

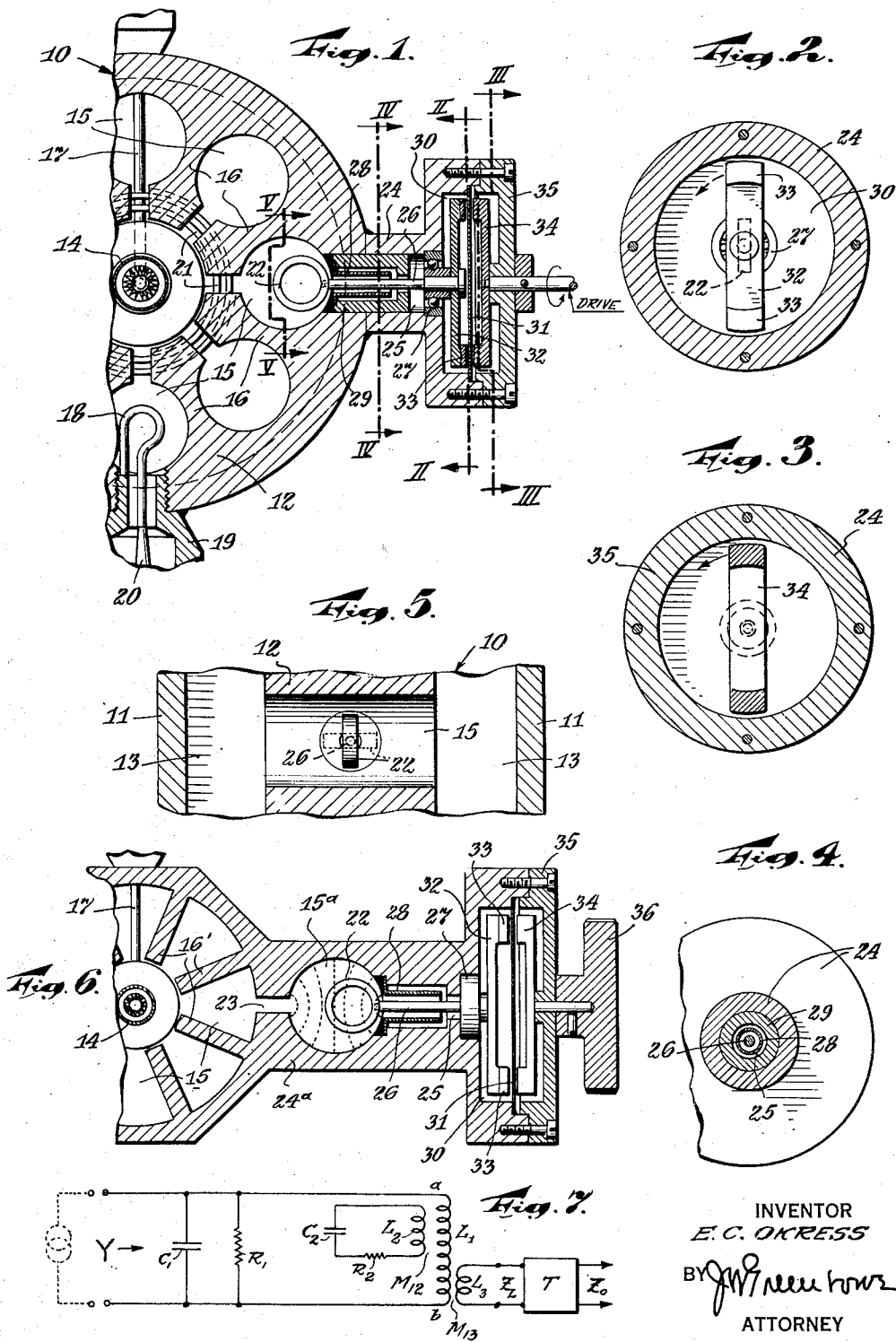
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TUNING MEANS FOR MAGNETRONS

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TUNING MEANS FOR MAGNETRONS

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This invention relates to electron discharge devices generally referred to as magnetrons, and more particularly to tuning means for the same.

