March 21, 1950 P. L. SPENCER 2,501,196

ELECTRON DISCHARGE DEVICE

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FIG. 1.

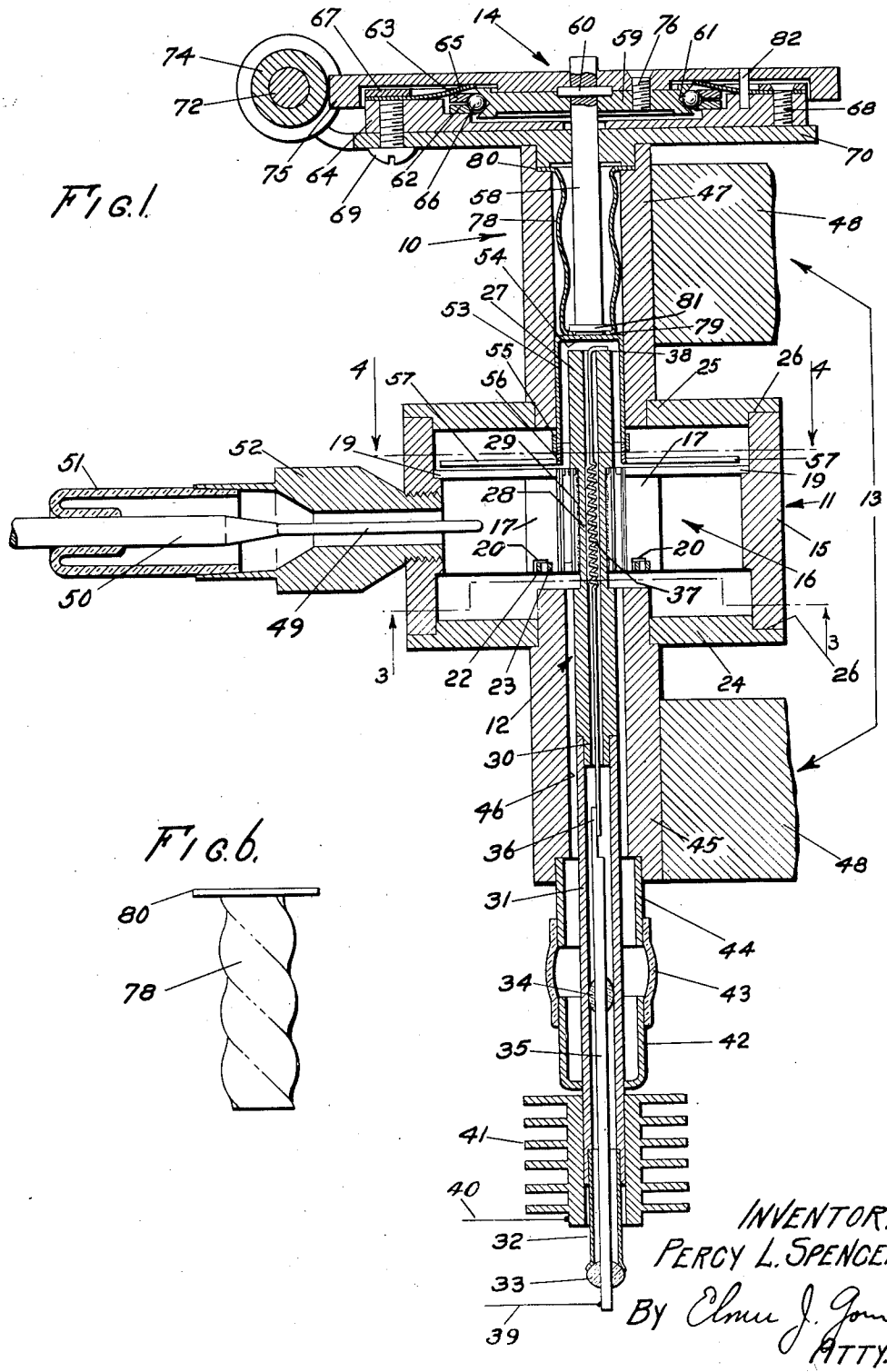


FIG. 6.

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FIG. 3.

