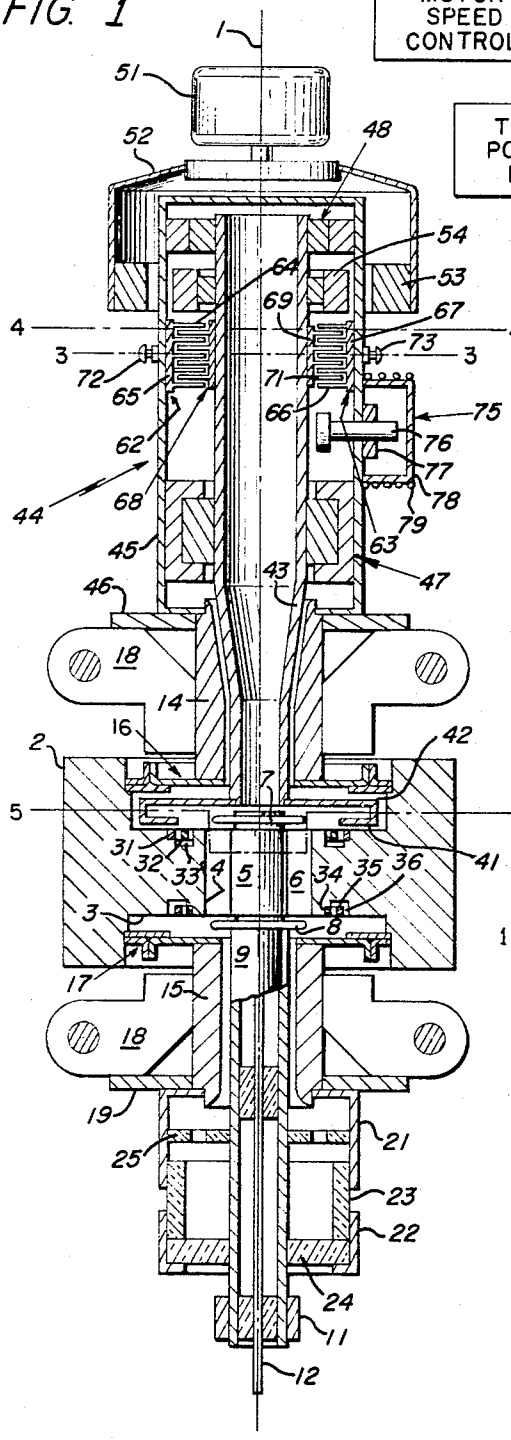
April 23, 1968 R. E. EDWARDS 3,379,925

TUNABLE MAGNETRON HAVING A CAPACITIVE TRANSDUCER MAGNETICALLY COUPLED TO THE TUNING MEMBER

2 Sheets-Sheet 1

Original Filed Dec. 24, 1962

FIG. 1



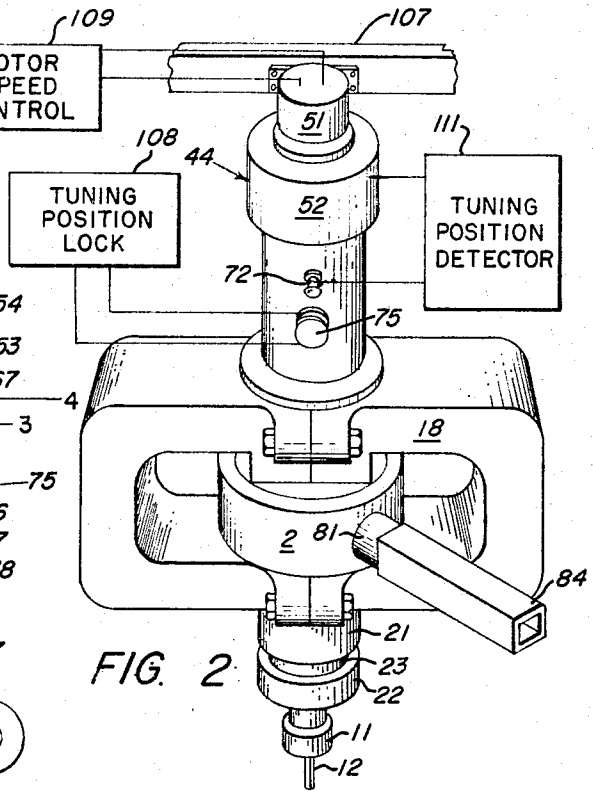


FIG. 2

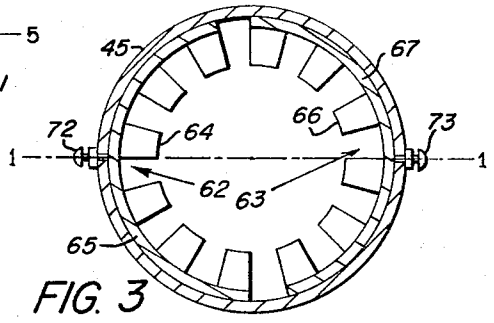


FIG. 3

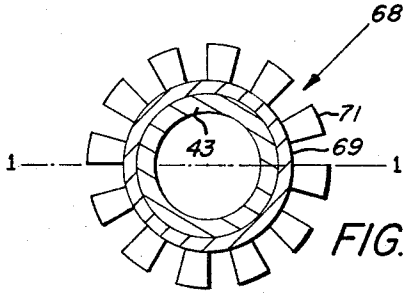


FIG. 4

INVENTOR
ROBERT E. EDWARDS
BY Edgar O. Rost
ATTORNEY

April 23, 1968 R. E. EDWARDS 3,379,925

TUNABLE MAGNETRON HAVING A CAPACITIVE TRANSDUCER MAGNETICALLY COUPLED TO THE TUNING MEMBER

Original Filed Dec. 24, 1962

2 Sheets-Sheet 2

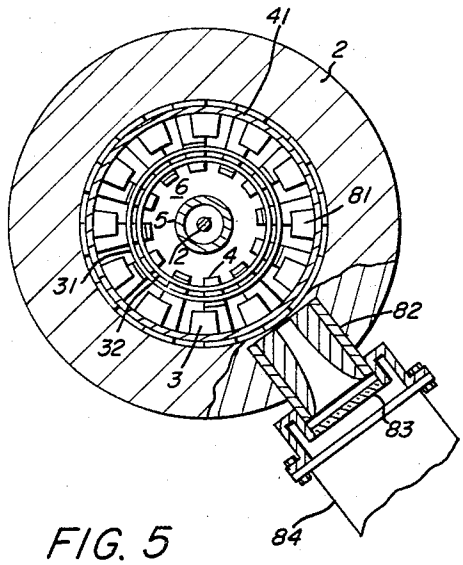


FIG. 5

INVENTOR
ROBERT E. EDWARDS

BY Edgar O. Lost

ATTORNEY

United States Patent Office 3,379,925 Patented Apr. 23, 1968

3,379,925

TUNABLE MAGNETRON HAVING A CAPACITIVE TRANSDUCER MAGNETICALLY COUPLED TO THE TUNING MEMBER

Robert E. Edwards, Lexington, Mass., assignor to Raytheon Company, Lexington, Mass., a corporation of Delaware

Original application Dec. 24, 1962, Ser. No. 248,179. Divided and this application Jan. 27, 1965, Ser. No. 428,392

2 Claims. (Cl. 315—39.59)

ABSTRACT OF THE DISCLOSURE

A tunable magnetron oscillator including a capacitive transducer coupled to a continuously rotatable member to indicate the position of the tuning means relative to the anode resonator structure.

The present application is a division of co-pending application, Ser. No. 248,179, filed Dec. 24, 1962, now abandoned. This invention relates generally to structure for tuning an electron discharge device and more particularly to structure for cyclically tuning a magnetron.

Heretofore, magnetrons have been tuned by the movement of conductive rods or plungers in and out of the magnetron cavities. Usually, a rod is provided for each cavity, and all rods are moved in unison into or out of the cavities. Where it is desired to cycle the tuning of the magnetron, the conductive rods must be moved first in and then out of the cavities with a reciprocating motion. Obviously, the force required to accomplish this motion must be sufficient to overcome the inertia of the rods and accelerate them to accomplish the motion. If it is desired to cycle frequency at a high rate, the acceleration of the rods is necessarily high, and the force required to accelerate them is high. Thus, in such devices, the rate at which the operating frequency can be cycled is limited by the inertia of the rods.

