

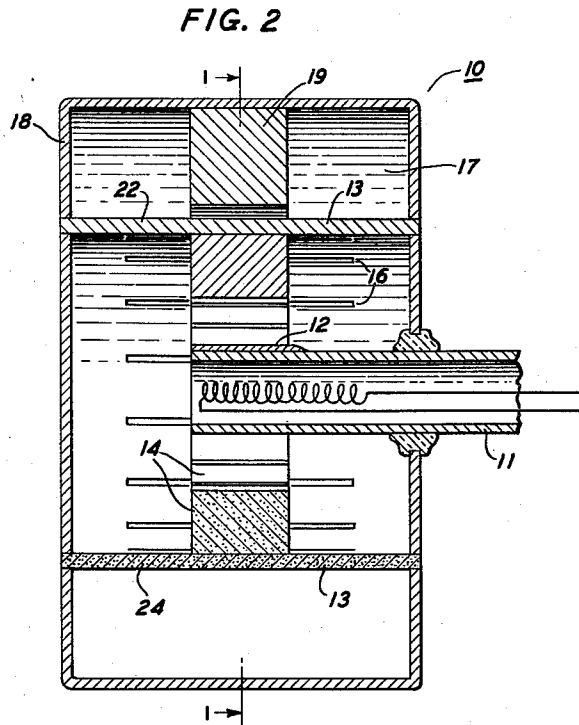
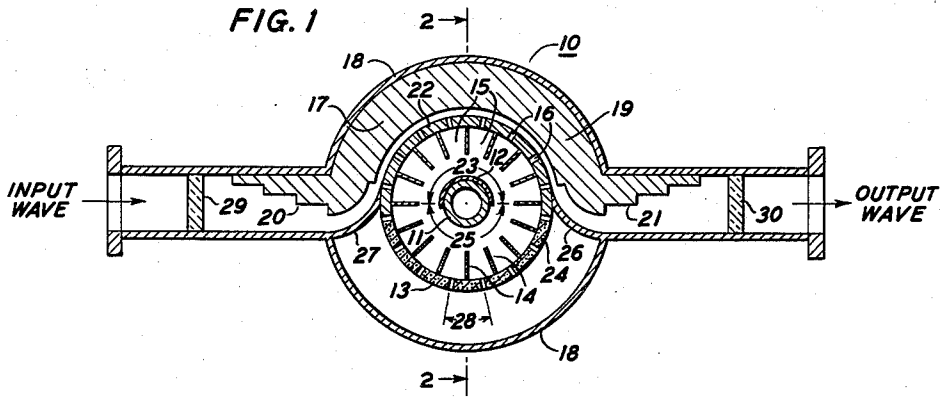
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MAGNETRON AMPLIFIER

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MAGNETRON AMPLIFIER

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This invention relates to electron discharge devices and more particularly to magnetron amplifier devices.

In R. J. Collier and J. Feinstein Patent 2,854,603, issued September 30, 1958, there is disclosed an oscillator, referred to as the coaxial magnetron, which utilizes two resonant systems to achieve a stability which is independent of loading. An inner resonant system includes a cylindrical anode from which a plurality of anode vanes radially extend inwardly toward the cathode. These vanes define a circumferential array of inner or anode cavity resonators. An outer cavity resonator is defined between an outer wall and the cylindrical anode. The two systems are coupled by an array of uniformly spaced slots through the cylindrical anode which connect the outer resonant system with alternate ones of the anode cavity resonators such that the inner system supports a desired π mode of oscillation. Since the output is taken from the outer system, changes in load have only a minimal effect on the π mode of oscillation of the inner resonant system, thereby providing greater stability.

Because of the presence of currents flowing around the periphery of the coupling slots in this type of magnetron, however, a certain amount of spurious energy is stored in the slots. As a result of uniform periodic coupling action between successive slots around the anode periphery, the electric and magnetic fields due to this energy storage tend to produce interfering modes of oscillation. Because of the successive coupling action, these slot modes can be thought of as traveling or propagating waves. The aforementioned coaxial magnetron removes certain of these slot modes through the use of damping elements at the ends of the coupling slots which absorb energy stored therein. Another arrangement for reducing slot mode interference is disclosed in the J. Feinstein application for patent Serial No. 783,597, filed December 29, 1958, wherein there are introduced into the coupling system nonuniformities which tend to break up the various slot mode patterns by deterring the slot mode propagation.

In a coaxial magnetron amplifier, as opposed to an oscillator, the slot mode problems are even more pronounced because it is desirable to use slots to couple each anode resonator, rather than alternate resonators. The closer proximity of the various slots therefore permits closer and stronger coupling therebetween. For this and other reasons, the aforementioned arrangements for preventing slot mode propagation are not entirely effective when used in a coaxial magnetron amplifier.