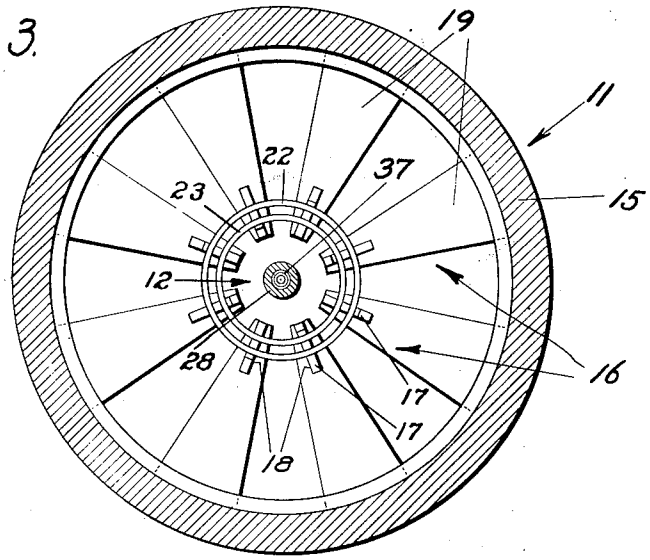
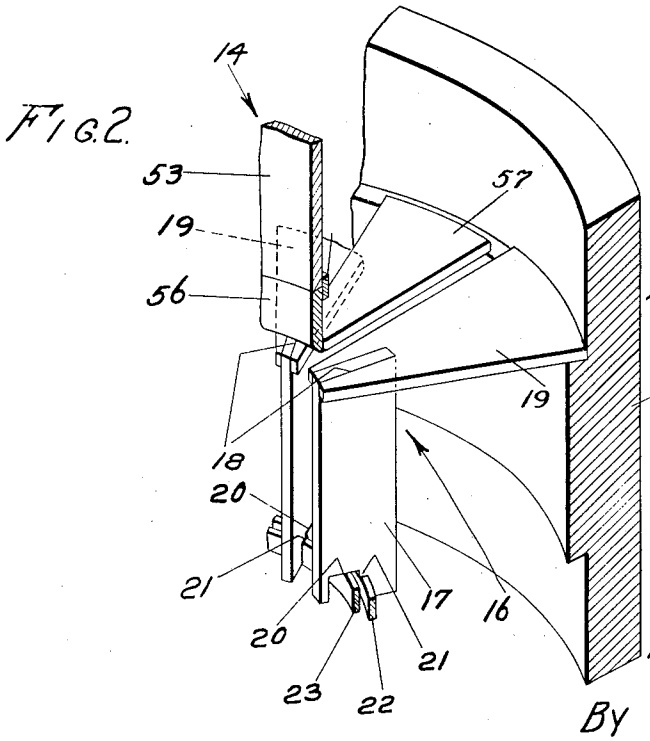


FIG. 2.



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FIG. 5.

