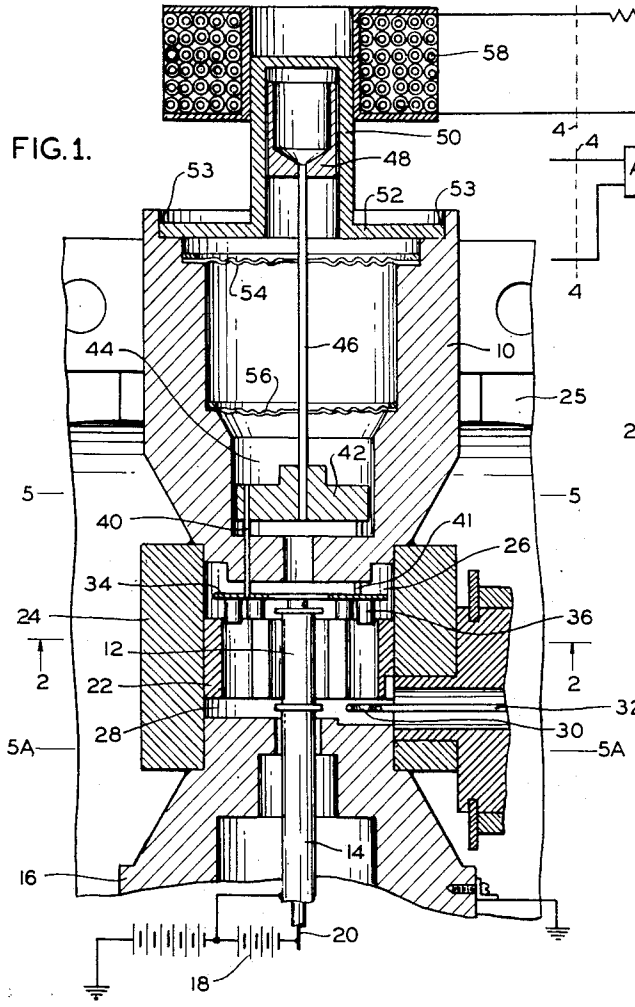
March 18, 1952 S. SONKIN 2,589,885

TUNABLE MAGNETRON

Filed Oct. 19, 1945 3 Sheets-Sheet 1

FIG. 1.



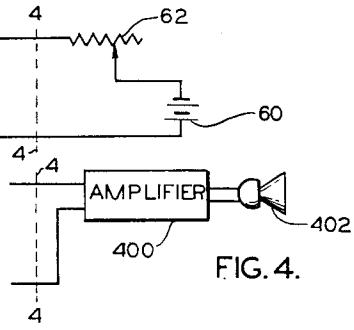


FIG. 4.

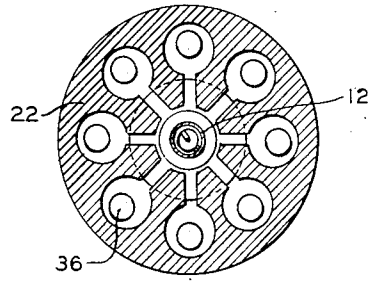


FIG. 2.

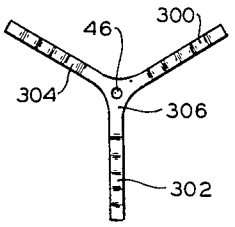


FIG. 3.

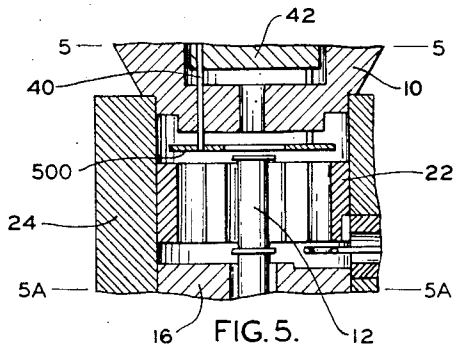


FIG. 5.