In most magnetron amplifiers the input is placed adjacent to the output such that the wave to be amplified can travel around substantially the entire anode periphery before being removed as an output. In a coaxial magnetron, however, although the desired mode can be removed as an output in a conventional manner, undesired slot modes tend to continue propagation back into the input. This, of course, is feedback and may result in an undesired oscillation of the amplifier. It has

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been found that the insertion of a barrier of lossy material between the input and output such as to prevent any slot mode propagation around the entire periphery of the cylindrical anode is not generally satisfactory since such barriers must inherently cause a certain amount of reflection. A reflected slot mode will feed back to the input and may, in turn, be reflected therefrom with resulting reamplification. If the net gain of a slot mode after reflection and reamplification is greater than one, undesired oscillation will take place.

It is a general object of this invention to provide an improved amplifier discharge device of the type wherein a signal wave traveling in a wave guide is amplified by energy coupled thereto from an adjacent arrangement of resonant cavities with which an electron stream is interacting. More specifically, it is an object of one embodiment of this invention to provide an improved amplifier of the coaxial magnetron type.

It is a further object of this invention to prevent undesirable oscillation in a coaxial magnetron amplifier.

It is another object of this invention to prevent undesired slot modes from propagating around the periphery of an anode in a coaxial cavity magnetron amplifier.

It is still another object of this invention to prevent reflection of undesired slot modes in a coaxial magnetron amplifier.

These and other objects of this invention are attained in one specific embodiment of the invention wherein a coaxial magnetron amplifier comprises an inner resonant system which is partially surrounded by an outer wave guide which transmits an electromagnetic wave for amplification. The inner resonant system comprises a plurality of anode resonant cavities defined by a plurality of anode vanes extending inwardly from a cylindrical anode. The cylindrical anode, in turn, comprises one of the walls of the outer wave guide. As a wave is transmitted along the wave guide, currents are induced in the cylindrical anode which flow through coupling slots which interconnect the wave guide with each of the anode cavities. The electron stream of the magnetron interacts with the fields produced in the anode resonators to amplify the anode currents which, in turn, amplify the wave propagated through the outer wave guide.

In accordance with one aspect of this invention, such interaction takes place along only a predetermined discrete portion of the anode or resonant structure. The remaining portion of the anode or resonant structure where no interaction takes place defines a dummy region. The input and output of the wave guide are so displaced that only a minimal amount of the wave induced anode current is allowed to flow into the dummy region.

It is a feature of this invention that the dummy region defined by a portion of the anode have a substantially lossy characteristic. Although the amplified wave propagates in a conventional manner out through the output, slot modes are effectively propagated by close coupling mainly between adjacent slots and, to a lesser extent, between adjacent vanes, as will be more fully explained hereinafter. The slot modes therefore propagate into the dummy region while the amplified wave does not. As slot modes propagate along the lossy dummy portion they are effectively absorbed.

It is another feature of this invention that the slot modes be absorbed gradually in the dummy region. This is done either by making the resistance of the dummy portion of the anode increase in proportion to the distance from those boundaries contiguous with the interaction portion, or by making the dummy portion of such a homogeneous resistance that slot modes are

completely absorbed only by propagating a substantial distance therealong. Such gradual absorption substantially prevents any reflection of the slot mode.

A complete understanding of this invention and of the foregoing and other features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a sectional view of one illustrative embodiment of this invention comprising a coaxial magnetron type amplifier; and

Fig. 2 is a sectional view taken along the lines 2—2 of Fig. 1.

Referring now more particularly to the drawings, the embodiment of this invention depicted therein comprises a coaxial magnetron 10 having a cylindrical cathode 11 with an emissive surface 12 for forming and projecting an electron stream. Surrounding the cathode 11 is a cylindrical anode wall 13 having a plurality of vanes 14 which extend radially inwardly therefrom. The planes of the anode vanes 14 are parallel with the axis of cylindrical anode 13 and define an array of anode cavity resonators 15. Crossed electric and magnetic fields force the electron stream to follow an arcuate path between the resonators and cathode in a manner well known in the art. Various types of well-known structure may be employed for producing crossed fields. For the sake of simplicity such structure has not been shown. Coupling slots 16 extend through cylindrical anode 13 and are centered between adjacent anode vanes 14 so as to communicate with each of the resonators 15. Partially enclosing the cylindrical anode 13 is a ridged wave guide 17. Attached to envelope 18 and adjacent the vane region of anode 13 is a conductive ridge 19 which will be fully discussed hereinafter.

