March 28, 1961 W. C. BROWN ET AL 2,977,502

ELECTRONIC DISCHARGE DEVICES OF THE MAGNETRON TYPE

Original Filed Oct. 15, 1951 3 Sheets-Sheet 1

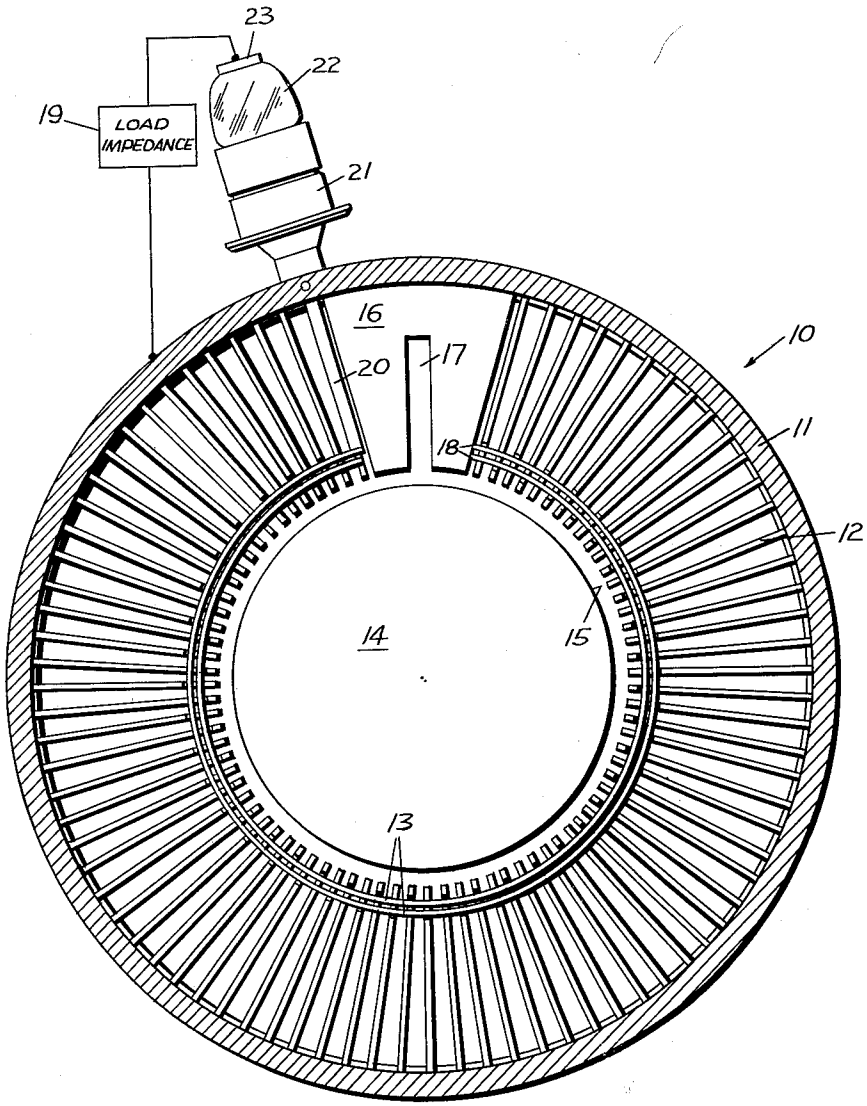


FIG. 1

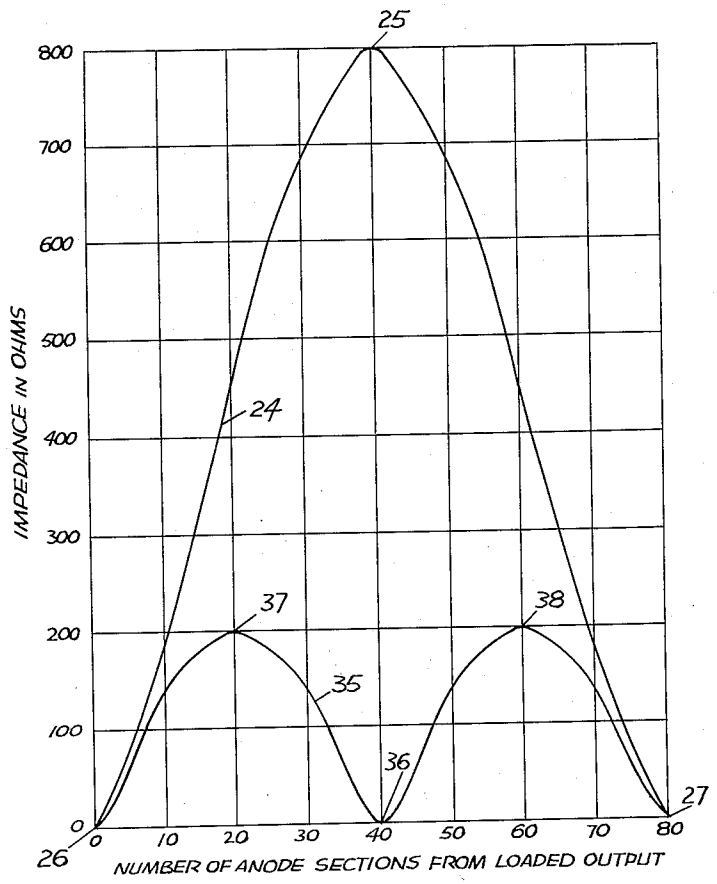
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ELECTRONIC DISCHARGE DEVICES OF THE MAGNETRON TYPE