The trend in magnetron construction at the present time is to improve their adaptability by overcoming, in one way or another their limitation as to fixed or monochromatic wavelength. While it is true that variations in the applied voltage, or current, and load will alter the wavelength of the magnetron, that is frequency pushing or frequency pulling, respectively, such variations are inadequate and impractical for most tuning purposes. It is highly desirable to provide a magnetron the wavelength of which is capable of being manually varied or rapidly swept over a reasonable range, at will. The fact that a magnetron has an evacuated interior, and tuning means generally requires movement of a mechanical part within the evacuated space, attainment of the objective is accompanied by difficult problems of not voiding the retention of the vacuum by repeated use of the tuning means and introduction of vibrations attainable in use by flexible diaphragms employed for sealing and for support of the tuning means.

Thus, as a more specific object of the invention, a solution to the problem is sought for obtaining controlled operation of a tuning means without passage of any mechanical part for the purpose through the vacuum-enclosing walls of the magnetron body.

Corollary to the foregoing object, is the desideratum of providing the controlling means entirely outside of the evacuated space and the controlled tuning means entirely within that space.

Inasmuch as wavelength of the output of a magnetron is dependent very largely upon dimensions of the cavity resonators thereof, it becomes a necessary object of the invention to conform the tuning means to accommodations offered by the fixed sizes and configurations of the magnetron housing, resonators and other parts thereof critical to its proper and intended operation.

Of similar purport, an object of the invention is to provide proper relation of both the mechanical and the electrical characteristics of the tuning means to the resonant system of the magnetron.

Other objects of the invention will appear to those skilled in the art to which it appertains as the description proceeds, both by direct recitation thereof and by implication from the context.

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Referring to the accompanying drawing in which like numerals of reference indicate similar parts throughout the several views;

Figure 1 is a cross-sectional view of a portion of a magnetron with the present invention incorporated as part thereof;

Figures 2 to 5, inclusive, are sectional views on lines II—II, III—III, IV—IV and V—V respectively of Figure 1;

Figure 6 is a sectional view similar to Figure 1 but showing a modified relation of tuning means to the magnetron proper, and

Figure 7 is a diagram of the equivalent circuit involved by use of the present invention.

In the specific embodiment of the invention illustrated in said drawing and devoting particular attention initially to Figures 1 to 5 thereof, the reference numeral 10 designates a generally cylindrical metallic magnetron body the ends whereof have cover or end plates 11 sealed thereon that the interior may be evacuated. Within and as an integral part of said body is the usual magnetron anode structure 12 also of generally cylindrical shape but shorter than the outer part of the body so as to provide end spaces 13 between the anode and said end plates 11. The anode structure is axially hollow to provide a cathode cavity for a cathode 14, and radiating from this cathode cavity as shown in Figures 1 and 5, are a plurality of cavity resonators 15, arranged in a circular series, each having a cylindrical portion parallel to the cathode cavity and a longitudinal constriction or slot connecting each throughout its length with said cathode cavity. The wall portions of the anode body intervening between successive cavity resonators are herein designated vanes 16.

It is to be understood, however, that the cavity resonators may have other shapes than that specifically described above, another conventional shape being shown in Figure 6 wherein the cavity resonators 15' are illustrated "pie-shape" or substantially triangular in cross-section with the apex radially inward and truncated to provide the constriction or slot between each resonator and the cathode cavity, and with the vanes 16' constituted as flat walls.

The ends of the cathode cavity and the ends of said cavity resonators, in both forms shown, open into the end spaces 13. Cathode 14 passes axially through the cathode cavity, and is adequately spaced from the anode or inner edges of the vanes, and is supported as usual at its ends from axially or radially disposed lead-in supports 17 entering the end cavities 13 at the sides

thereof. Suitable output means is provided, the same being herein illustrated as a loop 18 one end of which is attached to the outer sleeve 19 of a coaxial line and the other end of which merges with the inner member 20 of that line.

