Feb. 7, 1950 R. B. NELSON 2,496,887

HIGH-FREQUENCY ELECTRICAL APPARATUS

Filed June 23, 1945

Fig. 1.

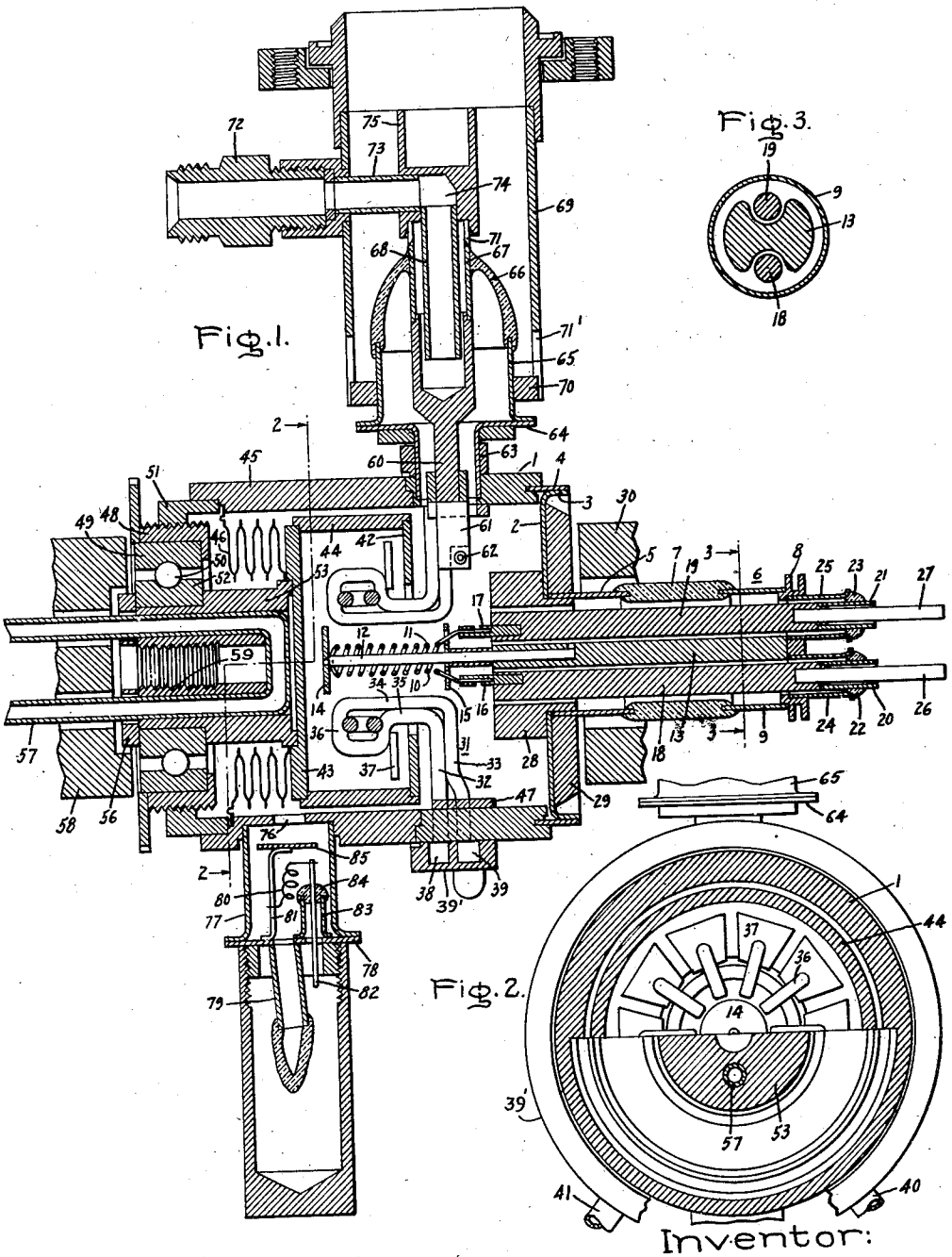


Fig. 3.

Fig. 2.