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March 18, 1952 S. SONKIN 2,589,885

TUNABLE MAGNETRON

Filed Oct. 19, 1945 3 Sheets-Sheet 2

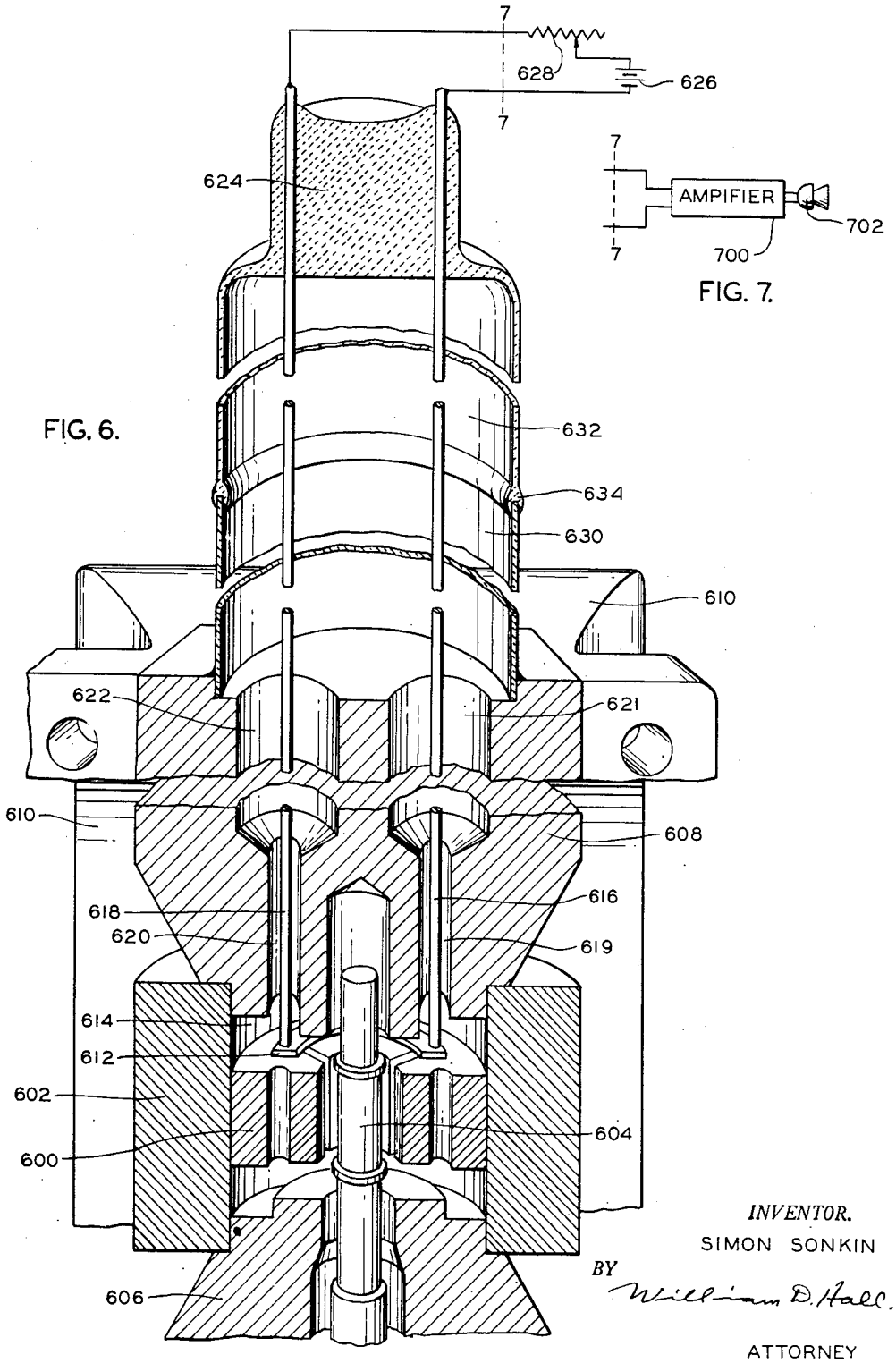

FIG. 7.

FIG. 6.

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TUNABLE MAGNETRON

Filed Oct. 19, 1945 3 Sheets-Sheet 3

FIG. 8.

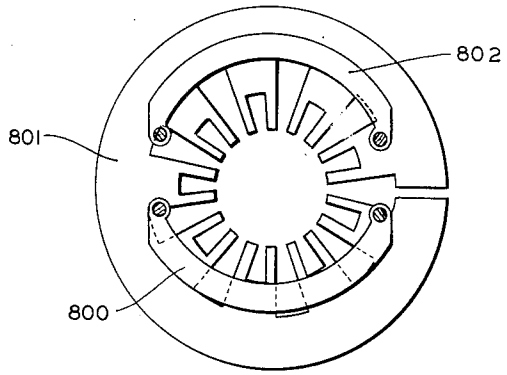


FIG. 9.