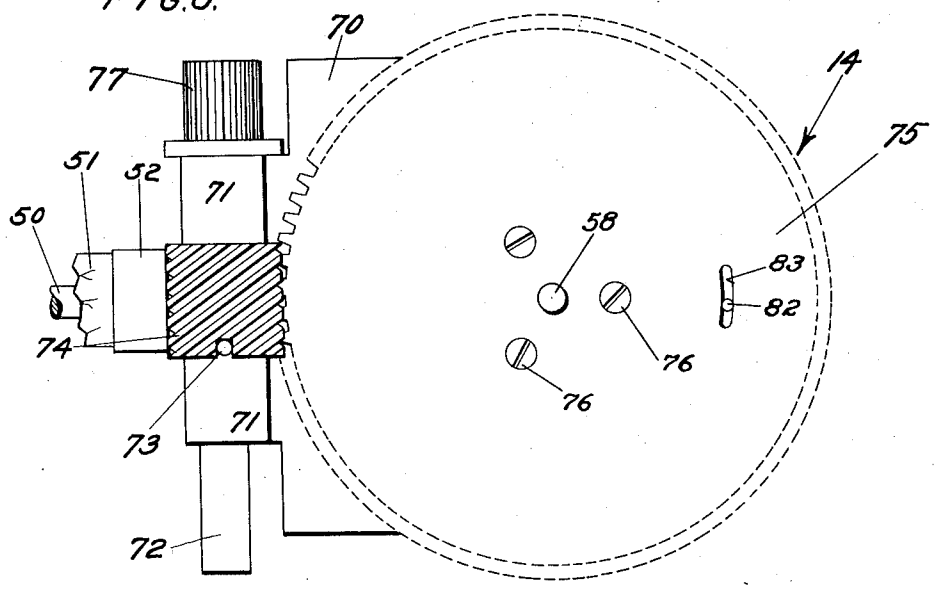
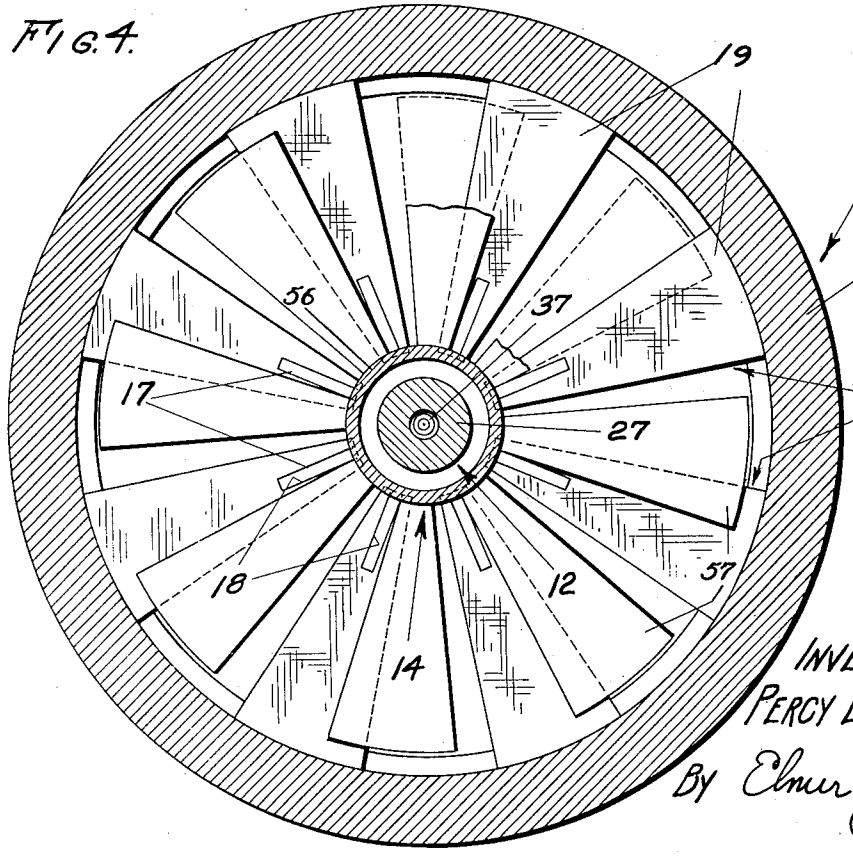


FIG. 4.



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UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE DEVICE

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Application March 20, 1945, Serial No. 583,802

9 Claims. (Cl. 250—27.5)

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My present invention relates to electron-discharge devices, and more particularly to tunable electron-discharge devices.

While not limited thereto, my present invention is especially suitable for tuning electron-discharge devices of the so-called magnetron type.

The main object of my present invention is to provide means for tuning an electron-discharge device through a much greater frequency range than has heretofore been possible, and, to this end, I so construct the device that both the capacitance and inductance thereof are simultaneously varied, each to a considerable degree, and in the same direction.

This, and other objects of my present invention, which will become more apparent as the detailed description thereof progresses, are attained, briefly, in the following manner:

As above stated, my present invention is particularly well adapted to the tuning of an electron-discharge device of the magnetron type. I prefer that said device include a cylindrical anode structure, made of highly conductive material, such as copper, and provided with a plurality of interiorly-extending, radially-disposed anode members, each adjacent pair of said anode members, together with that portion of said anode structure lying therebetween, constituting a resonant line, for example, a shorted quarter-wave line.

I prefer that each such anode member consist of a conducting vane supported, parallel to the axis of the anode structure, at the inner end of a conducting arm or sector-like member having a substantial surface area lying in a plane perpendicular to said anode structure axis, the arcuate, outer end of said arm being secured to said anode structure.

While not absolutely necessary, I have found it advisable, in order to suppress spurious oscillations in devices of the type to which my present invention relates, to provide the anode structure with at least one pair of conducting straps alternately contacting successive anode members, said straps presenting a capacitance therebetween which, together with the distributed capacitance and inductance built into the device as a function of the geometry thereof, and as a function of additional structure to be shortly described, enters into a determination of the natural resonant frequency of the device.