It will be readily understood by those skilled in the art that the several resonators are tightly coupled, for which purpose the alternate vanes may be connected by straps 21. The magnetron is assumed to operate exclusively in the π mode of the fundamental multiplet. That is, in the radio frequency field in the slots adjacent to the interaction space between cathode and anode 180° phase difference exists between adjacent segments. According to the present invention the π mode wavelength is varied, or the magnetron tuned, by a controlled variation of loading one of the cavity resonators, which, to distinguish from the other cavity resonators, will be herein designated as the tuning resonator. An appropriate means or internal circuit characteristic adjuster, herein shown as a revolvable element or ring 22, is provided in the tuning cavity for effecting variation of frequency of the magnetron by change of the mutual coupling coefficient between said element or ring and the tuning resonator. Said circuit characteristic adjuster or ring 22 is revolvable upon an axis diametric to the ring and radially of the magnetron, and in Figure 1 is shown located within, but eccentric to, the tuning resonator which is a selected one of the series of resonators 15. In Figure 6 an additional resonant cavity offset from the series of cavities is provided to constitute a tuning resonator 15a and connected by an iris 23 to one of the series of resonators. The construction of the tuning means or element is substantially similar in both of the assemblies of Figures 1 and 6, except for size of the tuning resonator and tuning ring or element. The tuning resonator is a closed system and either cylindrical, square or other suitable shape. The tuning element 22 can also assume other shapes than circular. In Figure 1 an extension 24 is provided at one side of the magnetron, soldered or otherwise secured to the body thereof next the tuning resonator. In Figure 6 an extension 24a of somewhat greater area is provided at the side of the magnetron to include the closed tuning resonator therein. In both views, the extension provides a passageway 25 from the other end of the extension to the tuning resonator for an operating means, here shown as a supporting and operating shaft 26 for ring 22 which is fixed in suitable manner on the inner end of said shaft. The shaft is shown rotatably mounted in a ball bearing 27, with suitable vacuum solid lubricants, at the outer end of the passageway. Between the ball bearing and the ring end of the shaft is provided a half-wave open-line choke in the form of a flanged sleeve 28 the flange of which constitutes means for mounting the choke in its fixed position. In Figure 1 the choke flange is shown secured to a coaxial sleeve 29 around the flanged sleeve and in turn fixed within the passageway, whereas in Figure 6, the flange is attached directly to a shoulder formed in the passageway.

At the outer end of the extension and passageway is provided a cylindrical recess 30 coaxial with and part of the passageway, the outer end of the recess being closed by a plate or diaphragm 31 of material which must be non-magnetic. This plate is sealed to the extension to provide a tight closure and enable the passageway and its said recess to be under the same vacuum condition as

the tuning resonator and interior of the magnetron. Within the recess and vacuum thereof, is an armature 32 in the form of a bar situated symmetrically cross-wise of and fixed to the end of shaft 26 and together constituting operating means for susceptance or reactance variation by means of ring 22. This armature is intended to be responsive to magnetic flux or attraction, so should be, at least next its ends, of magnetic responsive material, and by way of illustration is shown with soft iron patches 33 adjacent the ends of the armature on the face thereof away from the magnetron body and toward diaphragm 31.

Operation of the armature is effected by magnetic control means exterior to the evacuated region in which the armature operates. Such a control means is exemplified by a stator or bar magnet 34 on the outside of diaphragm 31 and of same length as the armature and revolvable upon a common axis with said armature. If the diaphragm 31 is a dielectric, such as suitable mica, then the stator 34 can be fixed like that of an induction motor. Proximity of the armature and stator on opposite sides of the non-magnetic diaphragm results in the following rotation of the stator, when it is a simple bar magnet, thereby rotating the tuning ring or element 22. As shown, a cover 35 is provided to enclose the magnet and diaphragm, said cover conveniently supporting a drive shaft to the inner end of which the stator is secured and to the outer end of which driving mechanism or manipulating means, such as knob 36, is attached. Adequate friction between the stator, when a simple bar magnet, and the cover and the knob and the cover or between the shaft and the cover is present to retain the magnet at any position to which it is turned, or if desired, more positive retaining means may be utilized.