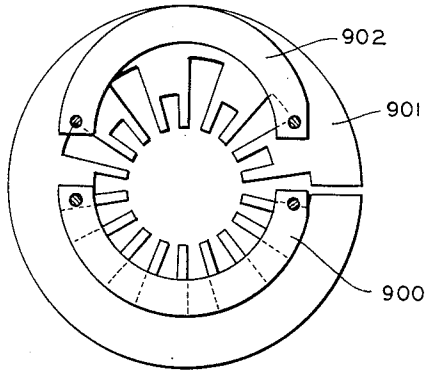
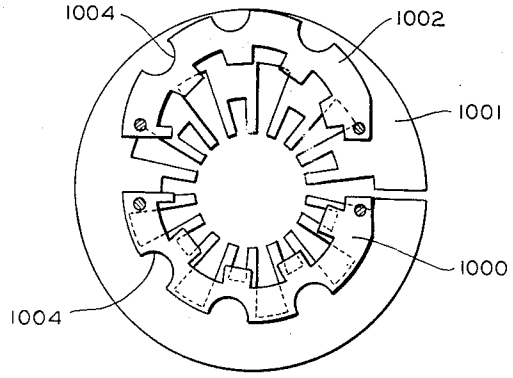


FIG. 10.



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UNITED STATES PATENT OFFICE

2,589,885

TUNABLE MAGNETRON

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Application October 19, 1945, Serial No. 623,423

11 Claims. (Cl. 315—40)

1

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to ultra-high frequency generators of magnetron type in which ultra-high frequency oscillations are generated by a plurality of resonators set into oscillations by high velocity electrons moving along curvilinear or orbital paths because of the joint action of the electrostatic and electromagnetic fields.

It is an object of this invention to provide a means for adjusting the frequency of oscillation of a magnetron.

An additional object of this invention is to provide instrumentalities which, when connected to a source of varying current such as alternating current, audio, or video signal, may be used for frequency modulating the output of the magnetron.

It is another object of this invention to provide a tuning mechanism for a magnetron in which the tuning mechanism is located within one of the magnetic pole pieces of a magnetron thereby conserving space, using the pole piece as a sturdy housing for the mechanism, and affording convenient manipulation of the tuning member.

Two extensively used forms of ultra-high frequency magnetron oscillators incorporate, in one instance the so-called hole-and-slot anode, and, in the other a vane-type anode with the cathode centrally positioned with respect to the resonators of the anode. In order to separate the modes of vibration in the magnetrons of these types they are ordinarily provided with some sort of strapping. The operating frequency of such plural cavity magnetrons is chiefly determined by the dimensions of the anode, which in turn determine the distributed capacities and inductances of the resonators. When the frequency generated by the magnetrons is especially high the use of strapping becomes quite difficult because of the small dimensions of the anode, and when this is the case the anode is given the form of the so-called "Rising Sun" in which the radial dimensions of the radially diverging cavities or slots have different radial lengths. The separation of the modes of vibration in the anodes of this type is accomplished by the asymmetry of the resonators. For a more detailed description of the Rising Sun magnetron, reference is made to an application for patent of Sidney Millman, filed March 1, 1946, Serial No. 651,317, title, "Rising Sun Magnetron."

2

In the production of plural cavity magnetrons, whether they are of the hole-and-slot, vane, or the Rising Sun types, it is often difficult to construct the components thereof to dimensions which generate the precisely desired frequency, this being especially so when the oscillations are of extremely short wave length. Consequently it becomes desirable to have some simple mechanical arrangement for tuning magnetrons after their assembly in order to shift its operating frequency to an exact predetermined desired value. The tuning means permits considerable relaxation of the anode manufacturing tolerances at the machine shops, and is also desirable for field use for obvious tactical reasons, for example, when the oscillator is used with the radar equipment, and there is an ever present possibility of "jamming" of the specific wave length by hostile transmitters