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FIG. 2



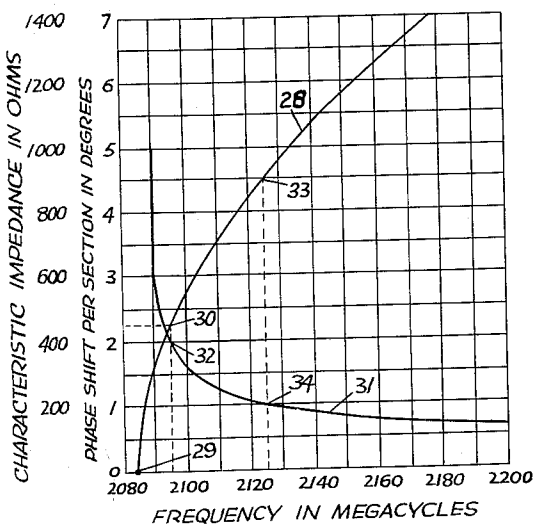


FIG. 3

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FIG. 4

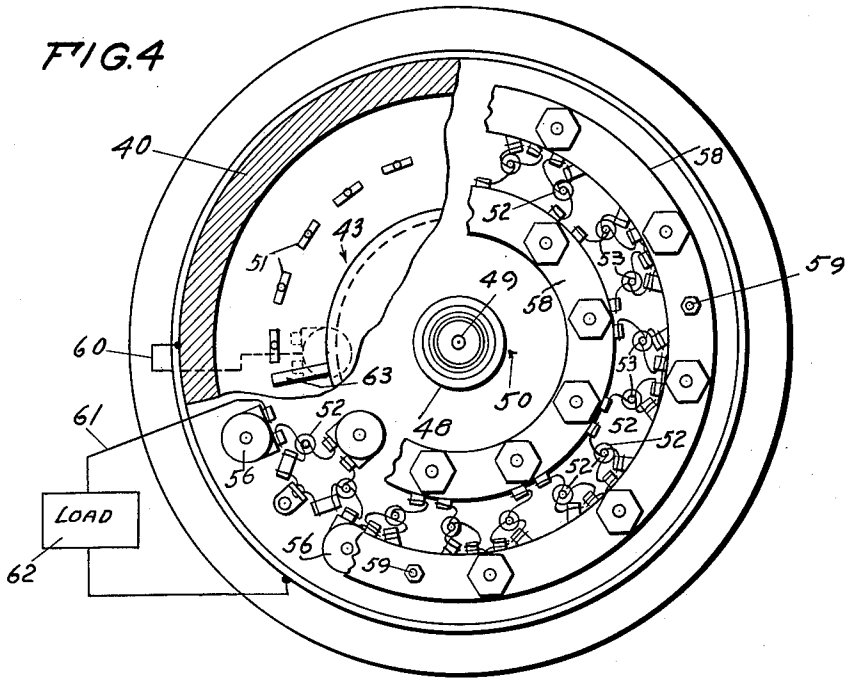
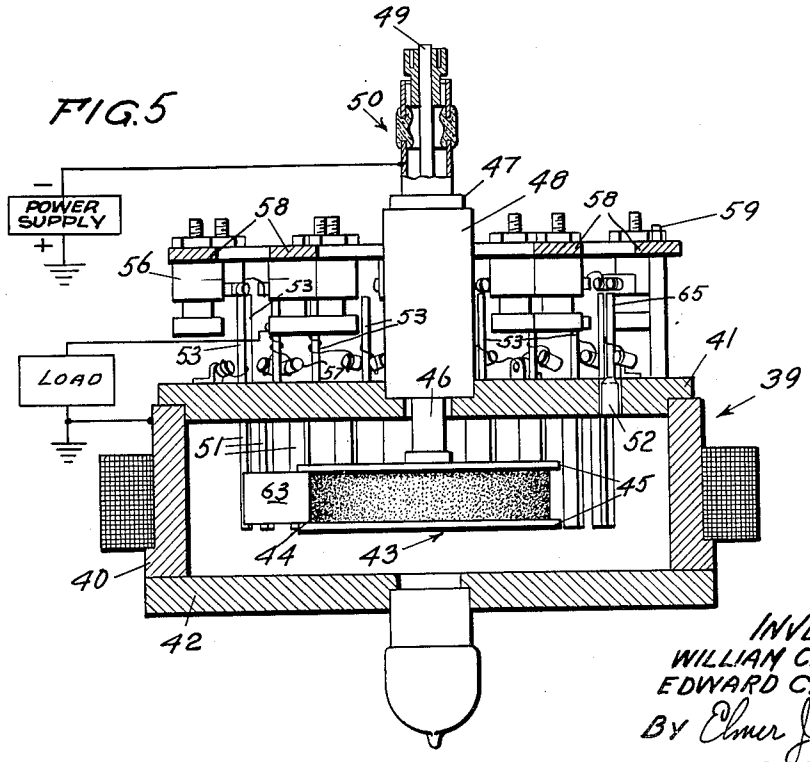


FIG. 5



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United States Patent Office 2,977,502 Patented Mar. 28, 1961

2,977,502

ELECTRONIC DISCHARGE DEVICES OF THE MAGNETRON TYPE

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Continuation of application Ser. No. 251,326, Oct. 15, 1951. This application Feb. 26, 1957, Ser. No. 642,613

13 Claims. (Cl. 315—39.3)

This is a continuation of our application, Serial No. 251,326, filed October 15, 1951, now abandoned.

This invention relates to electron discharge devices and, more particularly, to electron discharge devices utilizing mutually perpendicular electrostatic and magnetic fields to control the electron discharge.

In copending application, Serial No. 81,804, filed March 16, 1949, by William C. Brown and Edward C. Dench, now Patent No. 2,673,306, issued March 23, 1954 to W. C. Brown, there is disclosed a traveling wave amplifier utilizing mutually perpendicular electrostatic and magnetic fields. It has been discovered that under certain conditions magnetron amplifiers of this type may be made to operate as stable efficient oscillators. Briefly, one set of conditions found to produce reliable operation employs an anode structure comprising a signal wave transmission network of the non-reentrant type with the ends thereof substantially isolated from each other except through said network. The ends of the transmission network are terminated in impedances substantially different from the characteristic impedance of the transmission network at the desired operating frequency of the device. For example, one end of the network may be short circuited and the other end thereof may be terminated in an output load impedance, the value of the load impedance being on the same order of magnitude as the characteristic impedance of the transmission network at the closest undesired frequency at which the device could oscillate.

Specifically, where the desired operating frequency is chosen as the mode adjacent the π mode such that there is a phase shift on the order of π radians between the two ends of the transmission network, the output impedance may be made of a value on the order of the characteristic impedance of the transmission network at the frequency of the second mode.

This invention further discloses that the signal wave transmission network may be made in arcuate form and with a suitable isolating device such as a radio frequency choke positioned between the two ends of the network. Electrons from any desired source, such as a cathode surface positioned adjacent the network, will be urged along paths adjacent the network under the influence of an electrostatic field maintained between the cathode and the network and a magnetic field produced in a direction transverse to the desired electron motion and the electrostatic field.