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HIGH-FREQUENCY ELECTRICAL APPARATUS

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Application June 23, 1945, Serial No. 601,123

16 Claims. (Cl. 250—27.5)

1

My invention relates to high frequency electrical apparatus and more particularly to improved space resonant structures and tuning mechanisms therefor. While not limited thereto, my invention is particularly adapted for tunable magnetron anode structures.

A variety of tunable magnetron constructions have been proposed in which one or more tuning elements are moved with respect to the space resonant anode structure to vary the effective inductance and capacitance of the various circuits of the anode structure. An arrangement for varying both the inductive and capacitive components of the resonant circuit including a pair of tuning disks arranged on opposite sides of the resonant anode structure is described and claimed in my application Serial No. 566,288, filed December 2, 1944, now Patent No. 2,424,496, dated July 22, 1947, and assigned to the assignee of the present invention. In arrangements of this type the somewhat complicated tuning structure introduces a number of additional resonant circuits which are a source of considerable power loss. This structure is also difficult to cool efficiently so that the power output of the device is limited. In accordance with the present invention, an improved resonant structure is provided which is shaped so that both the inductive and capacitive reactance components may be controlled by a single tuning member.

It is an object of my invention to provide a new and improved space resonant structure.

It is another object of my invention to provide a new and improved tunable space resonant structure.

It is still another object of my invention to provide a new and improved tunable magnetron construction.

In accordance with the illustrated embodiment of my invention, I provide an improved magnetron construction in which the space resonant anode may be considered as a modification of the radial vane type in which each of the vanes is partially cut away so that the cross section of the vane in a radial plane is essentially J-shaped. The longer arm of each of the J-shaped vanes is secured to the wall of the enclosing envelope and the shorter arm extends a portion of the distance from the end of the vane towards the wall of the envelope. A substantially planar tuning member is received between the arms of the anode sections and is axially movable with respect to the structure by an improved supporting structure including essentially an end wall of the envelope. This wall is sealed to the

2

side wall of the envelope by a flexible bellows and is moved with respect thereto by an adjusting collar which is threaded to an extension of the envelope. The collar is rotatably carried by a hub extending from the movable end wall of the envelope. In the particular embodiment illustrated, the vanes are formed of copper tubing which is bent into the desired form and mounted on the envelope wall with the ends thereof communicating with a header formed on the exterior of the tube wall and providing passages for cooling fluid. Certain features of this tubular anode construction are described and claimed in my application Serial No. 601,122 filed concurrently herewith and assigned to the assignee of the present invention.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims. In the drawing, Fig. 1 is an elevational view, in section, of a magnetron device embodying my invention, Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1, and Fig. 3 is a sectional view taken along the line 3—3 of Fig. 1.

Referring now to the drawing, the magnetron device embodying my invention includes a generally cylindrical envelope 1 formed of copper or other good conducting material. Although the discharge device is illustrated in the drawing with the axis of the envelope horizontal, it is preferable that the device be mounted with the axis vertical and in the folowing description the parts are referred to as if the tuning mechanism were at the upper end of the device. The envelope is closed at its lower end by a wall 2 preferably formed of fernico or sheet steel and having a marginal flange 3 which is adapted to be welded or otherwise bonded to a fernico or sheet steel extension 4 formed on the lower end of the cylindrical member 1. The end wall 2 is provided with a centrally located aperture surrounded by a depending circular flange 5 to which a cathode mount 6 is sealed by means of a cylindrical insulator 7. The cathode mount 6 includes a circular header 8 to which is bonded a fernico sleeve 9. The other end of the sleeve 9 is sealed to the lower end of the insulating cylinder 7. The cathode proper includes a pair of helical wires 10 and 11 which are wound in bifilar relation and joined at their upper ends to the upper end of a conductor 12 which provides a support and direct current cathode supply conductor. The conductor 12 is received in an