Magnetrons have also been tuned by varying the effective electrical dimensions of the cavities. Heretofore, this has been accomplished in conventional type magnetrons by varying the effective position of the back or outer wall of the cavities. An aperture is provided in the back wall of the cavities, and conductive bodies are caused to move in and out of this aperture, thus varying the effective electrical dimensions of the cavities and thereby varying the cavities' resonant frequency. One limitation of such devices is that only a portion of the back wall can be varied to vary substantially only the inductance of the cavity, and the range of tuning is limited accordingly.

The present invention avoids some of the limitations of prior structures for mechanically tuning magnetrons and provides a substantially circular plate concentric with the tube axis including a number of openings or electrical discontinuities corresponding to different cavities. The plate preferably closely couples with the fields of waves conducted by the cavities, and, in operation, the plate is rotated to cyclically vary the composite reactances of the cavities, and, thus, the operating frequency of the magnetron is varied. Other features of the invention will be apparent from the following specific description taken in conjunction with the drawings in which:

FIG. 1 is a sectional view taken through the axis of a magnetron tube which includes tuning structure incorporating features of the present invention;

FIG. 2 is a perspective view of the magnetron;

FIGS. 3 and 4 are sectional views taken transverse to the tube axis showing details of a capacitive transducer for detecting rotary position of the tuning mechanism within the magnetron envelope; and

FIG. 5 is a transverse sectional view showing details of the tuning plate which is rotated to vary the composite reactances of the cavities.

Turning first to FIG. 1 there is shown a magnetron structure which is substantially a figure of revolution about an axis 1. Parts thereof which are not figures of revolution about the axis 1 will be apparent from the description below.

The body of the magnetron includes an anode block 2 which is substantially cylindrical in shape and includes a plurality of vanes such as vane 3 which extend from the inner perimeter of the block in a radial fashion toward the center at the axis 1. The ends 4 of the vanes define a cylinder substantially concentric with the cathode cylinder 5, and between these two lies the annular interaction space 6. The cathode 5 includes end shields 7 and 8 which are substantially flat discs attached to the opposite ends thereof, and is supported at the end of a tube 9 which extends concentric with the axis 1 to a terminal 11 which is referred to herein as the cathode terminal. A lead 12 is insulatedly supported within the cylinder 9 and carries electric power to a heater element located within the cathode cylinder 5.

The upper and lower ends of the anode cylinder 2 are sealed to magnetic field pole pieces 14 and 15 by mutual attachments to flexible structures 16 and 17, respectively. These structures are preferably somewhat flexible to accommodate differences of expansion of the various parts of the tube during operation. Pole pieces 14 and 15 attach intimately to opposite poles of a magnet 18, and thus there is produced between these pole pieces a transverse magnetic field which extends through the interaction space 6 substantially parallel to the axis 1. The cathode tube 9 extends through an evacuated housing attached to support ring 19 and comprised of conductive cylinders 21 and 22 connected together by an insulating cylinder 23, and cylinder 22 is connected and sealed to the tube 9 by an insulating disc 24. A second insulating disc 25 is provided so that the tube 9 is rigidly supported by the two insulating discs insuring rigid positioning of the cathode 5 relative to the anode vanes.

The anode vanes are preferably strapped by two pairs of ring-shaped conductive straps. The upper pair of straps 31 and 32 are set into notches such as 33 in the vanes. Strap 31 is directly attached to one group of alternately disposed vanes, while strap 32 is directly connected to the other group of alternately disposed vanes. The lower pair of straps 34 and 35 are inserted in another set of notches in the vanes such as notch 36, and strap 34 is connected to the same vanes as strap 31, whereas strap 35 is connected to the same vanes as strap 32. The purpose of these straps is to short-circuit undesired modes of operation by insuring that alternate vanes are instantaneously at the same RF potential. Two pairs of straps are employed, one attached along the upper edge of the vanes, and one attached along the lower edge to provide electrical symmetry.

Between the flexible seal 16 and the upper edge of the vanes 3 there is located a tuning ring or element 41. In the embodiment of the invention shown in FIG. 1 and FIG. 5, the tuning ring 41 is mounted to the outer periphery of a circular plate 42 which in turn attaches near its center to a tubular drive shaft 43. The drive shaft 43 is concentric with the axis 1 and extends through the pole piece 14 into the tuner drive housing 44. The housing 44 includes an evacuated envelope 45 enclosing the shaft 43, and sealed at its bottom end to the housing support ring 46 which in turn seals to the pole piece 14.