This invention further discloses that if no obstruction is placed in the path of the electron stream between the two ends of the transmission network, electrons may continue to circle the cathode for many revolutions, thereby producing conditions for high efficiency in the generation of the desired oscillations.

There is disclosed herein a first embodiment of the invention wherein the signal wave transmission network comprises an anode structure made up of a plurality of anode members with alternate anode members being connected by conductive strapping.

A second embodiment disclosed herein utilizes a signal wave transmission network comprising an unstrapped anode structure. The strapped anode structure of the first embodiment may be made to oscillate at frequencies above the π mode frequency, while the unstrapped anode structure may be made to oscillate at frequencies below the π mode.

Other objects and advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings wherein:

Fig. 1 illustrates a transverse cross-sectional view of a first embodiment of this invention wherein the anode structure comprises a plurality of strapped anode members;

Fig. 2 illustrates a graph showing the impedance of the signal wave transmission network illustrated in Fig. 1 as a function of the distance along said network at the frequency of the first mode adjacent the π mode and at the frequency of the second mode adjacent the π mode;

Fig. 3 illustrates a graph indicating the characteristic impedance and the phase shift as a function of frequency for the network illustrated in Fig. 1;

Fig. 4 illustrates a partially broken away transverse cross-sectional view of the second embodiment of this invention having an unstrapped anode structure; and

Fig. 5 illustrates a longitudinal cross-sectional view of the device shown in Fig. 4.

Referring now to Fig. 1, there is shown an anode structure 10 comprising an anode cylinder 11. Extending radially inwardly from the inner surface of anode cylinder 11 is a plurality of anode members 12. Anode members 12 are connected at points near their inner ends on the edges thereof by conductive strapping 13 of the type wherein alternate anode members are electrically connected together through the conductive strapping 13.

Positioned inside the anode structure, concentric therewith and spaced therefrom, is a cathode structure 14 comprising a cylinder 15 coaxial with anode cylinder 11. Cylinder 15 has the outer surface thereof coated with electron emissive material on the area adjacent the inner ends of anode members 12. Cathode structure 14 may be of any desired type and for a more specific description of a type of cathode structure found to work well with this device, reference may be had to the aforementioned copending application.

At one point in the anode structure 10, the anode members 12 and strapping 13 have been omitted and a radio frequency choke 16 has been substituted therefor. Choke 16 comprises a metallic block extending radially inwardly from anode cylinder 11 for substantially the same distance as anode members 12. The inner face of choke 16, which is adjacent the cathode 14 is relatively large and extends along the surface of cathode 14 for a distance equal to that occupied by several of the anode members 12. At a point substantially in the middle of said inner face of choke 16 a slot 17 is positioned said slot extending outwardly toward cylinder 11 and being effectively a quarter wave length deep at the desired operating frequency of the device. The purpose of slot 17 is to effectively isolate any signal waves occurring on one side thereof from the other side thereof thereby effectively isolating the two ends of the signal wave transmission network made up of the anode members 12, the conductive strapping 13, and the spaces defined by anode members 12.

One end of the transmission network is effectively short-circuited by connecting all of the conductive strapping to the block 16 as at 18. The other end of the transmission network is connected to a load impedance 19 by connecting one of the straps of the conductive strapping 13 to a lead-in member 20 which extends out

through an aperture in anode cylinder **11** spaced therefrom. Lead-in member **20** is surrounded, after it passes through anode cylinder **11**, by a metallic cylindrical member **21** which is insulatedly sealed to lead-in member **20** by a glass seal **22**. Member **20**, after it passes through glass seal **22**, terminates in a connector **23** which is connected to one side of the load impedance **19**, the other side of load impedance **19** being connected back to anode cylinder **11**.

A magnetic field is produced in a direction parallel to the axis of anode cylinder **11** by any desired means such as, for example, a permanent magnet not shown.

The operation of the device will now be described, reference being had to Figs. 2 and 3. When a suitable potential is applied between the anode structure **10** and the cathode **14**, electrons emitted from the surface of cathode **14** will move around cathode **14** in the space between cathode **14** and the inner ends of anode members **12**. By adjustment of the anode voltage and magnetic field, the electrons may be made to move substantially at the same speed as a component of a wave travelling along the signal wave transmission network, whereupon interaction will occur between the electron stream and the wave, thereby producing generation of a signal at the desired frequency. The end of the network away from which electrons move will be referred to as the upstream end, while that end of the network toward which electrons move will be referred to as the downstream end.