The invention discloses three methods of tuning magnetrons by means of electromagnetic converters which act to convert controlling currents into variations in the position of tuning instrumentalities. In the first two methods the tuning is accomplished by varying the posotion of a washer equipped with a plurality of metallic tuning pins or a tuning metallic washer with the pins placed above the anode in one of the end zones of the magnetron, the position of the washer being adjustable by means of a solenoid and a plunger mounted within the solenoid and connected to the washer. The plunger is either raised or lowered in the solenoid, depending upon the current carried by the solenoid winding, and the linear travel of the plunger either raises or lowers the washer with respect to the anode. This varying of the air-gap between the washer and the anode changes the distributed capacitance and inductance of the anode and thus changes the output frequency of the magnetron. If the position of the washer is varied in response to some intelligence signal, the position of the washer with respect to the anode will follow the intelligence signal, which will produce a frequency modulated signal in the output of the magnetron.

In the third embodiment of the invention tuning or frequency modulation of magnetron's output is obtained by varying the positions of two metallic elements made of copper or copper-plated stainless steel whose shape may best be defined as two split portions of a washer or semiwashers which are separated from each other and the anode by air-gaps. Each of the semiwashers is placed in the end zone of the magnetron where they are held in suspended position above the

anode by the metallic rods protruding through a pole piece. When current of proper polarity is impressed on the rods and on the semiwashers, the semiwashers either approach or recede radially from the center of the anode structure because of the interaction between the permanent magnetic field and the electromagnetic field produced by the currents carried by the semiwashers. When the semiwashers either approach or recede from the center of the anode, they vary the distributed inductances and capacitances of the resonators and thus produce a variation in the frequency generated by the magnetron.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawings in which;

Fig. 1 is a vertical cross-sectional view of a tunable magnetron,

Fig. 2 is a horizontal cross-sectional view of the anode proper taken along line 2—2 illustrated in Fig. 1,

Fig. 3 illustrates a plan view of the corrugated springs used in connection with Fig. 1,

Fig. 4 illustrates connections between the magnetron of Fig. 1 and a source of signals for frequency modulating the output of the magnetron,

Fig. 5 is a vertical cross-sectional view of a modified tuning arrangement for the magnetron,

Fig. 6 is a vertical cross-sectional view of still another tuning arrangement for a magnetron,

Fig. 7 illlustrates modified connections between the tuning means and a source of signals which produce frequency modulation in the output of the magnetron of Fig. 6,

Figs. 8, 9, and 10 illustrate several versions of an application of the tuning arrangement illustrated in Fig. 6 to a magnetron having the Rising Sun anode.