The shaft 43 extends the length of the housing and is supported along its length by bearings. These are bearings made of a material sold under the trademark "Graphitar" which is suitable for use as a bearing surface within an

evacuated envelope. The bearings 47 and 48 each include two parts which slidably engage. One part attaches to the envelope 45, and the other part attaches to the shaft 43. The outer part to bearing 47 includes bosses as shown to prevent axial movement of the shaft 43 while permitting rotational motion.

The shaft 43 is driven in rotation by magnetic coupling through the wall of envelope 45 to an external drive motor 51. The motor drive engages a shell 52 disposed substantially concentric with the axis 1 and which is driven in rotation about the axis. The lower inside rim of shell 52 is equipped with one or more magnetic pole pieces which substantially encircle the envelope 45. Within the envelope 45 the shaft 43 is equipped with one or more magnetically permeable members 54 disposed to couple magnetically with the pole pieces 53. Accordingly, in operation, the motor 51 drives shell 52 in rotation, and this motion is imparted to the shaft 43 by way of the magnetic coupling between the pole pieces 53 and magnetically permeable pieces 54. Thus, the shaft is driven in rotation by the motor 51.

The position of shaft 43 is detected by a capacitive transducer. The transducer includes capacitive elements 62 and 63, each of which includes stacks of vanes attached to a section of a ring disposed against the inside wall of the envelope 45. For example, capacitive element 62 includes vanes 64 attached to ring section 65, while capacitive element 63 includes vanes 66 attached to ring section 67. The arrangement of the rings and vanes is shown in FIG. 3 which is a sectional view taken through the axis 1 as illustrated. The elements 62 and 63 are in capacitive relationship with a third capacitive element 68. Element 68, as shown in FIG. 4 which is a sectional view taken through the axis 1 as shown, is attached to the drive shaft 43 and in electrical contact therewith. It is composed of a ring 69 fixed to the shaft and concentric with the shaft supporting vanes 71 which are interleaved with the vanes 64 or 66. Thus, each of the elements 62 and 63 are in capacitive relationship with the element 68. In operation it is preferable that the anode structure and the drive shaft 43, as well as the magnet and other parts electrically connected directly to the anode be at ground potential, and so each of the elements 62 and 63 form a capacitance to ground, and the total capacitance between elements 62 and 63 is the summation of these capacitances to ground. With this structure it is preferable to attach terminals 72 and 73 to the elements 62 and 63, respectively, neither of which is grounded, and to detect the capacitance between the terminals as an indication of the rotary position of the tuning ring which in turn is indicative of the operating frequency of the magnetron. Since neither of the terminals 72 or 73 is grounded, the capacitance between them is unaffected by fluctuations in ground potential level. For example, if the ground potential level at the magnetron should deviate slightly from ground potential in circuitry for detecting the capacitance between terminals, the detector indication would be in error. The structure described above avoids this.

The capacitive transducer described above as shown in FIGS. 3 and 4 includes inductive fingers such as 64, 66 and 71 which are interleaved and may be positioned in substantial registry with each other. It is preferred that when the fingers are in substantial registry and form stacks that the number of such stacks be the same as the number of openings or discontinuities in the tuning ring 41. This is desired so that when the shaft 43 is rotated and the output frequency from the magnetron varies through a complete cycle that the capacitance between the terminals 72 and 73 also varies through a complete cycle and that the phasing between the cycling of the capacitance and the cycling of the output frequency be substantially the same. In other words, it is preferred that there be synchronism between the signal from the transducer which indicates output frequency and the output frequency itself.

A braking mechanism 75 is included to provide means for bringing the shaft 43 to an immediate stop, and thus hold the output frequency to a fixed value, if desired. This braking mechanism might include, for example, a plunger 76 which extends through the envelope wall 45 for exerting a friction drag against the shaft 43 to slow down or stop its motion. The plunger is mounted slidably to a bearing 77 which is enclosed by housing 78 sealed to the envelope 45. A portion of the plunger is preferably highly magnetically permeable so that the position of the plunger can be controlled by a magnetic field generated by a coil 79 external to the housing 78. This coil 79 is energized by a controllable source of current not shown.