While the influence of many factors plays a part in determining the build-up of oscillations, it is believed that one of the most important factors is the impedance of the network at the point where interaction occurs between the electron stream and the signal travelling in the network. Since the coupling between waves in the network and the electron stream is, for the particular anode structure illustrated herein, of the electric type rather than the electro-magnetic type, the coupling between the beam and the wave is increased at points of high network impedance, and hence greater interaction occurs. For purposes of analysis, the anode structure may be considered to be a high-frequency pass filter network with the cutoff frequency at the π mode. For such a device, the impedance at any point in the network is the algebraic sum of the input impedance looking toward one end of the network, and the input impedance looking toward the other end of the network. The impedance looking toward the end of the network, which is terminated in a load, is given by the formula

$$Z_R = Z\beta \frac{Z_T j^{Z\beta} \tan n\beta}{Z\beta j^{Z_T} \tan n\beta} \quad (1)$$

while the input impedance looking toward the end of the network which is short circuited is given by the formula

$$Z_L = j^{Z\beta} \tan (m-n)\beta \quad (2)$$

where

β=phase shift per section,
$Z\beta$=characteristic impedance of the network,
Z_T=terminating impedance (considered real),
n=number of sections or anode members from loaded end to point at which impedance is being measured,
m=total number of magnetron cavities.

The total input impedance, Z_n is, of course, the impedance 1 and 2 in parallel.

In particular, when the total phase shift $m\beta$ along the network is 180°, or any integral multiple of 180°, the impedance

$$Z_n = \frac{-Z\beta}{Z_T}(j^{Z_T} - Z\beta \tan n\beta)\frac{(\tan n\beta)}{(1-\tan^2 n\beta)} \quad (3)$$

Formula 3 is plotted as curve **24** in Fig. 2, wherein impedance in ohms is plotted along the axis of ordinates, and the number of sections or anode members from the loaded output is plotted along the axis of abscissae. Curve **24** reaches a maximum of 800 ohms, illustrated by point **25**, at a distance of forty anode members from the output end. For the anode structure used, which has eighty anode members, this is midway between the two ends of the transmission network. At the particular operating frequency of curve **24**, which is the frequency of the mode adjacent the π mode, the phase shift along the transmission network going from zero to eighty anode members is substantially π radians, or 180 degrees. Consequently, a point on the fortieth anode member is positioned substantially a quarter wave length from either end. Accordingly, the input impedance, looking in either direction along the transmission network, at this point, is given by the formula

$$Z_n = \frac{(Z\beta)^2}{Z_T}$$

and the total impedance is the algebraic sum of the two. Looking toward the short circuited end, therefore, the input impedance is infinite, while looking toward the loaded end, the input impedance is substantially 800 ohms, if the characteristic impedance of the network at the frequency under consideration is substantially 400 ohms and the terminating impedance is 200 ohms.

The curve **24** indicates that the impedance at either end of the transmission network is zero as indicated by points **26** and **27**, respectively. It is believed quite obvious that the impedance at point **27** would be zero since this is at the eightieth anode member where a short circuit is placed across the transmission network. Since the other end of the transmission network, before the first anode member, is substantially 180 degrees, or a half wave length away from the short circuit at the eightieth anode member at the frequency under consideration, a short circuit is reflected to the output end by the short circuit at the eightieth anode member.

In Fig. 3, there is shown a graph illustrating the relationship between the phase shift per section and the frequency for the signal wave transmission network illustrated in Fig. 1. Along the axis of ordinates is plotted phase shift per section in degrees where a section is defined as one complete cavity including the adjacent walls of a pair of adjacent anode members and the portions of the conductive strapping included therebetween. Along the axis of abscissae is plotted frequency in megacycles. The curve **28**, representing the relationship between the phase shift per section and the frequency, passes through zero phase shift per section at a frequency of around 2085 megacycles as indicated at point **29**. A zero phase shift per section, as indicated by point **29**, is indicative of a resonant condition and in this case represents the π mode. Curve **28** passes through a point **30** at a frequency around 2095 megacycles at which the phase shift per section is substantially two and one-quarter degrees. In the anode structure under consideration, where there are eighty anode members and hence eighty sections, a two and one-quarter degree phase shift per section produces a 180 degree phase shift between the ends of the transmission network. Point **30**, then, on curve **28**, represents the operating frequency of the curve **24** of Fig. 2.