opening formed in the center of a ferromagnetic member 13 having a generally dumbbell shape cross section, as shown in Fig. 3, and which is supported at its lower end by the header 8. End shields 14 and 15 are also supported from the conductor 12. The free ends of the cathode elements 10 and 11 are joined to molybdenum inserts 16 and 17 received, respectively, in the ends of steel rods 18 and 19 which are received in the openings provided by the restricted portion of the dumbbell shaped member 13. These rods are provided at the lower ends with fernico sleeves 20 and 21, respectively, which are sealed by glass beads 22 and 23 to fernico sleeves 24 and 25 of larger diameter which are, in turn, brazed to the header 8. The current supply connections with the steel rods 18 and 19 are provided by conductors 26 and 27 which pass through the sleeves 20 and 21 in spaced relation with respect thereto and are received in recesses formed in the lower ends of the steel rods. With this construction the current supply circuits include the ferromagnetic members 13, 18 and 19 which provide a portion of the magnetic circuit for providing a magnetic field in the interelectrode space. This magnetic circuit also includes a cylindrical member 28 surrounding the members 13, 18 and 19 and projecting into the interior of the discharge device and an annular disk 29 which is brazed to the exterior of the end wall 2. A pole face 30 of the magnet or electromagnet may be shaped to conform generally with the shape of the disk 29 and to advantage may be slotted at one side to facilitate slipping it in place around the supporting flange 5 and the insulator 7. The construction just described provides a very effective way of supporting and supplying current to the cathode while at the same time providing a magnetic circuit for distributing the flux in the desired relation with respect to the cathode.

The anode structure of the device includes a plurality of space resonant circuits defined by anode sections, each of which is of generally J-shaped cross section. As illustrated in the drawing, each anode section 31 is formed from a length of tubular conductor, such as copper tubing, which is folded back on itself to provide radially extending arm portions 32 and 33 which are received in openings formed in the wall of the envelope 1. The tubing is shaped to define axially extending portions 34 and 35 joined to the outer ends of the arm portions 32 and 33 at one end and joined to a loop portion 36 at the other end. A generally trapezoidal shaped member 37 is brazed to the lower edge of each looped conductor 36 and together therewith form the short arm of the J-shaped anode section. The extended arm of the member 37 cooperating with a tuning member 42 provides for an effective variation of the capacitance of the various space resonant circuits with the position of the tuning member. The ends of the arm portions 32 and 33 received in the wall of the envelope 1 communicate, respectively, with passages 38 and 39 formed in a circular header 39' which surrounds the envelope. This header may be formed in any suitable way and in the illustrated embodiment is a copper ring which has been machined to provide the passages 38 and 39 and then brazed to the exterior of the envelope. Fluid supply connections 40 and 41 communicate, respectively, with passages 38 and 39. In prior constructions it is common practice to connect conductively all of the even numbered sections at their inner ends to provide one group of strapped sections and

to connect all of the odd numbered sections together to provide a second group. In the arrangement illustrated these straps are provided by conducting rods which join alternate sections and pass through the opening provided by the looped portion 36 of the intermediate anode section. This arrangement is claimed and more fully described in my above referred to copending application Serial No. 601,122.

The shape of the anode sections described above makes possible a novel arrangement of the tuning member and its associated mechanism which forms an important aspect of my invention. Referring now to the drawing, a tuning member in the form of an annular disk 42 is received between the loop portion 36 of the anode members 31 and the radial arm portions including tubular conductors 32 and 33. This disk is arranged in parallel relation to and between the opposed surfaces provided by the radial arm portions 32 of the anode sections and the members 37 which are secured to the loop portions of the anode sections. The tuning member 42 is supported from a disk 43, preferably formed of copper, which may be considered an end wall of the tubular envelope 1, by means of a continuous cylindrical conductor 44. With this tuning structure, which is essentially a hollow cylinder with one end apertured to receive the axially extending portions of the anode sections, the number of resonant frequencies introduced is a minimum and the power loss in the tuning mechanism is very small. The cylinder 44 and end wall 43 are slightly smaller in diameter than the cylinder 45 which extends substantially beyond the end wall 43 and is in effect a continuation of the envelope 1. The disk 43 is sealed to the end of the cylinder 45 by a flexible metallic bellows 46 which hermetically seals the tube envelope and permits the desired relative movement between the anode structure and the tuning structure including the tuning disk 42. In order to prevent substantial leakage of electromagnetic flux past the tuning member 42 and the supporting cylinder 44 a cylindrical extension 47 is provided on the inner wall of the envelope with the upper edge thereof flush with the upper edge of the radial arm portions of the anode sections. This extension may be formed integrally with the tube envelope 1 if desired.