Referring to Fig. 1, it discloses a vertical cross-sectional view of the magnetron with the tuning mechanism mounted in the upper pole piece 10 of the magnetron and with the cathode 12 being supported by a (Kovar) tube 14 mounted in the opposite pole piece 16. The heater coil of the cathode is mounted within the cathode 12 and is not visible in the figure. The heater is connected to a heater battery 18 through a centrally mounted and insulated conductor 20 and tube 14. The outer surface of the cathode is coated in the usual manner with the electron-emitting oxides such as barium and strontium oxides. An anode 22 whose horizontal cross-sectional view taken along line 2—2 is illustrated in Fig. 2, is by the way of an example a known hole-and-slot anode. As mentioned previously, any other type of anode could be used with the tuning structure disclosed in Fig. 1 so long as the tuning elements are modified or adapted to produce the desired frequency changes in the output of the anode. Some of the possible modifications of the tuning elements are illustrated in Fig. 5 and also in my co-pending application Serial No. 623,422, titled "Tunable Magnetron," filed on October 19, 1945, now abandoned. The anode is mounted in a non-magnetic metallic shell 24 which integrates the pole pieces 16 and 18 and the anode 22 into a single rigid structure with the pole pieces being positioned above and below the anode and defining the upper and lower end zones 26 and 28 of the magnetron respectively. The magnetic field is supplied by a pair of permanent magnets, one of which, magnet 25 being partially illustrated in Figure 1. The lower end zone is used for mounting a loop 30 which is connected to an outgoing concentric line 32 representing the output circuit of the magnetron. The concentric line may be connected to a broadly tuned wave guide or any other means for utilizing its output in well known manner. The upper end zone includes a flat washer 34 provided with a plurality of metallic tuning pins 36 made of copper or copper-plated stainless steel which are primarily responsible for altering the frequency of the magnetron in the manner fully discussed in my previously mentioned application, Serial No. 623,422, now abandoned. In Fig. 2, the diameter of the tuning pins 36 has been illustrated as being considerably smaller than the diameter of the holes. Whenever maximum obtainable range of tuning or maximum frequency modulation is desired the diameter of the tuning pins should be made as large as possible and only enough clearance provided between the pins and the cavities to prevent flash-overs with the existing ultra high frequency potentials. Moreover, the pins should be positioned coaxially with the holes for obtaining the maximum change in frequency per unit length of travel of the pins. The disk is supported by a plurality of metallic rods 40 and 41 which are attached to a rod holder 42 made of ferromagnetic metal placed in a well 44 of the upper pole piece 10. The rod holder itself is attached to a rod 46 and a ferromagnetic solenoid plunger 48. The plunger is mounted in a non-magnetic metallic cylinder 50 which, together with plate 52, acts as the upper vacuum seal of the magnetron, the seal being accomplished by a soldered joint 53 between the pole piece and plate 52. Rod 46 is coaxially supported within pole piece 10 by a pair of spaced corrugated springs 54 and 56 which are connected in the center to rod 46 and whose outer ends are connected to pole piece 10. The plan view of springs 54 and 56 is illustrated in Fig. 3. The spring is bifurcated and consists of corrugated elements 300, 302, and 304, the central junction portion 306 of the three arms being joined to rod 46 by a soldering joint. The corrugations in springs 54 and 56 are introduced for making them very flexible so that they offer low resistance to the vertical travel of the structure centering rod 46 within the pole piece. The springs also hold plunger 48 in the central position within cylinder 50, the plunger fitting loosely into the cylinder for avoiding the frictional losses between the cylinder and the plunger. Cylinder 50 is surrounded by a coil 58 which is connected to a source of potential 60 through a rheostat 62. When the solenoid coil 58 is energized, plunger 48 is drawn up, against the resistance of springs 54 and 56, to the position corresponding to the least reluctance path for the flux produced by the solenoid. The plunger is drawn into the solenoid to the extent controlled by the magnitude of the voltage applied to coil 58 and the resiliency of the springs. The frequency of the magnetron is varied in accordance with the position of the tuning pins with respect to the anode. When it is desirable to produce a frequency modulated signal in connection with the tuning arrangement illustrated in Fig. 1, the solenoid coil 58 is connected to an amplifier 400 and a microphone 402, in which case the position of the tuning disk 34 will follow the signal impressed on microphone 402. It is obvious that microphone 402 may be substituted by any other source of audio or video signals, the limitation imposed on the frequency of the signal impressed on the solenoid being the natural period of the mechanical system operated by the solenoid.

Fig. 5 discloses a tuning or frequency modulating arrangement for a magnetron in which the tuning is accomplished by means of a metallic washer **500** made of copper or copper-plated steel, the remaining elements in the structure illustrated in Fig. 5 being identical to those illustrated in Fig. 1 and therefore bear the same numerals. Fig. 5 may be superimposed over Fig. 1 for the completion of Fig. 5 by matching the illustrated dotted lines 5—5 and 5A—5A illustrated in both figures. The tuning arrangement illustrated in Fig. 5 will produce smaller frequency changes than the one illustrated in Fig. 1 since the pins produce larger changes in the distributed inductances and capacitances of the anode than the disk. For a more detailed description of the functioning of the tuning arrangement illustrated in Fig. 5 reference is made to my co-pending applications on "Tunable Magnetron," Serial No. 623,422, filed October 19, 1945, now abandoned, and Serial No. 623,624, filed October 19, 1945, now Patent No. 2,450,619, dated October 5, 1948. Fig. 6 illustrates a vertical cross-sectional view of an additional modification of the magnetron tuning or frequency modulation arrangement, with some of the elements of the structure foreshortened to illustrate the mechanism in a single drawing. A slot-and-hole magnetron anode **600** is fixed to an outer shell **602**. A cathode **604** is centrally mounted in the central opening of the anode in the usual manner, the cathode structure being supported by a lower "cathode" pole piece **606** in the known manner. The upper "tuning" pole piece **608** besides being used as a low reluctance path for a permanent magnet **610**—which furnishes the necessary flux for the cathode-anode space—is also used for supporting the tuning structure of the magnetron. Since the illustrated cross-sectional view bisects the anode, only one half of the tuning structure is visible in the drawing, the other half being identical in all respects to that illustrated in Figure 6. The illustrated half of the tuning structure consists of a semiwasher **612** which is supported in the upper end zone **614** of the magnetron in spaced relationship with respect to the anode by two metallic rods **616** and **618** placed in elliptical slots **619**, **620**, **621**, and **622** of the tuning pole piece. The four rods, two for each semi-washer **612**, protrude through a glass seal **624**, the protruding terminals of the rods being connected either to a source of potential **626** through a rheostat **628** or to an amplifier **700** and a microphone **702** illustrated in Fig. 7, which may be connected to Fig. 6 along a dotted line 7—7. The two pairs of rods may be connected either in series or in parallel to the source of potential, preferably in a manner which will result in the instantaneous currents in the semiwashers to flow in opposite directions. The vacuum seal of the magnetron is completed by means of a metallic cylinder **630** and a glass cylinder **632**, the metallic cylinder **630** being soldered to the pole piece and the glass cylinder making a glass seal **634** with the metallic cylinder.