An electromagnetic wave is introduced into coaxial magnetron 10 as shown by the input arrow. The stepped ridge input transformer 20 permits the wave to be introduced into ridged wave guide 17 with a minimum of reflection or distortion. Conductive ridge 19 is advantageously of the same thickness as the width of anode vanes 14 thereby concentrating the field pattern along the vane region of anode 13 as is best seen in Fig. 2. These fields produce currents along the outer wall of anode 13 with equal and opposite currents on the opposed surface of ridge 19. Anode vanes 14 are approximately one-quarter wavelength long in the frequency band to be amplified such that the infinite impedances at their tips are reflected at the anode wall as small finite impedances. Anode currents therefore "see" a small impedance at the vane region of the anode and flow through coupling slots 16 into anode resonators 15. Because of the concentration of the fields by ridge 19 and the properly chosen length of slots 16, the anode currents are further constrained to flow through the slots rather than around the slot ends. Electric coupling between adjacent vanes produces a field which interacts with the magnetron electron stream in a well-known manner. Currents in the anode resonators then flow out through coupling slots 16 to amplify the electromagnetic wave propagating along wave guide 17. As can be seen from Fig. 1, the propagating wave is removed in a conventional manner when it reaches output transformer 21.

The anode 13 is divided into two portions: a conductive portion 22 which, together with cathode 11, defines an interaction region 23; and a dummy portion 24 which, together with cathode 11, defines a dummy region 25. Septa 26 and 27 prevent the electromagnetic wave from propagating along the dummy portion 24 such that interaction with the magnetron beam takes place only along the interaction region 23 between the cathode and anode. For this reason, only the part of cathode 11 defining the interaction region is coated with emissive material 12. A vacuum is maintained within magnetron 10 by means of an envelope 18 and electro-

magnetic wave permeable windows 29 and 30. The significance of dummy region 25 will be discussed hereinafter.

Consider next the effect which varying anode potentials may have on an individual slot 16. Alternating potential differences produce a capacitance action between opposite sides of each of the coupling slots 16 which, in turn, produces a discharge current which tends to flow around the slot ends. A certain amount of discharge current may also flow along the adjacent vanes 14, depending upon the impedance which the vane reflects. The reflected impedance, as pointed out above, is a function of the frequency of operation. The current flowing around the slot ends creates a self inductance thereat which, when considered with the capacitance existing at the middle portion of the slot, produces an oscillatory current around the sides of the slot, and the slot itself acts as a resonator. The capacitance at the middle of each slot may be considered to be in parallel with, and therefore augmented by, that vane capacitance due to discharge current flowing along the vanes, the amount of augmentation depending upon the frequency.

The fields produced by energy storage in the slots tend to couple with those fields produced in adjacent slots thereby creating spurious slot modes. Because of the successive coupling action involved, slot modes may be considered to be the equivalent of traveling waves which propagate along anode 13 and interact with the magnetron electron stream with resulting amplification. Of itself, a spurious slot mode or modes has little overall deleterious effect, even when so amplified, since the energy stored in a slot is small compared to energy stored in a resonator 15. Further, there is a constant interchange of energy between the desired mode of the inner resonant system and the traveling wave of the outer wave guide, while very little slot mode energy is to given up because of the close coupling between adjacent slots.

If, however, slot modes are fed back to the input and are thereafter reamplified, the device may oscillate at a slot mode frequency and therefore be inoperative. Examination of Fig. 1 will show that the amplified wave which propagates through wave guide 19 is removed at the region of output transformer 21 and is prohibited by septum 26 from propagating back to the input. This removal is accomplished substantially without reflection or distortion through proper design of the wave guide and output transformer as is well known in the art. Since, however, the spurious slot modes do not propagate as an electromagnetic wave in wave guide 19 but rather by close coupling between slots 16 and to a lesser extent between vanes 14, there is substantially no interruption by septa 25 and 26 and they would be expected to feed back into the input and through reamplification eventually cause oscillation. Realizing this, the first solution that came to mind was the insertion in the anode of a barrier of lossy material between the input and output. Where such a barrier is used, however, a certain amount of reflection results. If part of the slot mode energy is reflected back to the input, a portion thereof may, in turn, be reflected toward the output with reamplification. If the net gain of reamplification, after the losses of reflection are considered, is greater than one, oscillation will occur. It has been found that even the most gradually tapered barrier (within the limits of practicability) does not totally insure against oscillation resulting from such reflection.