The system, as shown, possesses properties of slow or rapid tuning, and, since the crucial parts are in vacuum, absence of arcing. Operation is both convenient and positive and cannot disturb or alter the vacuum condition or by wear or otherwise instigate vacuum leakage. The inclusion of the tuning ring or circuit characteristic adjuster 22 within one of the circular series of magnetron resonators, as shown in Figure 1, lends itself to compactness of structure. The alternative showing of oriented tuning ring or circuit characteristic adjuster 22 in the offset or specially provided tuning resonator as shown in Fig. 6 possesses the advantage of better stability due to the additional energy storage in the cavity which raises the Q, looking in the magnetron output lead.

The theory and operation of the variable tuning element or ring 22 within the magnetron system, Figure 1, may be obtained by an examination of the approximate equivalent circuit for the π mode of oscillation of the magnetron illustrated in Figure 7. Usually employed letters, L for inductance, M for mutual inductance, C for capacitance, R for resistance and Z for impedance are applied with distinguishing subscripts in this view. The equivalent circuit for tuning ring 22 is accordingly to be found represented with $L_2R_2C_2$ and the equivalent circuit of the magnetron resonant system will be recognized by designations of $R_1C_1L_1$ and the additional letter T represents the network between the line and loop L_3 in the magnetron, that network usually constituting the output lead. The ring coupled

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into the resonator at ab has the impedance Z_s defined approximately by the expression.

$$Z_s = \frac{(wM_{12})^2}{jwL_2 - \frac{1}{jwC_2} + R_2}$$

Likewise the load impedance, Z_L transformed through the coupling device T , and coupled to the resonator is

$$Z_s' = \frac{(wM_{12})^2}{Z_L + jwL_3}$$

The admittance Y at the slot in the presence of the ring tuner is simply

$$Y = \frac{1}{R_1 + jwC_1} + \frac{1}{Z_s' + Z_s + jwL_1}$$

Brief analysis of this relation indicates that the tuning ring should be used above its resonant region when the susceptance is essentially linear. Note that the resonant region of the tuning ring is avoided in order to reduce spurious moding difficulties. The mutual coupling coefficient M_{12} between the cavity and ring in Z_s is the variable component and is responsible for the variation of the frequency of the magnetron, in other words, the tuning thereof, since the variation of value of M_{12} by revolving the ring, as can be seen by the above formula, gives a change of the coupled impedance Z_s . The admittance Y which the space charge sees will vary about a mean value governed by M_{12} and the physical characteristics of the ring. The admittance change in any one resonator affects the system as a whole. The tuning in the present showing is accomplished by a reactance or susceptance variation in the tuning resonator due to the influence of the ring or internal circuit characteristic adjuster 22. In Figure 6, the reactance or susceptance in the tuning resonator communicates its effect by way of the iris 23 so that reactance or susceptance of the resonator with which the iris connects is varied in proportion to the fixed coupling and reactance or susceptance variation in the tuning resonator. An equivalent circuit for this arrangement can readily be formulated and analysed.

It may be appropriate to add that in order to prevent distortion of the radio frequency field in the interaction space between cathode and anode, it is desirable to select a tuning range which is near the normal wavelength of the magnetron (without the ring included). Satisfactory performance is obtained if the criteria is observed represented by

$$|\Delta\lambda| \leq \left| \frac{\lambda_0 - \lambda_n}{4} \right|$$

where $\Delta\lambda$ represents the deviation from the normal wavelength, λ_0 , and λ_n represents the adjacent unloaded magnetron mode.