Movement of the tuning structure is effected by a threaded bushing 48 which is secured to the outer race 49 of a ball bearing 50. The threaded portion of the bushing is received in an adaptor 51 which rests on a shoulder formed on the upper end of the extension 45 of the envelope of the device. The inner race 52 of the bearing is clamped in fixed relation with respect to a hub 53 which is bonded to the upper side of the end wall 43. The clamping is effected by a disk-like member 56 which is secured to the upper end of the hub to clamp the inner race 52 of the bearing against a shoulder formed on the hub 53. As illustrated in the drawing, the hub is provided with axially extending passages which are joined at their lower ends by a groove for the reception of a U-shaped tube 57 which is placed in position in the hub before it is bonded to the end wall 43. The tube 57 forms a passage for circulating cooling fluid through the tuning structure to extract heat therefrom generated by high frequency currents induced therein. The hub 53 is preferably formed of ferromagnetic material to provide a relatively low reluctance path for the axial magnetic flux

of the device and cooperates with a pole piece 58 which, as will be well understood, forms a part of the permanent or electromagnetic structure (not shown) of which the pole piece 30 is a part. Inasmuch as the interior of the device is evacuated, it will be apparent that a considerable pressure tending to force tuning structure including the adaptor 51 into the tube envelope exists. In the manufacture of the device certain of the parts of the tuning mechanism are omitted during the exhaust and for this reason the central opening 59 in the hub 53 is threaded to permit it to be retained in position with respect to the tube envelope by a suitable jig (not shown).

High frequency electrical energy may be extracted from the device by a suitable output circuit coupled with the space resonant structure. In the illustrated embodiment this output is of the concentric type and includes an inner conductor 60 having a looped portion 61 bolted or otherwise secured to one of the anode sections as shown at 62. The outer conductor 63 of the output line is joined to the tube envelope and terminates in a radially extending flange 64. A cylindrical sleeve 65 is joined at one end to the flange 64 and sealed at the other end to a body of glass 66 which is, in turn, sealed to a conductor 67 which forms an extension of conductor 60. The conductor 67, as illustrated, is larger than the conductor 60 and is hollow to receive a fluid supply conduit 68. The collar 65 is electrically connected with an outer conductor 69 of the output transmission line by an adaptor 70. As illustrated, the outer end of the conduit 67 is slotted in the region beyond the glass seal 66 to provide passages 71 for the cooling fluid introduced by the conduit 68. This fluid is allowed to escape through similar passages 71' formed at the end of conductor 69 adjacent the adaptor 70. Air or other cooling fluid is introduced to the conduit 68 through a fitting 72, a section of insulating conduit 73 and a passage 74 formed in a conductor 75 which forms an extension of conductor 67 and provides the central conductor of the output transmission line.

Evacuation of the envelope is accomplished through an opening 76 formed in the wall of the device and surrounded by an outwardly extending sleeve 77 which is closed by a header 78 and an exhaust tube 79. The header 78 also provides a support for a getter 80 having one end connected with the header through a conductor 81 and the other end sealed to the header by means of a conductor 82 sealed to a collar 83 by a body of glass 84. The conductor 81 also provides a support for a shield 85 which prevents the getter material from depositing on the interior of the envelope.

Although the features and advantages which characterize my invention are believed to be readily understood from the foregoing detailed description of the illustrated embodiment, a brief description of the operation of the device may further emphasize them. As is well understood, electrons emitted by the cathode elements 10 and 11 move in the interelectrode space under the resultant action of an electric field produced by voltage applied between the anode and cathode and an axial magnetic field produced in the interelectrode space by pole pieces 30 and 58. The resultant motion of these electrons is effective to excite the anode structure into oscillation at a high frequency dependent in part upon the geometry of the anode and in part by the position of

the tuning structure including the tuning disk 42. With the disk in the intermediate position shown, the magnetron will operate at an intermediate frequency. As the tuning member is moved downwardly toward the radial arm portions of the anode members, the electromagnetic flux linking the various circuits defined by the anode sections is gradually cut off, thereby decreasing the inductance of the anode members. At the same time the distance between the disk 42 and the members 37 which form extensions of the overhanging portions of the anode sections is increased, thereby decreasing the capacitance between the anodes and the disk 42, which latter has very little high-frequency voltage. Since the resonant frequency of the anode structure is determined by the product of the inductance and capacitance of the resonant elements, a downward motion of disk 42, by decreasing both inductance and capacitance, causes a large increase in the operating frequency. Conversely, as the disk is moved upwardly the capacitance is increased and the inductance is increased, with the result that the operating frequency is decreased.