Figs. 8, 9, and 10, illustrate a plan view of the anode and tuning semiwashers **800** and **802**, **900** and **902**, **1000** and **1002**, with respect to the anodes **801**, **901**, and **1001** respectively. The anode structure illustrated in these figures is of the "Rising Sun" type which is disclosed in the co-pending application of Sidney Millman on "Rising Sun Magnetron," filed March 1, 1946, Serial No. 651,317. The figures illustrate the two extreme possible positions of the tuning semiwashers with respect to the anode. The lower washers **800**, **900**, and **1000**, illustrate the extreme inward position of the semiwashers while semiwashers **802**, **902**, and **1002**, illustrate their extreme outward position with respect to the resonating elements of the Rising Sun anode. This change of the positions of the semiwashers with respect to the anode is accomplished by impressing a current of desired magnitude on the metallic semiwashers from a source of potential **626** or microphone **702** illustrated in Figs. 6 and 7 respectively. When current flows through the metallic rods **616** and **618**, Fig. 6, and semiwasher **612**, because of the interaction between the permanent magnetic flux produced by the permanent magnet **610** in the end zones of the magnetron and the magnetic field surrounding the semiwashers such as **612** or any of the semiwashers illustrated in Figs. 8 through 10, these semiwashers are deflected toward or away from the center line of the magnetron as is illustrated in Figs. 8 through 10. When the semiwashers are deflected outwardly and away from the center line of the anode structure as illustrated by the positions of the semiwashers **802**, **902**, and **1002**, the effect of the semiwashers on the distributed inductances and capacitances of the resonating elements of the anode is least and therefore the frequency of the magnetron is determined primarily by the physical dimensions of the anode. When the deflecting forces acting on the semiwashers are such as to swing both of them simultaneously toward the center of the anode, as illustrated by the semiwashers **800**, **900**, and **1000**, the electrical coupling between the tuning semiwashers and the anode is maximum, which produces a corresponding change in the modes of vibration of the resonating elements in the anode. This in turn produces the sought frequency change in the output circuit of the magnetron. While the semiwashers in Figs. 8 through 10 are illustrated so that the right semiwashers are in the extreme outer position while the left semiwashers are in the extreme inner position with respect to the center of the anode structure, the actual operation of semiwashers is such that both of them simultaneously are either in the extreme inner or outer positions. It is obvious that such operation of the semiwashers will produce the desired maximum frequency changes as well as uniform loading and uniform frequency changes over the entire circumference of the anode, a condition always desirable in any tuning arrangement of the symmetrical anode structures of the magnetrons.

While the invention has been specifically illustrated in connection with the hole-and-slot and "Rising Sun" types of anodes, it is to be understood that it is equally applicable to the anodes having other known configuration of the resonating elements, such as vane type anodes, in which case the tuning washers, such as washer **500**, may be of plain circular type and the semiwashers also of the plain circular type, such as those illustrated in Figs. 6, 8, and 9. In Fig. 10 the semiwashers are provided with circular cut-outs **1004** for reducing the local resonances in the semiwashers. For additional modifications of the shapes of the semiwashers, reference is made to my co-pending application Serial No. 623,422, filed October 19, 1945, now abandoned.

While the invention has been described with reference to several particular embodiments, it will be understood that various modifications of

the apparatus shown may be made within the scope of the following claims.

