June 17, 1952 H. W. JAMIESON ET AL 2,601,025

HIGH-FREQUENCY ELECTRIC DISCHARGE DEVICE

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Fig. 1.

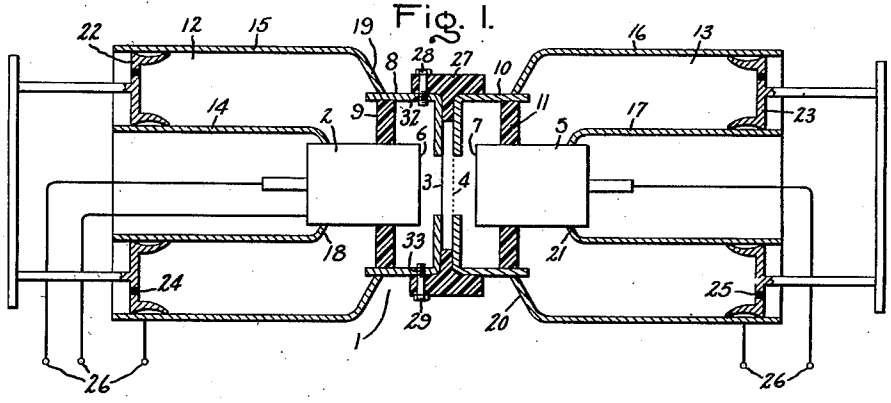


Fig. 2.

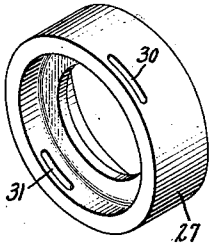


Fig. 3.

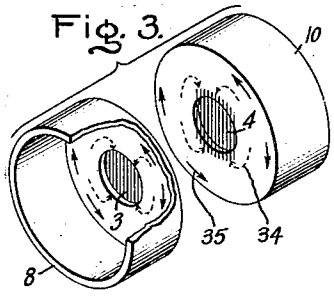


Fig. 4.

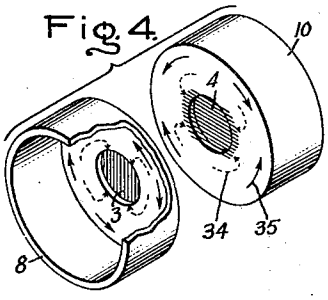
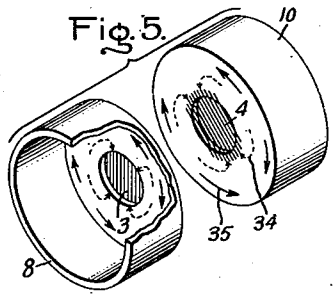


Fig. 5.



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HIGH-FREQUENCY ELECTRIC DISCHARGE DEVICE

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6 Claims. (Cl. 315—6)

1

Our invention relates to high frequency discharge devices and, more particularly, to multi-grid high frequency electric discharge devices of the type employing cylindrical cavity resonators. The term "multi-grid" as herein employed, refers to electric discharge devices of the type having two, or more, electron discharge controlling electrodes; while the term "cylindrical cavity resonators" refers to any resonators having radial symmetry about a central axis.

On of the most vexatious problems which is encountered in the construction of multi-grid cavity resonator type high frequency electric discharge devices, is that of controlling the amount of internal coupling of electromagnetic energy between the various cavity resonators comprising the high frequency circuit. Due to the requisite close proximity of the grids, the high frequency electromagnetic waves produced in cavity resonators associated with each grid interact within the grid region with the high frequency waves produced in cavity resonators associated with other grids. In some applications, such as in amplifier circuits, it is usually desired to minimize this inter-resonator coupling as much as possible, while in other applications, such as in oscillator circuits, it is often advantageous to introduce a small amount of such inter-resonator coupling to supply regenerative feed-back energy sufficient to sustain self-oscillations in the circuit. It has, heretofore, commonly been necessary to resort to special decoupling or external feed-back circuits in order to control the degree of this inter-resonator coupling.

