May 22, 1956 L. TONKS 2,747,137

HIGH FREQUENCY ELECTRICAL APPARATUS

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Fig. 1.

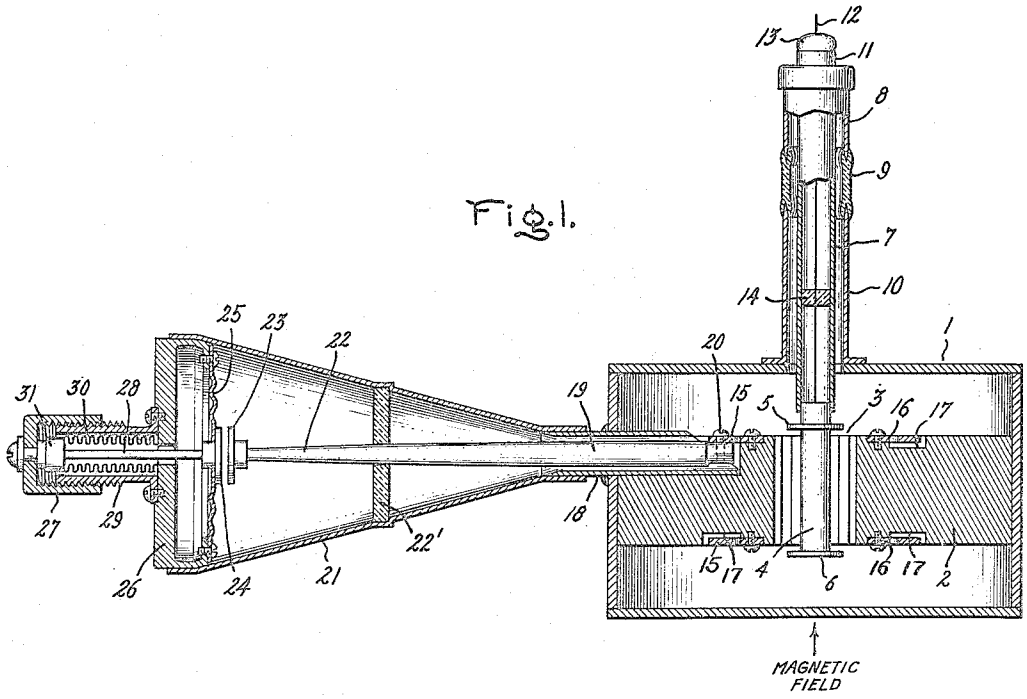
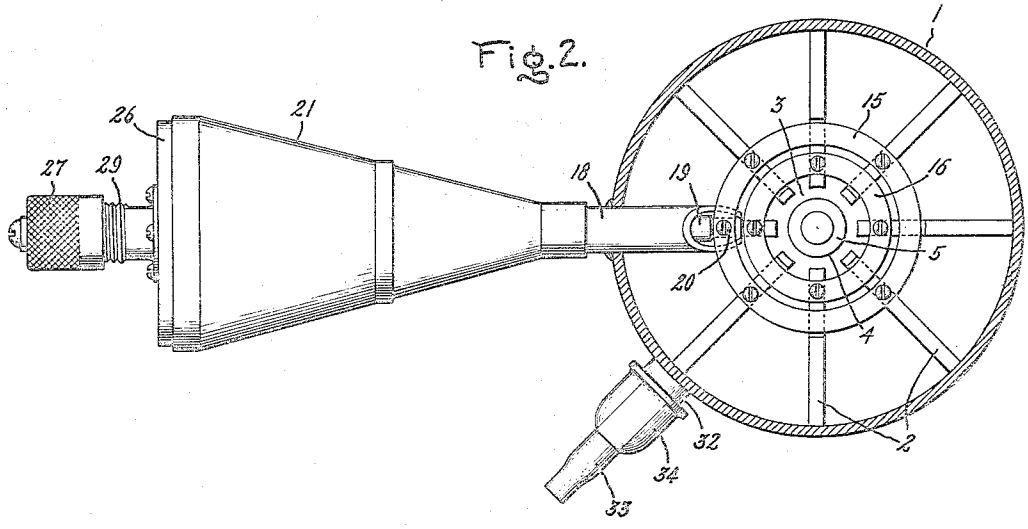


Fig. 2.



Inventor:
Lewi Tonks,

by Harry E. Dunham
His Attorney.

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HIGH FREQUENCY ELECTRICAL APPARATUS

Lewi Tonks, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

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9 Claims. (Cl. 315—39)

My invention relates to high frequency electrical apparatus and more particularly to an improved high frequency coupling for connecting a concentric type transmission line with a resonant structure. While not limited thereto, the coupling of my invention is well adapted for tuning or susceptance controlling systems for high frequency electric discharge devices of the magnetron type.