I claim:

1. A magnetron having a multi-resonator anode, pole pieces mounted in spaced relationship with respect to said anodes thereby defining the end spaces of said magnetron, electrically conductive tuning means located within one of the end spaces in spaced relationship with respect to said anode and the adjacent pole piece, movable conductive supporting means for said tuning means mounted within one of said pole pieces, said tuning means being electromagnetically adjustable with respect to said anode, the position of said tuning means controlling the operating frequency of the resonators of said anode.

2. A magnetron as defined in claim 1 in which said tuning means is a metallic washer mounted coaxially with respect to said anode, the radial dimension of said washer being proportioned so as to produce a predominantly inductive tuning of said anode.

3. A magnetron as defined in claim 1 in which said tuning means includes a plurality of metallic tuning pins insertable into the resonating cavities of said anode, the position of said metallic pins—when inserted—being in the inductive region of said resonators whereby the tuning of said anode is accomplished by altering primarily the distributed inductances of said resonators.

4. An ultra-high frequency magnetron including a cathode, a multi-resonator anode coaxially mounted with respect to said cathode, first and second pole pieces mounted in spaced relationship with respect to said anode, said first pole piece and said anode defining an end space, metallic instrumentalities located within said end space, movable conductive supporting means for said instrumentalities mounted within said first pole piece, and means, including an electromagnetic converter for altering the position of said supporting means and said instrumentalities with respect to said first pole piece for varying the operating frequency of said magnetron.

5. An ultra-high frequency magnetron having a multi-resonator anode, pole pieces mounted in spaced relationship with respect to said anode thereby defining the end spaces of said magnetron, tuning instrumentalities mounted within one of the end spaces in spaced relationship with respect to said anode and the adjacent pole piece, and electromechanical means for adjusting the position of said tuning instrumentalities with respect to said anode, said means including a solenoid for altering position of said tuning instrumentalities with respect to said anode whereby the operating frequency of the resonators of said anode is governed by the action of said solenoid.

6. An ultra-high frequency magnetron having a multi-resonator anode, first and second pole pieces respectively above and below the circumferential surfaces of said anode, end spaces between said pole pieces and said surfaces, a metallic element positioned in spaced relationship with respect to the adjacent circumferential surface of said anode and said first pole piece in the end space defined by said first pole piece, a solenoid coil, a plunger within said solenoid, and mechanical connections between said plunger and said element, said plunger varying the position of said element with respect to said anode in response to the electromagnetic field of said coil whereby the operating frequency of the resonators of said anode is governed by the electromagnetic field produced by said coil.

7. An ultra-high frequency magnetron as defined in claim 6 in which said anode is a hole-and-slot anode, and said element is a washer having a radial dimension substantially equal to the combined radial dimension of said slot and said hole.

8. An ultra-high frequency magnetron as defined in claim 6 in which said element is a metallic washer and a plurality of metallic tuning pins connected to said washer.

9. An ultra-high frequency magnetron including a cathode, an anode with a plurality of resonators, said cathode and said anode having a common longitudinal axis, first and second pole pieces mounted in spaced relationship with respect to the circumferential surfaces of said anode, two semiwashers, each of said semiwashers being mounted on two metallic rods in spaced relationship with respect to each other, said cathode and with the adjacent circumferential surface of said anode and said first pole piece, metallic and glass members mounted on the first pole piece and forming a part of a vacuum seal of said magnetron, said rods protruding through said glass member, and a gas-tight seal between said glass member and said rods.

10. An ultra high frequency magnetron including a cathode, an anode with a plurality of resonators, said cathode and said anode having a common longitudinal axis, electrodynamic means for reacting with the fields in said resonators to modify said fields, comprising a plurality of metallic washer segments held in spaced relationship with respect to each other, said cathode and one of the circumferential surfaces of said anode.

11. An ultra-high frequency magnetron including a cathode, an anode with a plurality of resonators, an evacuated chamber enclosing said cathode, anode and resonators, said cathode and said anode having a common longitudinal axis, a tuning instrumentality mounted adjacent to said anode resonators, electrodynamic means for altering the position of said instrumentality relative to said resonators, resilient supporting means for said tuning instrumentality located within said chamber and intermediate said electrodynamic means and said instrumentality, for varying the characteristics of the generated wave in accordance with variations in the position of said instrumentality with respect to said resonator.

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