There is also shown in Fig. 3 a curve **31** illustrating the functional relationship between the characteristic impedance of the signal wave transmission network and the frequency. The characteristic impedance of ohms is plotted on another scale along the axis of ordinates, while the same scale for frequency in megacycles is plotted along the axis of abscissae. At a frequency of 2095 megacycles, the curve **31** passes through a point **32** where the characteristic impedance is on the order of 400 ohms, said impedance being used for computation of the curve **24** in Fig. 2. Curve **28** passes through a point **33** at a phase shift of four and one-half megacycles at a frequency on the order of 2125 megacycles. At a frequency of substantially 2125 megacycles, the curve **31** passes through a point **34** at a characteristic impedance on the order of 200 ohms. Thus, where the load

impedance 19 is 200 ohms, the terminating impedance Z_T of the transmission network at one end is the characteristic impedance of the network at a frequency where the phase shift per section along the network is four and one-half degrees, and hence the total phase shift is 360 degrees. A phase shift of 360 degrees represents a point where oscillations could occur, and hence it is desirable that the impedance along the transmission network be less at this frequency than at the desired operating frequency of the device. The impedance along the network for a total phase shift along the network of 360 degrees is plotted as curve 35 in Fig. 2. At the input points, curve 35 coincides with curve 24, as indicated by points 26 and 27, respectively. At the fortieth section, as indicated by point 36, the impedance is again zero since the short circuit indicated at point 27 is reflected a half wave length to point 36. The curve 35 passes through maximums of 200 ohms impedance at sections 20 and 60, as indicated by points 37 and 38, respectively. Since points 37 and 38 are a multiple of an odd number of quarter wave lengths from the ends of the transmission network, the short circuited end will reflect an open circuit impedance to each of these points, while the loaded end, being terminated in the characteristic impedance of the network, will reflect the characteristic impedance to these points. The impedance at these points will, therefore, be equal to the characteristic impedance of the network or substantially 200 ohms for the frequency under consideration which is the frequency of the second mode adjacent the π mode.

As is indicated by point 29, on curve 28 in Fig. 3, the phase shift at the π mode is zero and, accordingly, the impedance at all points along the network will be substantially the same for this frequency. Under these conditions, the short circuit at the eightieth section will appear effectively all along the transmission network. As a result, oscillations at the π mode are prevented. Since the impedance for the mode adjacent the π mode, as indicated by curve 24 in Fig. 2, is greater at all points along the transmission network, and at many points is much greater than the impedance at the second mode adjacent the π mode, oscillations will always appear first at the frequency of the mode adjacent the π mode, thereby effectively preventing build-up of oscillations at any of the other frequencies. Furthermore, the load impedance may be varied considerably before the impedance of modes other than the mode adjacent the π mode becomes greater than the maximum impedance of the mode adjacent the π mode and, accordingly, the device will oscillate stably in the mode adjacent the π mode over a wide range of load impedances or through sudden changes in load impedance without moding or changing operation to a different frequency.

A plot of additional modes of frequency higher than the second mode adjacent the π mode may be made, but the impedances of these modes will also be substantially less than the peak impedance of the mode adjacent the π mode. Accordingly, oscillation will not occur in these modes.

Another factor which improves stabilization is the desirability of having the velocity of the electron stream substantially equal to the phase velocity of a component of the desired frequency of the signal wave traveling on the transmission network. Since phase velocity varies with frequency, the second mode adjacent the π mode will have poor interaction with the electron beam because the component thereof, which would normally interact with the electron stream to produce oscillation, is traveling at a different velocity from the velocity of the stream.

Furthermore, since the transmission network is of the non-reentrant type, the modes are non-degenerate. This differs from ordinary magnetrons where only the π mode is non-degenerate, while the modes adjacent the π mode exhibit a so-called degenerate phenomenon. This degenerate phenomenon is essentially the presence of two possible frequencies of operation spaced very close together and is produced by output loading or any other means which influence the symmetry of the wave configuration along the anode structure. In a non-reentrant structure, such as the non-reentrant transmission network disclosed in Fig. 1, the modes are all non-degenerate. In other words, the device will oscillate at only one frequency within a given mode.