Accordingly, an important feature of our invention is to provide a multi-grid cavity resonator type high frequency electric discharge device in which the degree of internal inter-resonator coupling can be predetermined and controlled to a considerable extent.

Another important object of our invention, is to provide an inter-electrode arrangement for high frequency multi-grid electric discharge devices which minimizes the electric coupling between cylindrical cavity resonators associated therewith.

An additional object of our invention, is to provide an inter-electrode structure for high frequency multi-grid electric discharge devices of the type employing cylindrical cavity resonators whereby the inter-resonator coupling may be easily adjusted during manufacture to an optimum value.

A specific object of our invention, is to provide a high frequency, cavity resonator type, electric discharge device suitable for use as a high frequency amplifier wherein the inter-resonator coupling is reduced to a small value.

2

A further specific object of our invention, is to provide a cavity resonator type high frequency electric discharge device suitable for use as a high frequency oscillator wherein a proper magnitude of feed-back energy can be internally supplied by inter-resonator coupling.

In general, our invention is based upon the discovery that if parallel wire grids are employed in multi-grid high frequency discharge devices having cylindrical cavity resonators, the relative rotational orientation of these grids considerably affects the degree and direction of inter-resonator coupling in the device. We have found that minimum inter-resonator coupling is achieved when the parallel wire grids are oriented with a relative angular displacement in the neighborhood of 45°, while maximum inter-resonator coupling is achieved when the relative angular displacement of the grids is either in the neighborhood of 0° or 90°. However, the direction of reactive coupling when the grids are collimately aligned, as in 0° relative angular displacement, is opposite to the direction of reactive coupling that exists when the grids are orthogonal, as when the relative angular displacement is 90°. In other words, when the grids are collimately aligned, the inter-resonator coupling causes, in effect, a reflection of a capacitive reactance component into one of the resonators; but when the grids are orthogonally aligned, an inductive reactance component is reflected into the same resonator.

Where the device is used as an amplifier, optimum amplification and stability commonly occurs when the inter-resonator coupling is at a minimum, i. e. when the relative orientation of these grids is in the neighborhood of 45°. However, when the device is used as an oscillator, optimum results are commonly achieved when the relative angular displacement of these grids is in the neighborhood of 0° or 90° depending upon the desired direction of reactive coupling of the feed-back energy.

The novel features which we believe to be characteristic of our invention, are set forth with particularity in the appended claims. The invention itself, however, together with further objects and advantages thereof, can best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is a side view, partly in section, of an electric discharge device having cylindrical cavity resonators and embodying our

invention, Fig. 2 is a perspective view of an adjustable spacing member which is preferably employed in our invention to enable an adjustment of the relative rotational angular displacement of the grids of the electric discharge device, during manufacture, and Figs. 3, 4 and 5 are exploded perspective views of the grids of the electric discharge device of Fig. 1 which illustrate the relationship of local electrical currents for various degrees of relative angular displacements of the grids.

Referring to Fig. 1, we have shown our invention in one form as comprising an electric discharge device having an electron discharge controlling member 1 which, in turn, includes a cylindrical cathode 2, a first or control grid 3, a second or screen grid 4, and a cylindrical anode 5 mounted in consecutive spaced alignment. An electron emitting surface 6 of the cathode 2 and an electron receiving surface 7 of anode 5, as well as the grids 3 and 4 are all aligned in mutually parallel planes. Both the control grid 3 and the screen grid 4 are constructed of parallel wire conductors as clearly illustrated in Figs. 3, 4 and 5. The control grid 3 is extended across a central preferably circular aperture in an electrically conducting cup-shaped grid supporting member 8 which also functions as an external contact for the grid 3. The proper positioning of the control grid 3 with respect to the electron emitting surface 6 of the cathode 2, as well as a partial hermetic enclosure of the internal electrodes, is provided by virtue of an annular insulating collar 9 sealed between the inner cylindrical surface of the grid supporting member 8 and the outer cylindrical body of the cathode 2. A similar cup-shaped electrically conducting supporting member 10 and an annular insulating collar 11, hermetically sealed between the anode 5 and the internal surface of the cup-shaped member 10, serve to support and provide external connection to the screen grid 4.