I claim:

1. A magnetron providing a cavity resonator, said resonator having a sealed passageway leading therefrom, a variable rotatable circuit characteristic adjusting element in said resonator, and means sealed within said passageway for supporting and rotatably operating said variable element.

2. A magnetron providing a cavity resonator, said resonator having a sealed passageway leading therefrom, a variable rotatable circuit characteristic adjusting element revolvable in said resonator, and a revolvable shaft entirely within the sealed passageway and resonator for supporting and rotatably operating said element.

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3. A magnetron providing a cavity resonator, said resonator having a sealed passageway leading therefrom, a variable rotatable circuit characteristic adjusting element movable in said resonator, a movable shaft entirely within the sealed passageway and resonator for supporting and rotatably operating said element, and magnetic means having magnetic coupling with said shaft for rotatably operating the same.

4. A magnetron providing a cavity resonator, said resonator having a sealed passageway leading therefrom, a variable circuit characteristic adjusting element revolvable in said resonator, a revolvable shaft entirely within the sealed passageway and resonator for supporting and operating said element, an armature on said shaft, and magnetic means exterior to the sealed passageway and opposed to said armature for operating said armature and shaft.

5. A magnetron having an extension at one side thereof, said magnetron having a cavity resonator disposed lengthwise in a direction transverse to said extension, a sealed passageway at least in part within and lengthwise of said extension and leading from said resonator, a variable tuning element in said resonator, operating means secured to and extending from said tuning element substantially to the outer end of said extension, manual control means exterior to the sealed passageway beyond the outer end of said extension, said operating means and manual control being magnetically coupled for operating said operating means and tuning element by manipulation of said manual control means.

6. A magnetron having an extension at one side thereof, said magnetron having a cavity resonator the lengthwise direction whereof is disposed transverse to the lengthwise direction of said extension, a sealed passageway at least in part within and lengthwise of said extension and leading from said resonator, a shaft from said resonator to the outer end of said extension and within said passageway, a variable tuning means on said shaft and within said resonator, the other end of said shaft providing means within the passageway responsive to magnetic flux for magnetically moving said shaft, and magnetic means in proximity to said magnetic responsive means for applying moving force to said magnetic responsive means and shaft.

7. A magnetron providing a cavity resonator, said resonator having a passageway leading therefrom, a non-magnetic closure at the end of said passageway remote from the resonator, a revolvable shaft in said passageway, an armature on said shaft in proximity to said closure, magnetic means exterior to and in proximity to said closure magnetically coupled to said armature for operating the same and rotating said shaft, and a tuning element on the other end of said shaft revolvable therewith in said resonator.

8. A magnetron providing a circular series of resonators of which one constitutes a tuning resonator, and said magnetron having a passageway leading outwardly from said tuning resonator, said resonator and passageway constituting a common region and said region being evacuated, a variable tuning element revolvable in said tuning resonator, and a revolvable shaft entirely within said resonator and passageway for supporting and operating said tuning element, said tuning element and shaft both being in said common region and vacuum.

9. A magnetron providing a circular series of resonators and an offset closed resonator for

tuning purposes, said offset resonator being connected to one of the series of resonators by an iris, a passageway leading from said offset resonator, a non-magnetic closure at the end of said passageway leading from said offset resonator, a tuning element revoluble in said offset resonator, a shaft wholly within said offset resonator and passageway, said tuning element being mounted upon said shaft to rotate therewith, and magnetic means outside of and in proximity to said non-magnetic closure for rotating said shaft.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,633,285	Proctor	June 21, 1927
2,225,032	Carbonara	Dec. 17, 1940
2,272,211	Kohler	Feb. 10, 1942
2,280,824	Hansen et al.	Apr. 28, 1942
2,419,572	Laico et al.	Apr. 29, 1947
2,435,984	Spencer	Feb. 17, 1948
2,445,282	Slater	July 13, 1948