I have found that if a slot mode is absorbed while it is propagating in a substantially normal manner, only a minimum amount of reflection will result. For this reason, dummy anode portion 24, including the vanes attached thereto, is made of lossy material of variable resistance. The regions of dummy portion 24 adjacent input and output transformers 20 and 21 are made of a

material which is only slightly lossy. From these boundaries of the dummy portion, the anode becomes uniformly more lossy toward the center of the dummy portion, and the anode section 28 is almost totally nonconductive.

As pointed out above, a slot mode propagates primarily by inductive coupling between adjacent slots and also by electric coupling between adjacent vanes. When a propagating slot mode traveling in a clockwise direction reaches dummy portion 24, it tends to produce currents in the dummy anode portion as previously described. As the traveling slot mode propagates into the dummy region 25, it is absorbed due to the gradual increase of the resistance of the anode dummy portion 24 which gradually dissipates the anode currents therein. Any energy which is reflected back to the input propagates in a counter-clockwise direction into that portion of the dummy anode 24 adjacent the input. The same absorptive process takes place before any portion of the slot mode can again be reflected for reamplification.

It is evident that the energy of the desired mode of the inner resonant system which propagates into the dummy region is also absorbed. Because of the interchange of energy which takes place between the inner resonant system and the outer wave guide, however, the quantity of desired mode energy which is absorbed is quite small.

There are several ways in which the anode 13 can be constructed. The dummy portion is shown as being constructed of lossy material. Although, as previously pointed out, the dummy portion should theoretically be of graduating resistance, it may be made of a homogeneous material of uniform resistance. The characteristics of such a material are determined by the compromise necessary to provide adequate damping while permitting a minimum amount of reflection. If the dummy portion of the anode is made of material which is too conductive, it will not provide adequate damping, while if it is too lossy, the sudden change of electrical characteristic from that of the interaction portion may cause too much reflection. The use of homogeneous material, however, obviously presents fewer manufacturing problems. Still another alternative is to spray part of a conventional cylindrical anode with lossy material. The lossy material may be sprayed rather thinly at the boundary regions of the anode dummy portion and be of graduating thickness.

Since it is intended that the embodiments shown and described be merely illustrative of the general principles of the invention, other methods and processes of manufacture will not be explored. Various arrangements may be devised by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. An electron discharge device comprising a cathode, an anode wall and a plurality of anode vanes extending therefrom adjacent said cathode, said anode wall and anode vanes defining with said cathode an interaction region and a dummy region, the anode wall and anode vanes defining said interaction region exhibiting a lower resistance to alternating current flowing therein than the anode wall and vanes defining said dummy region.

2. An electron discharge device comprising a cathode, an outer wall, an anode interposed between said cathode and said outer wall having an array of slots extending therethrough, an outer wave guide being defined between part of said anode and said outer wall, a plurality of anode resonators defined by an array of vanes extending from said anode toward said cathode, certain ones of said resonators being coupled to said wave guide by said array of slots, said slots being capable of giving rise to spurious slot modes, and means for providing substantially reflectionless absorption of said slot modes comprising a mode absorber, said mode absorber comprising a portion of said anode, said array of vanes, and

said array of slots, at least part of the material from which said mode absorber is fabricated being of greater resistance than the material from which the remainder of the anode and vanes are fabricated.

3. A magnetron amplifier comprising a cathode, a cylindrical wall surrounding said cathode and coaxial therewith, a plurality of anode resonators defined by vanes extending radially inwardly from said cylindrical wall, part of said wall comprising a wall of a wave guide and made of conductive material, the remainder of said wall being made of lossy material, the vanes extending from the conductive portion of said wall being made of conductive material, and the remainder of said vanes being made of lossy material.

4. An electron discharge device comprising a cathode and an anode wall having a plurality of vanes thereon and an array of slots extending therethrough, a conductive portion of said anode wall comprising a wave guide wall and a nonconductive portion of said anode wall comprising a slot mode absorber, said mode absorber having boundaries contiguous with said wave guide wall, the resistance of said slot mode absorber being higher than said wave guide wall and increasing in proportion to distance from those mode absorber boundaries which are contiguous with said wave guide wall.

5. A coaxial magnetron amplifier comprising a cylindrical cathode, a cylindrical anode surrounding said cathode and including a plurality of slots, a plurality of anode resonators defined by a plurality of anode vanes extending radially inwardly from said anode, a conductive portion of said anode and said cathode defining an interaction region therebetween, the vanes in said interaction region being made of conductive material, an outer wall coextensive with said conductive portion and defining a wave guide therebetween, said plurality of slots extending through said anode and communicating with each of said resonators, means to concentrate anode current flow in said conductive portion comprising a conductive ridge extending toward said anode from said outer wall and being of the same thickness as the width of said vanes, an electromagnetic wave input adjacent one of the boundaries of said conductive portion and an electromagnetic wave output adjacent another boundary of said conductive portion and an attenuating portion of said anode together with said cathode defining a dummy region therebetween, that portion of the cathode defining the interaction region being coated with emissive material and that portion of the cathode defining the dummy region being substantially nonemissive.