The additional structure to which reference has been made, and which is intended to enable the alteration of the distributed capacitance and inductance of the aforesaid resonant lines, whereby the device may be tuned, may take the form of one or more conducting sections or segments having surface areas substantially cooextensive with those of the above-described conducting

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arms, and being spaced therefrom, and bidirectionally movable with respect thereto, so that relative movement, between said conducting sectors and conducting segments in one direction, introduces a capacitance in parallel with the existing capacitance of each pair of adjacent anode members, and simultaneously introduces an inductance in series with the existing inductance of each such pair of adjacent anode members, relative movement between said elements in the opposite direction having opposite effects.

Inasmuch as the alteration of the capacitance and inductance of the device is simultaneous, and in the same direction, I am able to achieve considerable frequency deviation from the natural resonant frequency of the device.

In the accompanying specification I shall describe, and in the annexed drawings show, an illustrative embodiment of the electron-discharge device of my present invention. It is, however, to be clearly understood that I do not wish to be limited to the details herein shown and described for purposes of illustration only, inasmuch as changes therein may be made without the exercise of invention and within the true spirit and scope of the claims hereto appended.

In said drawings,

Fig. 1 is a longitudinal sectional view of a tunable electron-discharge device assembled in accordance with the principles of my present invention;

Fig. 2 is an enlarged, fragmentary, perspective view more clearly showing the physical relationships between the anode structure, anode members, and tuning members constituting components of the device shown in Fig. 1;

Fig. 3 is a transverse sectional view taken along line 3—3 of Fig. 1;

Fig. 4 is an enlarged, transverse section view taken along line 4—4 of Fig. 1;

Fig. 5 is a top plan view of the device shown in Fig. 1; and

Fig. 6 is a side elevation view of one of the components of the device shown in Fig. 1.

Referring now more in detail to the aforesaid illustrative embodiment of my present invention, and with particular reference to Figs. 1 to 4 inclusive of the drawings, the numeral 10 generally designates an electron-discharge device of the so-called magnetron type. Said device comprises an anode structure 11, a cathode structure 12, magnetic means 13 for establishing a magnetic field in a direction perpendicular to the path of the electron-flow between said cathode and anode structures, and tuning means 14.

In the device shown, the anode structure 11 includes a cylindrical body 15, made of highly conductive material, such as copper, said body

being provided with a multiplicity, here shown in the interest of simplicity, as eight, but preferably with sixteen, of radially-disposed, interiorly-extending anode members 16.

Each anode member 16 may comprise, for example, a rectangular conducting vane 17 disposed in a plane parallel to the axis of the cylindrical body 15 and supported, at its upper end, in a slot 18 formed in the inner end of a conducting arm 19, the outer end of which is secured to said cylindrical body 15, as may best be seen in Fig. 2 of the drawings. The plane of the conducting arm 19 is, preferably, perpendicular to said cylindrical body axis, and the surface area thereof should be substantial, for this purpose, taking the form, by way of illustration, of a sector of a circle.

The arrangement is such that each adjacent pair of anode members 16, which includes, primarily, two vanes 17, two arms 19, and that portion of the cylindrical body 15 lying therebetween, may be considered a resonant line.

Because of the numerous paths which the oscillating energy can follow in a structure of the nature just described, spurious oscillations appear, which reduce the efficiency of the device, and in order to eliminate such spurious oscillations, I prefer to proceed as follows:

The vane 17 of each anode member may be provided, in its lower edge, with a slot 20, the opposite side edges of the slots in adjacent vanes being provided with shoulders 21 upon which there is adapted to be seated concentrically disposed, circular conducting straps 22 and 23, said straps alternately contacting successive vanes and thereby assuring that alternate vanes will always be at the same instantaneous potential.

The anode structure 11 is closed at its ends, for example, by end plates 24 and 25, with the junctions between the cylindrical body 15 of said structure, and said plates 24 and 25, hermetically sealed, as at 26.

The cathode structure 12, which is coaxial with the anode structure 11, includes a cathode sleeve 27, conventionally made of nickel, or the like, provided with a reduced portion 28 whose length, preferably, is coextensive with the height of the vanes 17, said reduced portion being provided with a highly electron-emissive coating 29, for example, of the well known alkaline-earth metal oxide type.