Thus it may be seen that a device may be produced in conformance with this invention having a great number of anode members, for example, eighty in number, with a relatively close spacing of adjacent modes to the desired operating mode without danger of moding. As a consequence of being able to use a large number of anode members, increased power output may be obtained, particularly at the upper microwave frequencies since the increased anode area allows increased heat dissipation. This, in turn, allows a high power device to be produced which has a relatively low input impedance where the input is defined as the anode-to-cathode voltage divided by the anode current. In practice, a relatively high power magnetron oscillator may be produced having an input impedance on the order of 100 ohms. Such a device requires a relatively low input voltage, and hence construction expense for insulating structures, such as supports and filament transformers, may be considerably reduced from that required for conventional magnetron oscillators. Furthermore, a relatively low input voltage reduces erosion of the cathode due to back bombardment from any ionized gas particles which may be present in the tube.

Referring now to Figs. 4 and 5, there is shown a second embodiment of this invention wherein the signal wave transmission network is of the unstrapped variety and behaves as a low-frequency pass filter with the cutoff frequency at the frequency of the π mode. There is shown an anode structure 39 comprising an anode cylinder 40. The ends of cylinder 40 are covered by upper and lower end plates 41 and 42, respectively. Positioned inside cylinder 40 is a cathode structure 43 comprising a cathode cylinder 44 whose outer surface is coated with electron-emissive material. The upper and lower ends of cylinder 44 are covered by end shields 45 whose purpose is to prevent movement of electrons in a direction parallel to the axis of cylinder 44 which is coaxial with anode cylinder 40. Cathode 43 is rigidly mounted with respect to the anode structure 39 by a cathode support rod 46 which extends upwardly through an aperture in upper end plate 41 spaced therefrom. Cylinder 46 is rigidly attached by means of a cup 47 to a ceramic cylinder 48 surrounding cylinder 46, and sealed to a recess in upper end plate 41. Cylinder 48 thereby provides an insulating-vacuum-tight support for the cathode structure 43. A heater lead-in wire 49 extends through cylinder 46, coaxial therewith, and is rigidly supported with respect thereto by an insulated support structure 50. Lead-in wire 49 is connected to one end of a heater coil positioned inside cathode cylinder 44, the other end of said coil being connected to the cathode structure 43. By application of a suitable potential between lead-in member 49 and the cathode structure, for example, through cup 47, current may be made to flow through the heater coil, thereby heating the cathode cylinder 44 to a sufficient temperature to produce electron emission from the coating thereon.

Surrounding cathode structure 43 is a plurality of anode members 51 comprising elongated conductors extending downwardly from insulating supports 52 set in upper end plate 41. Portions of anode members 51 extend through supports 52, which are insulating seals set in apertures in end plate 41, thereby providing lead-in members 53, which are respectively connected to anode members 51 through insulating seals 52, and which are positioned outside the evacuated space within anode cylinder 40. Attached to lead-in members 53 are inductors 56

and capacitors 57 which are so arranged as to form a low-pass filter type of signal wave transmission network. This is accomplished by connecting an inductor between each pair of adjacent anode members, and by connecting each anode member to a ground plane, in this case, end plate 41, through one of condensers 57. As is shown here, by way of example only, the inductors 56 are supported on a pair of rings 58, which are attached to end plate 41 by bolts 59. At one point in the network, a connection is eliminated between adjacent anode members and the two ends of the transmission network thus formed are brought out through leads 60 and 61, respectively. The details of the device of Figs. 4 and 5, referred to thus far, are described more completely in the aforementioned copending application. Lead 60 is connected to ground by being connected back to anode cylinder 40, while lead 61 is connected to one side of a load 62, the other side of load 62 being connected back to anode cylinder 40.