Magnetron devices embodying the present invention may be tuned over a wide range and operated at high power. The tuning range is large partially because of the relatively smaller distributed capacity of the J-shaped anode sections as compared with the conventional vane type sections and because of the effectiveness of the single tuning disk as a tuning element for both the inductive and capacitive reactance components. The tuning structure is essentially a hollow cylinder having continuous walls except for the apertured end which receives a portion of the resonant anode, and for this reason has very few resonant frequencies associated with it which tend to absorb power and lower the tube efficiency as well as to generate unwanted heat. The tuning structure is also well suited for cooling because of the relatively large heat conducting paths which are connected with the tube envelope and which may be fluid cooled, as illustrated in the drawing. The incorporation in the magnetic circuit of a part of the support for the tuning structure and of a portion of the support and lead-in for the cathode also improves the distribution of the flux in the interelectrode space. It is believed apparent that the combination of these features produces a high frequency device of high efficiency, relatively large power output, and wide tuning range.

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 high frequency device comprising a substantially planar tuning member, a space resonant structure including a plurality of sections mounted in spaced relation to define a plurality of coupled space resonant circuits, each of said sections having a substantially J-shaped cross section in a plane perpendicular to said tuning member with the arms of said J extending substantially parallel to and on opposite sides of said tuning member, and means connected with said tuning member for moving said tuning

member in a direction perpendicular to the plane thereof to tune said structure.

2. A high frequency device comprising a substantially planar tuning member, a space resonant structure including a plurality of sections mounted in spaced relation to define a plurality of space resonant circuits, each of said sections having a substantially J-shaped cross section in a plane perpendicular to said tuning member with the arms of said J extending on opposite sides of said tuning member, and means connected with said tuning member for moving said tuning member with respect to said sections to tune said structure.

3. A substantially cylindrical space resonant structure comprising a plurality of radially extending sections defining coupled space resonant circuits and each having arms of different radial lengths interconnected at their inner ends and defining a central opening in said structure.

4. A substantially cylindrical space resonant structure comprising a plurality of radially extending sections each having a J-shaped cross section in a radial plane and terminating short of the axis of the structure, a tuning member located between the arms of said J-shaped sections near the inner ends of said sections and movable between said arms to tune said space resonant structure.

5. An electric discharge device comprising a symmetrical space resonant anode structure including a plurality of anode sections, each section including radially extending portions of different lengths lying in axially displaced planes and connected by an axially extending portion, a tuning member positioned between said radially extending portions, and means connected with said tuning member for moving said member in an axial direction.

6. A tunable magnetron device comprising a substantially cylindrical envelope, a plurality of anode sections supported from said envelope and extending radially inwardly a distance less than the radius of said envelope to define a plurality of coupled space resonant circuits, said anode sections each having a J-shaped cross section in a radial plane, a tuning member positioned between the arm portions of the said J-shaped section, and means supported from said envelope for moving said member in an axial direction.

7. An electric discharge device comprising an envelope, a generally cylindrical space resonant anode structure mounted within said envelope and including a plurality of anode sections, each section including radial portions of different lengths lying in axially displaced planes and connected by an axially extending portion, a tuning structure including an apertured disk received between the radial extending portions of each of said anode sections, the outer ends of the shorter radial arms of said anode sections being arranged on a circle having a diameter intermediate the diameters of the inner and outer edges of said tuning disk, a substantially continuous cylindrical member joined to said disk, and means connecting said cylinder with the envelope of said discharge device in vacuum-tight and axially movable relation with respect thereto.

