grid side rods. Thus as shown in Fig. 9, the grid 42 which may be used in place of the grid 5 of Figs. 1 to 5, may consist of a series of vertically parallel grid wires 43 which are strung or supported between two end rings 44, 45, forming in effect a squirrel cage grid. An additional advantage of this type of grid is that the grid wires 43 can be arranged with different spacings, and these different spacings may be designed to provide the desired equivalent potential around the grid. This construction will therefore minimize the required adjustment in spacing between the grid 5 and the next succeeding grid 6. As shown in Fig. 9, the wires 43 which are furthest removed from the cathode 2 are closer spaced than are the wires which are closer to the cathode. In other words, the space between the wires 43 decreases as the grid periphery recedes from the cathode 2. It will be clear that instead of using wires of different spacing to achieve the equivalent uniform potential along the grid, the wires may be of different thicknesses with their thicknesses respectively increasing as their location recedes from the cathode 2.

This same principle may be applied to the helically wound form of grid such as the grid 5 of Figs. 1 to 5 by making the grid laterals of gradually increasing thickness as they recede away from the cathode. For example, the grid laterals may be flattened out as indicated diagrammatically in Fig. 12 to provide a gradually decreasing interwire space with the minimum interwire spacing corresponding to the maximum remoteness of the grid laterals from the cathode 2. This manner of correcting or achieving the uniformity of potential along the grid can be applied not only to the grid 5 but also to the grid 6 (Figs. 1 to 5).

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention. Thus, while a frequency converter tube is shown of the kind wherein the modulator section is a tetrode, i. e., with three grids between the oscillator section and the output anode, a greater or less number of grids may be employed between the oscillator section and output anode, such for example as are employed in "octode" or "hexode" frequency converter tubes.

What is claimed is:

1. An electron-discharge device, comprising an electron-emitting cathode, an anode, and a grid located in the path of electron emission from said cathode, said grid having a substantial part of its control periphery in the configuration of a logarithmic curve.

2. An electron-discharge device, comprising an electron-emitting cathode, an anode, and a grid located between the cathode and anode, said grid having its effective control periphery curved substantially in the shape of a logarithmic spiral curve.

3. An electron discharge device, comprising, an electron source, an anode, a control grid between said source and anode, said grid having the major part of its control periphery curved and with one end of the curve closer to said source than the opposite end, the curvature of said part of the grid making a substantially uniform angle with radial electron trajectories from said source which angle is different from 90 degrees.

4. An electron-discharge device, comprising an electron source, an anode, a pair of grids between said source and anode, the grid nearer the anode having its effective control periphery in the configuration of a logarithmic spiral curve whereby the greater part of the electrons reflected there-

from are returned to a region outside the boundary of the grid which is nearer the cathode.

5. An electron-discharge device, comprising an electron-emitting cathode, an anode, a control grid between said cathode and anode, said control grid having its effective control periphery formed to a curvature which makes a substantially uniform angle with radial electron trajectories from said source which angle is different from 90°, and another grid in spaced relation to said control grid for rendering the effective potential substantially uniform along said control grid periphery.

6. An electron-discharge device, comprising an electron-emitting cathode, an anode, a control grid between said cathode and anode, said control grid having its effective control periphery formed to a curvature which makes a substantially constant angle with radial electron trajectories from said source which angle is different from 90°, and another grid having its effective periphery in substantially equally spaced relation to said control grid on the anode side thereof.

7. An electron-discharge device, comprising an electron-emitting cathode, an anode, a control grid between said cathode and anode, said control grid having its effective control periphery formed to a curvature which makes a substantially uniform angle with radial electron trajectories from said source which angle is different from 90°, and another grid having a configuration similar to said control grid and mounted in spaced relation thereto for rendering the effective potential uniform along said control periphery.

8. A grid electrode for electron-discharge tubes comprising a foraminous member having substantially its entire periphery which is effective on the electrons which pass therethrough in the configuration of a logarithmic spiral curve.

9. A grid electrode for electron-discharge tubes comprising a foraminous member having a peripheral contour which is substantially cardioidal.

10. A grid electrode according to claim 9 in which a substantial part of the cardioidal periphery is in the configuration of a logarithmic spiral curve.

11. A grid electrode for electron-discharge tubes comprising a foraminous member having a peripheral contour in the shape of an irregular ellipse with the effective sections through which the electrons pass in the shape of logarithmic spiral curves.

12. A frequency converter tube, comprising an oscillator section including an electron-emitting cathode, a control grid, and an anode-grid; a modulator section including a grid, and an output anode common to both said sections; said sections being mounted so that the electrons from said emitting cathode serially traverse both said sections to said anode; said grid of said modulator section having a substantial part of its effective peripheral contour of a curvature which intercepts radially directed electrons at a substantially uniform angle which angle is different from 90°.

13. A frequency converter tube according to claim 12 in which a substantial part of the effective peripheral contour of said modulator grid is in the configuration of a logarithmic spiral curve.

14. A frequency converter tube according to claim 12 in which said cathode is surrounded by the control grid of the oscillator section and by the modulator grid and output anode, said modulator grid having a substantially cardioidal periphery.

15. A frequency converter tube according to claim 12 in which said modulator grid surrounds said oscillator section and is in the form of an irregular ellipse with the effective control portions in the shape of a logarithmic spiral curve.

16. A frequency converter tube according to claim 12 in which said modulator grid surrounds the cathode and has its effective control periphery in the form of logarithmic spiral curves, and an additional similar grid surrounds said modulator grid to render substantially uniform the equivalent potential along said effective peripheral contour of the modulator grid.

17. A multi-grid electron tube, comprising an elongated cathode, a grid surrounding said cathode, an anode surrounding said cathode, said cathode being concentrically mounted with respect to said grid and anode, and another grid surrounding the first grid and comprising substantially two half sections each having its major portion in the configuration of a logarithmic spiral curve.

18. A frequency converter tube, comprising an oscillator section comprising a substantially linear cathode, a control grid, and an anode-grid; a modulator section comprising a second control grid and an anode which is common to both said sections, the grids of said oscillator section having side rods located in a common plane, said modulator grid being in the form of an irregular ellipse having the effective control peripheries thereof in the shape of logarithmic spiral curves, said modulator grid having a pair of side rods which are located on the major axis of said irregular ellipse and with the plane of said modulator grid side rods at an angle less than 90 degrees with respect to the plane of the oscillator grid side rods.

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