A large number of tuning arrangements have been employed for controlling the frequency of electric discharge devices of the type employing a space resonant structure. For example, in magnetrons employing a space resonant anode structure a large variety of mechanical tuning arrangements have been employed in which a disk or other tuning structure is moved relative to the anode to control the operating frequency of the device. In other arrangements, a concentric transmission line has been coupled to the resonant anode and the length of the line controlled to vary the operating frequency of the magnetron. In known arrangements of the latter type the coupling with the anode has been such that unwanted impedances and voltages have appeared in the resonant circuits of the anode and the mechanical movements required for tuning the line have been relatively large.

In accordance with the teachings of my invention, I provide an improved tuning or impedance controlling arrangement particularly in combination with a resonant anode structure which provides a wide variation in susceptance with a relatively simple mechanism requiring movements of small magnitude.

It is an object of my invention to provide a new and improved impedance controlling or tuning system for high frequency electrical apparatus.

It is another object of my invention to provide a new and improved coupling between a resonant anode structure and a transmission line of the concentric type.

In accordance with the illustrated embodiment of my invention, the operating frequency of a magnetron of the radial vane type is controlled by controlling the susceptance between the straps which conductively connect alternate vanes. The susceptance is controlled by a transmission line of the concentric type having the outer conductor formed as part of one of the vanes of the magnetron and the inner conductor connected with the strap associated with the vanes not directly connected through the straps with the outer conductor. The transmission line includes a section having a progressively varying characteristic impedance which is terminated by an adjustable capacitor formed by a plate carried by the end of the central conductor and a co-operating plate carried by a diaphragm secured to the outer conductor. The value of capacitance introduced is adjusted so that at a frequency at some mean of the frequency range of operation desired, the susceptance reflected at the anode straps is zero. This frequency will be called the untuned frequency. Physically, the length of line is less than one-half wavelength at the untuned frequency by an amount determined by the magnitude of the capacitance introduced by the terminal plates. In other words, the concentric line is equivalent to a half

wavelength open-ended line with this adjustment of the terminating capacitor. As the capacity at the end of the line is increased by decreasing the gap between the plates, the susceptance at the straps is capacitive and the resonant anode structure is tuned to a lower operating frequency. In a similar manner, by moving the plate in the opposite direction to decrease the capacitance terminating the line, the susceptance at the straps is effectively inductive and the anode structure is tuned to a higher operating frequency. By utilizing a section of transmission line of increasing characteristic impedance with distance from the straps, a multiplication in the susceptance change at the straps as compared with the susceptance change at the end of the line is obtained. By forming the outer conductor of the transmission line as a portion of one of the anode sections, the inner conductor is completely shielded from electromagnetic fields in the region above and below the anode so that unwanted voltages and impedances are not introduced between the straps of the anode.

In the copending Fiske and Nelson application Ser. No. 593,492, filed concurrently herewith (now Patent 2,523,286, dated September 26, 1950), is described and claimed a frequency control system in which a tunable resonator is coupled by a transmission line to an oscillator, such as the resonant anode structure of a magnetron. The disclosure of the Fiske and Nelson application is prior art with respect to my invention.

My invention will be better understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is an elevational view, partially in section, of a tunable magnetron embodying my invention, and Fig. 2 is a plan view, partially in section, of the arrangement shown in Fig. 1.

Referring now to the drawing, the magnetron device includes a generally cylindrical envelope 1 which is formed of material, at least the surface portion of which possesses good electrical conductivity. The space resonant anode structure of the device includes a plurality of vanes 2 extending radially from the side wall of the envelope 1 and terminating short of the axis of the envelope to provide a generally cylindrical space 3 for the reception of a cathode 4. The cathode is generally cylindrical in shape and is provided at its ends with circular end plates or shields 5 and 6 which in the particular form illustrated are formed as an integral part of the cathode. The cathode 4 is supported by a tubular support 7 extending through an opening in the cover of the envelope and secured in vacuum-tight relation to the upper end of a sleeve 8. The sleeve 8 is in turn supported from the cover of the envelope by a cylindrical and vacuum tight insulator 9 and a sleeve 10 which is welded to the cover about the opening through which the tubular support 7 extends. The portion 11 of the support 7 extending beyond the sleeve 8 may be employed as an external connection for the cathode and one terminal of a heater element (not shown). The other supply terminal for the heater element is provided by a conductor 12 sealed through the end of the support 7 by a body of glass 13 and maintained in spaced relation with the interior of the tube 7 by one or more spacing insulators 14.