In operation, it is preferable that all parts except the cathode 5 and the parts directly attached thereto be at ground potential or at a substantially fixed potential. A power supply, not shown, provides a relatively large negative potential which is coupled to coupling 11 and also provides a supply of current to the heater lead 12 for causing a heater element, not shown, to heat the cathode 5. Thus, the outside surface of the cathode 5 and the ends of the vanes 4 bound a substantially radially directed electric field in the interaction space 6. This field combines with the substantially axial magnetic field bounded by the pole pieces 14 and 15 to compel electrons issuing from the cathode to move along arcuate paths adjacent the anode cavities and, thus, initiate operation of the magnetron. During operation as the tuning ring 41 is rotated, the composite reactances of cavities (these are the spaces between the vanes 3) are altered cyclically, and thus the output frequency of the magnetron is varied cyclically.

FIGS. 1 and 5 illustrate one embodiment of the invention in which the tuning ring is mounted to the outer periphery of the circular plate 42 and includes a plurality of flat vanes such as 81, each of which is capable of covering at least a part of the opening at the top of a cavity. As shown in FIG. 5, these tuning vanes do not extend the full depth of the opening at the top of the cavities, but extend only from substantially the back wall of the cavities to the straps 31 and 32. Thus, the tuning vanes 81 in FIG. 5 are designed primarily to cyclically vary the composite inductance of the cavities and only to a lesser degree the composite capacitance in the particular configuration illustrated when the tuning ring is driven in rotation. FIG. 5 also illustrates structure for coupling an output from the cavities. This structure includes a circular transformer section 82 inserted in an opening through the anode cylinder 2 entering one of the cavities at the back wall thereof, a circular window 83 of material transparent to RF waves covering the transformer section, and an output waveguide 84 extending therefrom.

FIG. 2 illustrates the external appearance of the magnetron showing the shape of the magnet and location of parts described above. The motor 51 is preferably mounted to structure such as 107 which attaches to the magnet. Controls 108 and 109 are for controlling the friction brake mechanism 75 and the speed of motor 51, respectively. The position of the tuning ring is detected by tuning position detector 111 which is coupled to the terminals 72 and 73.

The specific descriptions included hereinabove relate to various embodiments of the applicant's invention including at least one body having electrically conductive parts disposed in capacitive and/or inductive relationship to resonant cavities in an electron discharge device of the magnetron type with means for rotating said body continuously in one direction or reversing in the opposite direction to thereby cyclically vary the operating frequency of the device. It should be clearly understood that the conductive parts of the tuning body may have shapes other than those illustrated and other drive mechanisms could be employed for imparting motion to the tuning body without deviating from the spirit or scope of the invention as set forth in the accompanying claims.

What is claimed is:

1. In an electron discharge device including a cathode, an anode member having a plurality of resonant cavities circumferentially disposed around the cathode, and a tuning means defining a plurality of conductive and nonconductive members spaced apart from and overlying the top wall of said cavities;

means for rotating said tuning means compirsing a drive motor magnetically coupled to a shaft attached to said tuning means;

capacitive transducer means for detecting the position of said shaft to thereby indicate the relative position of the tuning means to the anode member;

said capacitive transducer means having a plurality of movable capacitive elements secured to said shaft and fixed capacitive elements interleaved with said movable capacitive elements;

the fingers of said fixed and movable elements being in intermittent registry to thereby form stacks of elements, the number of said stacks being substantially

equivalent to the number of nonconductive parts in said tuning means.

2. An electron discharge device according to claim **1** wherein said fixed capacitive elements comprise first and second annular members with inductive fingers attached thereto and each of said annular members are in capacitive relationship with said movable capacitive elements.

References Cited

UNITED STATES PATENTS

3,087,124	4/1963	McLeod	331—5 X
3,121,839	2/1964	Malenick et al.	340—200 X
3,247,421	4/1964	Backmark	315—39

FOREIGN PATENTS

326,602	11/1954	France.

HERMAN KARL SAALBACH, *Primary Examiner.*

ELI LIEBERMAN, *Examiner.*

S. CHATMON, JR., *Assistant Examiner.*