A pair of cylindrical cavity resonators 12 and 13 are arranged in a conventional manner to form the control grid-cathode and the screen grid-anode cavity resonators respectively. Concentric conducting cylinders 14 and 15 bound the grid cathode cavity resonator 12 while similar conducting cylinders 16 and 17 bound the grid-anode cavity resonator 13. Good electrical contact is made between the cathode 2 and the inner concentric conductor 14 by virtue of a plurality of contact fingers 18 extending from the conductor 14 and wiping against the cylindrical surface of the cathode 2. Similar resilient contact finger terminations 19, 20 and 21 of cylindrical conductors 15, 16 and 17 make contact respectively with the outer surface of the control grid supporting member 8, the screen grid supporting member 10 and the anode 5. Proper tuning of the resonators 12 and 13 may be accomplished by such means as annular tuning plungers 22 and 23 respectively. Means, such as insulating washers 24 and 25 embedded within tuning plungers 22 and 23 respectively, are also provided to isolate electrically the concentric conductors of each resonator in order that proper unidirectional operating potentials of different magnitude may be applied to the electrodes of the device through suitable conductors 26.

It will be appreciated that although we have shown the resonators 12 and 13 as making separable contact to the electron discharge controlling portion of the discharge device 1, the resonators 12 and 13 may alternatively be constructed as an integral part of the discharge controlling portion of the device itself. Moreover, although we have shown a preferred axially extending "fold back" type of cylindrical resonator system, a radially extending cylindrical cavity resonator system may be provided instead. It is only necessary that the electromagnetic field be symmetric and uniformally disposed radially within the resonator system. A uniform symmetric radial field of this type is produced, for example, when a cylindrical resonator is operated with transverse magnetic waves of the first order, commonly referred to in the art as TM_{01} or E_0 mode of operation.

In order to enable an adjustment of the relative rotational orientation of the parallel grids 3 and 4 during manufacture as well as to provide proper spacing therebetween, we preferably provide an annular insulating spacing member or spacer 27, best seen in Fig. 2, having a T-shaped cross-section. The circumferential ridge formed by the inner surface of this insulating spacer 27 at one side of the T is constructed to conform to the outer peripheral corner surface of the screen grid supporting member 10. Similarly, the internal circumferential ridge of this spacer 27 formed on the other side of T is constructed to conform to the outer peripheral corner surface of the control grid supporting member 8. The insulating spacing member 27 is rigidly secured in an air-tight manner, by such means as hermetic sealing, to one of these grid supporting members, such as supporting member 10. The other grid supporting member, such as supporting member 8, may then be inserted as a slidable fit within the opposite internal ridge of the T-shaped spacer 27 and the rotational position of the grid supporting member 8 adjusted to effect the desired degree of angular displacement of grid 3 relative to grid 4. An external indication of the relative angular displacement of the internal grids may be provided by such means as set screws 27 and 28 inserted through suitable slotted apertures 30 and 31 respectively of the spacing member 27 and threaded into corresponding holes 32 and 33 in the supporting member 8. The slotted apertures 30 and 31 preferably extend through 90 angular degrees and are arranged with respect to the threaded holes 32 and 33 so that the parallel wires of the grids 3 and 4 will be collimately aligned when the grid supporting member 8 is adjusted to one furthermost rotational position. Consequently, when the grid supporting member 8 is adjusted to its opposite rotational limit, the parallel wire grids 3 and 4 will be oriented in mutually perpendicular directions with a relative 90 degree angular displacement in the direction of the parallel wires. Adjustment of the relative angular displacement anywhere within this 0 to 90 degree range, may be easily accomplished by merely loosening screws 28 and 29, turning grid supporting member 8 within insulating spacing member 27 and then retightening screws 28 and 29. After the grids 3 and 4 are properly oriented, the enclosed electron discharge controlling member 1 is evacuated and the grid supporting member 8 sealed to the spacing member 27.