In order to improve the stability of operation of the magnetron in the desired mode, the two sets of alternate vanes are conductively connected together by conducting rings 15 and 16, respectively, which are screwed or otherwise secured to the edges of the vanes 2 at the region adjacent the inner ends thereof. As illustrated in the drawing, each vane is recessed at 17 to receive one strap in contact with the walls of the recess and the other strap in spaced relation with the walls of the recess. As appears from Fig. 2 of the drawing, the recesses in alternate vanes are arranged in reverse relationship so that the straps are conductively connected only with alternate

vanes. The straps 15 and 16 may be provided at both ends of the anode structure as shown in Fig. 1.

In accordance with an important aspect of my invention, the susceptance between the straps 15 and 16, and as a result the operating frequency of the magnetron, is controlled by a tuning system including a transmission line of the concentric type having an outer conductor 18 and an inner conductor 19. The outer conductor 18 extends through the wall of the envelope 1 in alinement with one of the vanes 2 which is recessed at its upper portion to receive the conductor which is secured in position by brazing or otherwise bonding to the envelope 1 and the recessed vane 2. The outer conductor thus forms a portion of the vane 2 and, as illustrated, terminates at its inner end at approximately the outer edge of the inner strap 16. Thus the outer conductor is directly connected with the alternate anode sections which are connected by strap 16. The inner conductor is secured to strap 15 in any suitable manner, as by a screw 20 and brazing, and is thus connected to the remaining anode sections. Alternatively, the outer conductor 18 may be made a part of one of the vanes connected to the outer strap 15. In that case, the inner conductor would be connected to the inner strap 16. The portion of the transmission line outside of the casing includes a section of outer conductor 21 of progressively increasing diameter and a section of inner conductor 22 of progressively decreasing diameter. The inner conductor may be maintained in position by a spring lock 22' of insulating material as illustrated in Fig. 1. It will be apparent that in the arrangement illustrated the ratio of the outside diameter to the inside diameter increases progressively and that the characteristic impedance therefore increases progressively from the small end of the flared portion 21 to the end of the line. The outer end of the inner conductor 22 terminates in a disk-like member 23 which cooperates with a similar disk-shaped member 24 carried by a flexible diaphragm or reflector 25 to terminate the line with an adjustable capacitor. The diaphragm or reflector 25 is connected with and supported from the outer conductor 21 by an end wall or header 26 which is received in and welded, or otherwise bonded, to the outer conductor 21. The movable disk member 24 is operated from an external thumb cap 27 by an operating rod 28 having its inner end secured to the disk 24 and its outer end rotatably received in the thumb cap 27. The cap engages a threaded sleeve 29 secured to the header 26 so that rotation of the cap 27 is effective to move the disk 24 axially with respect to the fixed elements of the transmission line. The transmission line is sealed by a bellows 30 surrounding the operating rod 28 and bonded to the header 26 and a flange 31 on the outer end of the operating rod 28.

Any suitable output connection for extracting energy from the resonant anode structure may be provided. As illustrated in the drawing, the output circuit is in the form of a concentric line having an outer conductor 32 secured to the side wall of the envelope 1 and an inner conductor 33 sealed through the envelope by a body of glass 34 joining the inner and outer conductors 32 and 33. The inner end of conductor 33 (not shown) is connected directly to one of the radial vanes 2. It will be understood that suitable permanent magnet or electromagnet means will be employed for producing a magnetic field in an axial direction in the interelectrode space. The field may be in the direction of the arrow in Fig. 1.

In the operation of the illustrated embodiment of the invention electrons emitted from the cathode 4 move in curvilinear paths in the space between the cathode and the ends of vanes 2 under the combined action of an axial magnetic field and a radial electric field produced by a voltage impressed between the anode and the cathode 4. The path of the electrons is also determined by the geometry of the anode structure. As the electrons move past the gaps between the ends of the vanes 2, the anode structure is excited into high frequency oscillation. The transmission line system connected with the straps 15 and 16 is designed so that for an intermediate value of operating frequency, namely the untuned frequency, the disk 24 occupies an intermediate position and the susceptance between the two sets of alternate anode sections connected by straps 15 and 16, respectively, is zero. As the disk 24 is moved toward the disk 23, the capacity terminating the line is increased with the result that a capacitive susceptance appears between the straps 15 and 16 thus tuning the device to a lower operating frequency. Conversely, as the tuning disk 24 is moved from its intermediate position away from the tuning disk 23, an effective inductive susceptance is connected between the straps 15 and 16 and the device is tuned to a higher operating frequency. Since the characteristic impedance of the tapered section of the transmission line increases progressively as the ratio of the outside diameter to the inside diameter increases, it will be apparent that the adjustable capacity is at the end of the line having a high value of characteristic impedance. With this arrangement a small change in the susceptance at the outer end of the line is reflected as a larger change in susceptance between straps 15 and 16, thus rendering it possible to effect a large range of tuning of the device with a relatively small change in capacitance at the end of the line. The arrangement of the inner end of the outer conductor of transmission line as a part of the anode structure has also been found very effective in eliminating unwanted impedances and voltages in the tuning system. It will be apparent that this feature is applicable to a concentric line coupled with a resonant anode structure, whether the line forms a part of a tuning system or simply a part of an output system.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. A tuning device for high frequency electrical apparatus comprising, a concentric transmission line including inner and outer conductors and having a portion the characteristic impedance of which increases progressively with the length of the line, an adjustable capacitor and means constituting a reflector terminating said line at the end thereof having the higher characteristic impedance, and means connected to said device for adjusting the magnitude of said capacitor to produce a multiplied change in susceptance at the other end of said line.