Positioned between the ends of the transmission network is a metallic block 63 which extends outwardly from cathode cylinder 44 to which it is rigidly attached. This block 63 is shown here, by way of example only, and prevents all movement of the electrons completely around the cathode cylinder 44, thus avoiding coupling of a signal from the output of the anode structure around to the input side through the electron stream. It is to be clearly understood that block 63 could be removed and the electrons allowed to rotate completely around the cathode cylinder 44, if so desired. The structure of Figs. 4 and 5 may be analyzed in a manner similar to that demonstrated for the structure of Fig. 1, and a formula may be derived for determining the impedance at any point along the transmission network for any given frequency. In addition, modes may be determined at frequencies below the π mode where the transmission network has a phase shift along its length of a multiple of π radians where its oscillations may occur. The device will operate stably in the first mode below the mode wherein the phase shift along the transmission network is π radians. The stability may be enhanced by making the value of the load 62 equal to the characteristic impedance of the transmission network at the frequency of the second mode below the π mode.

The magnetic field is of such a polarity that the electrons rotate clockwise about the cathode in the species as shown in both Fig. 1 and Fig. 4. This causes the electrons to move along paths adjacent the signal wave transmission structure toward the output. However, if desired the electrons may be made to rotate in the opposite direction.

While in both the embodiments of the invention disclosed herein, the output load has been connected to one end of the transmission network, it could be connected to other points thereof if so desired, and the ends of the transmission network could both be shorted or left open circuited, or one could be short circuited, and the other open circuited. In addition, the ends could be terminated if desired in reactive impedances.

This completes the description of the particular embodiments of the invention illustrated herein. However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, any desired type of transmission network could be used for the anode structure such as, for example, an interdigital structure. Also, the principal of group strapping, or connecting discrete points on the transmission network together by oscillatory transmission lines may be used. Further, the structure is not necessarily limited to devices where the cathode is positioned adjacent the anode members but, rather, a cathode may be positioned remote from the interaction space adjacent the anode members, and the electrons directed into said space in the form of a beam. Accordingly, it is desired that this invention be not limited by the particular details of the embodiments disclosed herein except as defined by the appended claims.

What is claimed is:

1. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for connecting one of said terminations directly to a load, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure.

2. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for connecting one of said terminations directly to a load, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction.

3. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for connecting one of said terminations directly to a load, a continuous cathode, said cathode being capable of emission from several regions thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration throughout, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction.

4. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, first coupling means coupled to said structure for connecting one of said terminations directly to a load, second coupling means coupled to said structure for connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, said first and second coupling means being mutually uncoupled a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure.

5. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for connecting one of said terminations directly to a load, means coupled to said structure for connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, a continuous cathode, said cathode being capable of emission from several regions thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction.

6. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, said structure including first and second sets of alternate members, the members of each set being interconnected by an electrically-con-

ductive element, means coupled to said structure for directly connecting one of said terminations to a load, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction.

7. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, said structure including first and second sets of alternate members, the members of each set being interconnected by an electrically-conductive element, means coupled to said structure for directly connecting one of said terminations to a load, means coupled to said structure for connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction.

8. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for directly connecting one of said terminations to a load, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction, said one termination being connected to the downstream end of said structure.

9. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for directly connecting one of said terminations to a load, means coupled to said structure for connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction, said one termination being connected to the downstream end of said structure.

10. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, said structure including first and second sets of alternate members, the members of each set being interconnected by an electrically-conductive element, means coupled to said structure for directly connecting one of said terminations to a load, means coupled to said structure for connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode being capable of emission from several regions thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction, said one termination being connected to the downstream end of said structure.

11. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for directly connecting one of said terminations to a load, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction, said one termination being connected to the upstream end of said structure.

12. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, means coupled to said structure for connecting one of said terminations to a load, means coupled to said structure for directly connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction, said one termination being connected to the upstream end of said structure.

13. An electron discharge device comprising a nonreentrant, nonresonant slow wave propagating structure having at least two terminations, said structure including first and second sets of alternate members, the members of each set being interconnected by an electrically-conductive element, means coupled to said structure for directly connecting one of said terminations to a load, means coupled to said structure for connecting the other of said terminations to a substantial short circuit at the main oscillation frequency of said device, a continuous cathode capable of emitting electrons from a major portion thereof, said cathode being capable of emission from several regions thereof, said cathode and said propagating structure combining to form a continuous interaction space of substantially uniform configuration, and means including said cathode for directing electrons along said interaction space more than once past said propagating structure in the same direction, said one termination being connected to the upstream end of said structure.

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