When this electric discharge device is to be employed as a high frequency amplifier, the control grid supporting member 8 is rotated approximately midway throughout its range of adjustment before evacuation and sealing with the result that the orientation of the direction of parallel wire grids 3 and 4 is approximately at a 45 degree relative angular displacement. How-

ever, when the discharge device is connected to proper operating voltages in a manner designed to produce self-sustained oscillations, the grid supporting member 8 is rotated to either of its limiting positions depending upon the desired direction of reactive inter-resonator coupling.

The theory of why the above described control over the degree of inter-resonator coupling may be achieved by the relative angular orientation of parallel wire grids in a symmetrical cavity resonator system, is not yet completely understood. The following explanation however, is offered as the most likely hypothesis upon which an understanding of this phenomena can presently be based. It is to be understood however, that the following explanation is not to be construed in any way as limiting the scope of our invention if a different theory should ultimately prove to be more comprehensive.

This variation in inter-resonator coupling is believed to be the result of circumferential variations in the symmetry of the electromagnetic waves produced by the parallel wire grids. These electromagnetic wave variations are localized adjacent the circumferential surface of the respective grid supporting members 8 and 10. They may best be visualized by considering the circumferential currents that must flow in these supporting members when a parallel wire grid is placed in the center of a resonator with a radially symmetric mode of electromagnetic wave propagation. Figures 3, 4 and 5 indicate by dashed arrows 34 how each parallel wire grid forces a circumferential redistribution of current from the uniform radial distribution of current in a symmetrical cylindrical resonator. The local electromagnetic waves associated with this current will, of course, penetrate through the interstices of the grid to a considerable extent. Therefore, if the waves from each resonator are oriented in the same general direction, they will cause a mutual exchange of energy from each resonator to the other. Such an orientation of electromagnetic waves in the same general direction is produced when the parallel wires are collimately aligned as illustrated in Fig. 3 since the areas of maximum circumferential currents, indicated by solid line arrows 35, are correspondingly aligned. If one of the grids, such as grid 3, is now rotated through 90 degrees relative to the other grid as illustrated in Fig. 4, the areas of maximum circumferential currents, as indicated by the solid line arrows 35, are again found to be correspondingly aligned. However, in this 90° relative angle position the direction of relative current flow is 180 degrees out of phase with that existing during the 0° relative angle position with the result that maximum inter-resonator coupling is again produced, but in an opposite reactive direction. Since the direction of coupling reverses between a zero and 90° relative angular displacement of the grids, there must be an intermediate angle at which the waves due to these circumferential currents tend to cancel each other and, therefore, to yield little or no substantial coupling. This angle of minimum coupling has been found to be in the neighborhood of 45 degrees.

Although we have shown a particular embodiment of our invention many modifications may, of course, be made and will occur to those skilled in the art. Our invention may be applied, for example, to any pair of adjacent grids in high frequency electric discharge devices having more than two grids.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. An electric discharge device comprising a cathode, an anode, and grids interposed in consecutive spaced planar alignment between said cathode and said anode, each of said grids being formed of spaced parallel electrical conductors, a first cylindrical cavity resonator connected in electrical relation with said cathode and one grid adjacent said cathode to form a grid-cathode resonator of said device, a second cylindrical cavity resonator in electrical relation with said anode and another grid adjacent said anode to form a grid-anode cavity resonator of said device, and means connected to said grids to indicate the relative rotational angular displacement of said parallel conductor grids whereby the parallel conductors of said grids may be oriented during manufacture to have a predetermined relative angular displacement to provide a predetermined degree of inter-resonator coupling.