6. A coaxial magnetron amplifier as set forth in claim 5 wherein the resistance of said attenuating portion increases in proportion to distance from those boundaries of the attenuating portion which are contiguous with said conductive portion.

7. An electron discharge device comprising means including a wall member and a plurality of vanes extending therefrom on one side thereof for defining a plurality of cavity resonators, means including a portion of said wall member for defining a wave guide, and means for projecting a stream of electrons adjacent said cavity resonators, said wall member having a plurality of slots therethrough between said vanes and capable of storing spurious energy, said slots being of such proximity to each other to allow successive inductive coupling therebetween, and said means defining said cavity resonators being divided into a conductive portion including said priorly mentioned portion of said wave guide and a lossy portion having an attenuation characteristic low enough to allow said successive inductive coupling to occur between a substantial number of said slots in said lossy portion and high enough to prevent successive inductive coupling along the entire length of said lossy portion.

8. An electron discharge device comprising a cathode, a wall member adjacent said cathode with an array of

slots extending therethrough, an array of vanes spaced at equidistant intervals along said wall and extending toward said cathode, said wall being divided into a conductive portion and an attenuating portion, each of said portions including a plurality of said vanes, means for propagating an electromagnetic wave along said conductive portion, means for preventing said wave from propagating along said attenuating portion, said slots in said wall giving rise to spurious slot modes, the lossiness of said attenuating portion being low enough to allow said slot modes to propagate a substantial distance therealong, and high enough to absorb said slot modes before they can propagate along the entire length thereof.

9. An electron discharge device comprising a cathode, an outer wall, an anode interposed between said outer wall and said cathode, a plurality of anode resonators defined by a plurality of equally spaced anode vanes attached to a vane region of said anode and extending toward said cathode, said anode having a conductive portion and an attenuating portion, the conductive portion of said anode and anode vanes defining with said cathode an interaction region therebetween, said conductive portion and said outer wall defining a wave guide therebetween, a plurality of slots extending through said anode and communicating with each of said resonators, and means to concentrate anode current flow in the vane region of the conductive portion of said anode comprising a conductive ridge extending toward said anode from said outer wall, the attenuating portion of said anode and anode vanes having boundaries contiguous with said conductive portion and defining with said cathode a dummy region.

10. An electron discharge device as set forth in claim 9 wherein the loss of said attenuating portion increases with distance from those boundaries of the attenuating portion which are contiguous with said conductive portion.

11. A magnetron amplifier comprising a wave guide for transmitting an electromagnetic wave, a cathode for forming and projecting an electron stream, a first anode portion comprising a wall of said wave guide and so placed as to separate said electromagnetic wave from said electron stream, said first anode portion having slots therethrough permitting interaction between said electromagnetic wave and said electron stream, said slots giving

rise to spurious slot modes, means for absorbing said slot modes comprising a second anode portion extending from said first anode portion, means for permitting said slot modes to propagate into said second anode portion comprising a plurality of slots in said second anode portion, and means for preventing said electromagnetic wave from propagating along said second anode portion.

12. A cylindrical magnetron anode for conducting alternating currents comprising first and second portions each having a plurality of vanes extending therefrom and defining therewith an array of anode resonators and having elongated slots therein communicating with each of said anode resonators, the slots in said first portion giving rise to slot modes when an alternating current is induced in said first portion, the resistance of said second portion being low enough to allow said slot modes to propagate a substantial distance therealong and high enough to absorb said slot modes before they can propagate along the entire length thereof.

13. An amplifier device comprising means defining a plurality of cavity resonators, a wave guide adjacent certain of said resonators and coupled thereto by slots extending through the back wall of said resonators, means for directing a stream of electrons adjacent said resonators, input and output means coupled to said wave guide, and means for preventing slot mode energy from being coupled between said output and said input means, said last-mentioned means including a portion of said means defining said cavity resonators, said portion being adjacent said input and output means removed from said wave guide and being of a lossy material to absorb said slot mode energy.

14. An amplifier device in accordance with claim 13 wherein said means defining said plurality of cavity resonators comprises a cylindrical anode structure having a plurality of vanes extending inwardly thereon, and said portion comprises said resonators not coupled to said wave guide.

15. An amplifier device in accordance with claim 14 wherein the entire anode structure of said portion is of a lossy material.

No references cited.