In order properly to support the cathode sleeve 27 with respect to the anode members 16, said sleeve may be reduced, as at 30, to fit into an elongated, electrically-conductive tubular member 31 having, at its outer end, a ferrule 32 closed by a glass seal 33. Said seal, together with one or more glass beads 34 disposed within the tubular member 31, supports a lead-in conductor 35 which passes through said member 31 and has its upper end connected, as at 36, to one terminal of a cathode heating filament 37. The other terminal of said filament may be connected, as at 38, to the cathode sleeve 27.

In order to convey current to the filament 37, the lead-in conductor 35 is connected by a conductor 39 to one terminal of a suitable source of E. M. F. (not shown), the other terminal of said source of E. M. F. being connected by a conductor 40 to a heat dissipating member 41 fixed upon the lower end of the tubular member 31.

In order properly to support the entire cathode structure 12, and insulate the same from the anode structure 11, the tubular member 31 may have fixed thereto a cup-like bushing 42 sealed into one end of a glass tube 43, the other end of said glass tube having sealed therein a tubular bushing 44, in turn, secured in the lower end of a tubular pole piece 45, constituting one of the components of the magnetic means 13.

Said pole piece 45 may be hermetically sealed into the end plate 24, and be provided with a central bore 46 whereby the cathode structure 12 may enter the device.

Another tubular pole piece 47 may be hermetically sealed into the end plate 25, said pole piece and the pole piece 45 being fixed, for example, to the opposite ends of a horseshoe magnet 48, only partially shown, whereby an appropriate magnetic field may be established, as previously indicated, in a direction perpendicular to the path of the electron-flow between the cathode structure 12 and anode structure 11.

Now, by suitably heating the cathode and applying a proper potential difference between said cathode and the anode, the device can be made to generate electrical oscillations of a wave length determined, primarily, by the distributed capacitance and inductance built into said device as a function of the geometry thereof, and more especially, of the dimensions of the above referred to resonant lines formed in the anode structure.

In order to extract power from the device, I may, for example, introduce a loop 49 into the space intermediate any two anode members 16, said loop coupling with the magnetic component of the above-mentioned electrical oscillations in the resonant line defined by the selected anode members. Said loop may, in turn, be connected to a conductor 50 supported in a glass seal 51 fused into an outlet pipe 52, said pipe being threaded and hermetically sealed into the cylindrical body 15 of the anode structure 11.

In the device as thus far described, there is no external control over the frequency of the generated oscillations, and in order to provide such control, I proceed as follows:

Rotatably mounted in the bore of the tubular pole piece 47 is a cylindrical member 53 closed at one end 54 and secured at its other end, by means of an overlapping ring 55, to the hub 56 of a conducting member consisting of a plurality of electrically connected, conducting segments 57, there being, preferably, the same number of said segments as there are anode members 16. The conducting segments 57 are disposed in a plane parallel to that of the conducting sectors 19, and are adapted to cooperate therewith, in a manner now to be described, to alter the distributed capacitance and inductance of the resonant lines formed by the anode members 16.

Assume, for the moment, that the conducting segments 57 are located intermediate adjacent anode members 16, as shown in Fig. 2 of the drawings. Further assume that the left-hand anode member 16 in said figure is instantaneously positive so that, said member and the adjacent similar members forming resonant lines, the right-hand anode member will be instantaneously negative. This means current is flowing from the inner end of the left-hand conducting arm 19 toward the cylindrical body 15 of the anode structure 11, through said body 15 to the outer end of the right-hand conducting arm 19, and from there, through said right-hand conducting arm, toward the inner end thereof. It follows that a clockwise magnetic field exists about the left-hand conducting arm 19, and a counter-clockwise

magnetic field exists about the right-hand conducting arm 19. The same fields will exist, respectively, around alternate anode members 16.

Now, with the conducting segments 57 in the assumed position shown in Fig. 2 of the drawings, the magnetic fields above described will cut said segments and induce voltages therein, such that currents will flow in the segments, in the plane thereof. These currents will, by transformer action, induce voltages in the adjacent anode members in opposition to the self-induced voltages therein, and thus, reduce the effective inductance of said adjacent anode members to a minimum.

At the same time, the space between the conducting segments 57 and the conducting sectors 19 will be maximum, so that the capacitance therebetween will be minimum.

With both the inductance and the capacitance at their minimum values, the resonant lines formed by the anode members 16 and, therefore, the entire device, will oscillate at its maximum frequency.