2. An electric discharge device comprising a cathode, an anode, and two grids interposed in consecutive spaced planar alignment between said cathode and said anode, each of said grids being formed of spaced parallel electrical conductors, a first cylindrical cavity resonator connected in electrical relation with said cathode and one grid adjacent said cathode to form a grid-cathode resonator of said device, a second cylindrical cavity resonator in electrical relation with said anode and the other grid adjacent said anode to form a grid-anode cavity resonator of said device, the parallel conductors of said grids being oriented relative to each other with a relative rotational angular displacement ranging from zero to ninety degrees thereby to control the magnitude of inter-resonator coupling of high frequency energy and means connected to said grid to indicate the relative rotational angular displacement of said parallel conductor grids whereby the parallel conductors of said grids may be oriented during manufacture to have a predetermined relative angular displacement to provide a predetermined degree of inter-resonator coupling.

3. An electric discharge device comprising a cathode, an anode, and at least two grids interposed in consecutive spaced planar alignment between said cathode and said anode to control the electron flow therebetween, a first cylindrical cavity resonator intercepting the path of electron flow between said cathode and one of said grids adjacent said cathode to form a grid-cathode resonator of said device, a second cylindrical cavity resonator intercepting the path of electron current flow between the other of said grids and said anode to form a grid-anode cavity resonator of said device, each said grids being formed of spaced parallel wire conductors, and the direction of the conductors in one of said parallel conductor grids being angularly displaced relative to the direction of the conductors of the other of said parallel conductor grids by an angle in the neighborhood of 45° thereby to minimize the inter-resonator coupling of high frequency energy within the grid region of said device.

4. An electric discharge device comprising a cathode, an anode, and at least two grids interposed in consecutive spaced planar alignment between said cathode and said anode to control the electron flow therebetween, a first cylindrical cavity resonator intercepting the path of electron flow between said cathode and one of said

grids adjacent said cathode to form a grid-cathode resonator of said device, a second cylindrical cavity resonator intercepting the path of electron current flow between the other of said grids and said anode to form a grid-anode cavity resonator of said device, each of said grids consisting of spaced parallel wire conductors, and the direction of the conductors in one of said parallel wire grids being angularly displaced relative to the direction of the conductors in the other of said parallel wire grids by an angle in the neighborhood of 90° thereby to introduce considerable feed-back energy through inter-resonator coupling when said discharge device is operated as a high frequency oscillator.

5. A high frequency electric discharge device comprising a cathode and an anode having their respective electron emitting and electron receiving surfaces aligned in spaced parallel planes, a pair of electric conducting grid supporting members located in adjacent spaced planes intermediate said cathode and said anode, each of said grid supporting members having a central hole, a pair of parallel wire grids each supported by a respective one of said grid supporting members and extending across corresponding one of said holes to intercept the electron current from said cathode to said anode, and means connected to said grid supporting members to indicate the rotational position of one of said grid supporting members relative to the other thereof to adjust during manufacture the relative rotational angular displacement of said parallel wire grids.

6. A high frequency electron discharge controlling device suitable for use with cylindrical cavity resonators comprising a plurality of electrodes including a cathode and an anode in spaced opposed alignment and a pair of parallel wire grids located intermediate the opposing surfaces of said cathode and said anode, a pair of electric conducting grid supporting members, each having a central hole across which a respective one of said grids is extended, and electric insulating and supporting means sealed between said grid supporting members, between said cathode and its adjacent one of said grid supporting members, and between said anode and its adjacent other one of said grid supporting members maintaining said electrodes in spaced planar alignment, one of said grids having the direction of its parallel wires oriented with an angular displacement in the neighborhood of 45° relative to the direction of the parallel wires of the other of said grids.

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