2. A tuning device for high frequency electrical apparatus comprising, a length of concentric-type transmission line including inner and outer conductors, said transmission line including a section in which the ratio of the diameter of the outer conductor to the diameter of the inner conductor increases progressively, a disk-like member terminating the inner conductor, a co-operating disk-like member electrically connected with the outer conductor by a reflector means and mounted in opposed relation to said first mentioned disk-like member, and means attached to said device for adjusting said second disk-like member to control the susceptance at the other end of said transmission line.

3. A high frequency electric discharge device of the magnetron type comprising, a generally cylindrical anode structure having a plurality of spaced radially extending anode sections defining a plurality of coupled resonant circuits, conducting means connecting alternate anode sections together, a transmission line of the concentric type having the outer conductor thereof formed as a portion of one of said anode sections and the inner conductor connected with adjacent anode sections by said conducting means, and means terminating said line at the end remote from said anode sections for adjusting the

effective length of said transmission line to control the operating frequency of said device.

4. A high frequency electric discharge device of the magnetron type comprising, a generally cylindrical anode structure having a plurality of spaced radially extending anode sections defining a plurality of spaced resonators, conducting means connecting alternate anode sections together, a transmission line of the concentric type having the outer conductor thereof formed as a portion of one of said anode sections and the inner conductor connected with the other set of alternate anode sections, said transmission line including a section in which the ratio of the diameter of the outer conductor to the diameter of the inner conductor increases progressively, and adjustable capacitance means terminating said line at the end transmission line section at which said ratio is larger.

5. A high frequency electric discharge device of the magnetron type comprising, an anode structure including a plurality of mutually spaced anode sections defining a plurality of cavity resonators, conducting means connecting alternate anode sections together, a transmission line of the concentric type having the outer conductor thereof formed as a portion of one of said anode sections and the inner conductor connected with adjacent anode sections by said conducting means.

6. A high frequency electric discharge device of the magnetron type comprising a generally cylindrical anode structure having a plurality of radially extending anode sections defining a plurality of cavity resonators and a transmission line of the concentric type including inner and outer conductors, said transmission line being mounted with the conductors thereof extending in the direction of one of said anode sections and with the outer conductor formed as a part of said one section, said conductor extending substantially to the inner end of said section, and means connecting the other of said conductors with an anode section adjacent said one section.

7. A high frequency electric discharge device of the magnetron type comprising a generally cylindrical anode structure having a plurality of radially extending anode sections defining a plurality of cavity resonators and a transmission line of the concentric type including inner and outer conductors, said transmission line being mounted

with the conductors thereof extending in the direction of one of said anode sections and with the outer conductor formed as a part of said one section, said conductor extending substantially to the inner end of said one section.

8. A high frequency electric discharge device of the magnetron type comprising a generally cylindrical anode structure having a plurality of radially extending anode sections defining a plurality of cavity resonators, and a transmission line of the concentric type including inner and outer conductors, said transmission line being mounted with the conductors thereof extending in the direction of one of said anode sections and with one of the conductors formed as a part of said one section, said one anode section and said one conductor being similar to the remaining anode sections and said conductor extending substantially to the inner end of said section, and means connecting the other of said conductors with an anode section adjacent said one section near the inner end thereof.

9. A tunable radio frequency generator comprising a magnetron, said magnetron having a plurality of individual cavity resonators having inner open ends, a coaxial transmission line having a portion external said magnetron and having a portion within said magnetron terminating near and connected across the inner open ends of one of said cavity resonators, and means terminating the external portion of said line for adjusting the effective length of said line to control the operating frequency of said generator.

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