Now, by moving the conducting segments 57 into register with the conducting sectors 19, the spacing therebetween is reduced to a minimum and the capacitance, therefore, becomes maximum. At the same time, it will be noted that the magnetic fields above referred to are now so cutting the conducting segments 57 that although some voltage may be induced therein, no current flows, and hence, the inductance of the conducting sectors 19 is not effectively shorted out, and remains substantially at maximum.

Under these conditions, the device oscillates at its minimum frequency. Intermediate conditions result in oscillations at intermediate frequencies.

I shall now describe one type of means which may be utilized to bring about the relative movement between the conducting segments 57 and the conducting sectors 19.

For this purpose, reference is best had to Figs. 1, 5 and 6 of the drawings. As there shown, the closed end 54 of the member 53 is secured to a shaft 58 the upper end of which is fastened to a disk 59 by means of a key 60. Said disk 59 is provided in its periphery with a V-cut 61, constituting a ball-bearing race. Surrounding said race is another race comprised of two cooperating bevelled rings 62 and 63, the ring 62 being carried by a disk 64, and the ring 63 being pressed into cooperation with said ring 62 by an annular spring 65. The races are receptive therebetween of bearing balls 66, and the spring 65 is affixed to the disk 64 by a flat retaining ring 67 and bolts 68.

The disk 64 is maintained against rotation by being bolted, as at 69, to a plate 70 fixed, at its center, in a recess formed in the upper end of the pole piece 47, said plate 70 being provided with bearings 71 in which is journalled a shaft 72. Mounted upon the shaft 72, as by means of a pin 73, is a worm gear 74 engageable with a worm wheel 75 secured to the shaft 58 by means of the key 60, and by means of bolts 76. The shaft 72 is provided, at one end, with a pinion 77, whereby the same may be manually or otherwise rotated to rotate, in turn, the conducting segments 57.

In order to maintain the device air-tight, I provide a flexible, metallic member 78 having an inwardly-directed flange 79 formed at its lower end and an outwardly-directed flange 80 formed at its upper end. The inwardly-directed flange 79 is hermetically sealed to the cylindrical member 53 intermediate the closed end 54 of said

member and a washer 81 carried by the shaft 58, and the outwardly-directed flange 80 is hermetically sealed intermediate the plate 70 and the seat of the recess formed in the pole piece 47 to receive said plate 70.

In order to limit the movement of the conducting segments 57 between positions corresponding to the minimum and maximum frequencies at which the device is intended to oscillate, I provide means for limiting the rotation of the worm wheel 75. Such means may comprise a pin 82 carried in the fixed disk 64 and extending into an elongated slot 83 formed in said worm wheel 75. Obviously, the movement of the worm wheel 75 is limited to the length of the slot 83.

This completes the description of the aforesaid illustrative embodiment of my present invention. It will be noted from all of the foregoing that I have provided relatively simple means for tuning an electron-discharge device, particularly, a magnetron, through an appreciable frequency range, the extensive deviation being made possible by reason of the tuning means being so constructed that both the distributed capacitance and inductance of the device are simultaneously alterable in the same direction. It will further be noted that the frequency deviation obtained through the use of my tuning means is continuous within the limits of the frequency band covered thereby, and is substantially linear.

Other objects and advantages of my present invention will readily occur to those skilled in the art to which the same relates.

What is claimed is:

1. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a pair of anode members which, together with that portion of said anode structure lying therebetween, constitute a resonant line; each of said anode members including a conducting vane, and a conducting arm secured to said vane; a conducting member, adjustably supported in spaced relationship to said anode members, whereby it affects the distributed capacitance and inductance of said resonant line; and means, connected to said conducting member, for changing the spacing thereof with respect to said anode members, whereby said distributed capacitance and inductance become altered simultaneously in the same direction.

2. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a plurality of interiorly-extending, radially-disposed anode members each adjacent pair of which, together with that portion of said anode structure lying therebetween, constitute a resonant line; each of said anode members including a conducting vane, and a conducting arm secured to said vane; a plurality of radially-disposed conducting members, adjustably supported in spaced relationship to said anode members, whereby they affect the distributed capacitance and inductance of said resonant lines; and means, connected to said conducting members, for changing the spacing thereof with respect to said anode members, whereby said distributed capacitance and inductance become altered simultaneously in the same direction.

3. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a pair of anode members which, together with that portion of said anode structure lying therebetween, constitute

a resonant line; each of said anode members including a conducting vane, and a radially disposed conducting arm extending in a plane perpendicular to the axis of said anode structure and having its inner end secured to said vane; a conducting member, adjustably supported in spaced relationship to said anode members, whereby it affects the distributed capacitance and inductance of said resonant line; and means, connected to said conducting member, for changing the spacing thereof with respect to said anode members, whereby said distributed capacitance and inductance become altered simultaneously in the same direction.

4. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a pair of anode members which, together with that portion of said anode structure lying therebetween, constitute a resonant line; each of said anode members including a conducting vane, and a radially disposed conducting arm extending in a plane perpendicular to the axis of said anode structure and having its inner end secured to said vane; a conducting member, disposed in a plane parallel to that of said conducting arm and adjustably supported in spaced relationship thereto, whereby it affects the distributed capacitance and inductance of said resonant line; and means, connected to said conducting member, for changing the spacing thereof with respect to said conducting arms, whereby said distributed capacitance and inductance become altered simultaneously in the same direction.

5. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a pair of anode members which, together with that portion of said anode structure lying therebetween, constitute a resonant line; each of said anode members including a conducting vane, and a radially disposed conducting arm extending in a plane perpendicular to the axis of said anode structure and having its inner end secured to said vane; a conducting member, disposed in a plane parallel to that of said conducting arm and adjustably supported in spaced relationship thereto, whereby it affects the distributed capacitance and inductance of said resonant line; and means, connected to said conducting member, for rotating the same in a plane parallel to that of said conducting arms, to change the spacing thereof with respect to said conducting arms, simultaneously to alter in the same direction said distributed capacitance and inductance.

6. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a plurality of interiorly-extending, radially-disposed anode members each adjacent pair of which, together with that portion of said anode structure lying therebetween, constitute a resonant line; each of said anode members including a conducting vane, and a radially disposed conducting arm extending in a plane perpendicular to the axis of said anode structure and having its inner end secured to said vane; a plurality of radially-disposed conducting members, lying in a plane parallel to that of said conducting arms and adjustably supported in spaced relationship thereto, whereby they affect the distributed capacitance and inductance of said resonant lines; and means, connected to said conducting members, for rotating the same in their own plane, to change the spacing thereof

with respect to said conducting arms, simultaneously to alter in the same direction said distributed capacitance and inductance.

7. A tunable electron-discharge device comprising: a cathode; an anode structure, spaced from said cathode, and including a plurality of interiorly-extending, radially-disposed anode members each adjacent pair of which, together with that portion of said anode structure lying therebetween, constitute a resonant line; each of said anode members including a conducting vane, and a radially disposed conducting arm extending in a plane perpendicular to the axis of said anode structure and having its inner end secured to said vane; a pair of concentric conducting straps alternately contacting the conducting vanes of successive anode members; a plurality of radially-disposed conducting members, lying in a plane parallel to that of said conducting arms and adjustably supported in spaced relationship thereto, whereby they affect the distributed capacitance and inductance of said resonant lines; and means, connected to said conducting members, for rotating the same in their own plane, to change the spacing thereof with respect to said conducting arms, simultaneously to alter in the same direction said distributed capacitance and inductance.

8. A tunable electron-discharge device comprising: a cathode; an anode structure spaced from said cathode, said anode structure including a body member; a pair of arms extending from said body member in a plane perpendicular to the axis thereof; a pair of vanes extending, respectively, from said arms in planes perpendicular to the plane of said arms; said vanes and arms, together with that portion of said body member lying therebetween, constituting a resonant line; and a conductive member adjustably supported in spaced relationship to said arms and movable with respect thereto to alter the distributed inductance and capacitance of said resonant line.

9. A tunable electron-discharge device comprising: a cathode; an anode structure spaced from said cathode; said anode structure including a cylindrical body member; a pair of radially disposed arms extending inwardly from said body member in a single plane perpendicular to the axis thereof; a vane supported from the inner end of each of said arms in spaced relationship to said body member in a plane including the axis thereof; each pair of adjacent vanes and arms, together with that portion of said body member lying therebetween, constituting a resonant line; and a plurality of conductive segments adjustably supported in spaced relationship to said arms and movable with respect thereto in a plane parallel to the plane thereof to alter the distributed inductance and capacitance of said resonant line.

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