8. An electric discharge device comprising a generally cylindrical space resonant anode structure including a plurality of anode sections, each section including radial portions of different lengths lying in axially displaced planes and connected by an axially extending portion, a tuning structure including an apertured member received between said radial extending portions of each of the anode sections, a substantially continuous cylindrical member joined to said disk, and means connecting said cylinder with the envelope of said discharge device in vacuum-tight and axially movable relation with respect thereto.

9. An electric discharge device comprising a substantially cylindrical envelope having an open end, a space resonant anode structure supported within said envelope, a structure for tuning said anode comprising a hollow metallic cylinder having an apertured end wall for the reception of a portion of said space resonant anode, and a flexible vacuum-tight connection between a second wall of said tuning structure and said envelope.

10. An electric discharge device comprising a substantially cylindrical envelope having an open end, a space resonant anode structure supported within said envelope, a structure for tuning said anode comprising a hollow metallic cylinder having an apertured end wall for the reception of a portion of said space resonant anode, and means connected with said tuning structure for producing relative movement between said anode structure and said tuning structure.

11. An electric discharge device of the magnetron type comprising a generally cylindrical envelope, a resonant anode structure supported within said envelope, a cathode supported from one end of said envelope and a tuning mechanism supported from the other end of said envelope, both of said supports comprising ferromagnetic material whereby a magnetic circuit of relatively low reluctance is provided from the exterior of the envelope to the opposite sides of said resonant structure in the region between said anode structure and said cathode.

12. An electric discharge device of the magnetron type comprising an envelope, a space resonant anode structure supported within said envelope and having a central opening therein, a header supported from one end of said envelope, a cathode assembly supported in said opening from said header in insulated relation with respect thereto, the support for said cathode assembly including an elongated ferromagnetic member joined to said header and to said cathode section, means connecting the inner end of said ferromagnetic member with said cathode, and a ferromagnetic member connected with said cathode to provide a supply circuit for heater current, said last mentioned ferromagnetic member being sealed in insulated relation with respect to said header.

13. An electric discharge device of the magnetron type comprising an envelope, a space resonant anode structure in said envelope and having a central opening therein, a cathode supported in said opening from one end of said envelope in insulated relation with respect thereto, the support for said cathode including an elongated ferromagnetic member of substantially dumbbell shape cross section, means connecting the inner end of said ferromagnetic member with a central point on said cathode, and a pair of ferromagnetic members connected with the ends of said cathode and positioned in passages provided by the portion of said first mentioned ferromagnetic member having a reduced cross section, said last-mentioned ferromagnetic members being supported in insulated relation with respect

to each other and with respect to the first mentioned ferromagnetic member.

14. An electric discharge device of the magnetron type including an envelope, a tuning member, a space resonant anode structure mounted in said envelope and including a plurality of anode sections, the walls of said anode sections defining coupled space resonant circuits having physically displaced portions contributing respectively the predominately capacitive and predominately inductive components of the resonant circuits, said portions being positioned oppositely with respect to said tuning member so that said member may be moved toward one of said portions of each of said anode sections as it moves away from the other of said portions, and means for moving said member.

15. A tunable magnetron device comprising a resonant electrode structure including a generally cylindrical array of radially extending circumferentially spaced anode sections defining a plurality of coupled space resonant circuits, said anode structure including a circumferentially extending recess, an annular tuning member positioned in said recess and means joined to said tuning member and extending generally in an axial direction with respect to said anode for moving said tuning member axially with respect to said anode so that said tuning member moves away from one surface of said recess as it moves toward the opposed surface of said recess.

16. An electric discharge device of the magnetron type including a space resonant anode structure having spaced opposed surfaces, a flat tuning member positioned between said opposed surfaces and relatively movable with respect to said structure for controlling the operating frequency of said device, a supporting structure for said tuning member including a hub of ferromagnetic material extending substantially normal to said tuning member, and means connected with said hub for adjusting the position of said hub and said tuning member in a direction substantially normal to said opposed surfaces.

RICHARD B. NELSON.

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Disclaimer

2,496,887.—*Richard B. Nelson*, Schenectady, N. Y. HIGH-FREQUENCY ELECTRICAL APPARATUS. Patent dated Feb. 7, 1950. Disclaimer filed Aug. 10, 1950, by the assignee, *General Electric Company*.

Hereby enters this disclaimer of claims 9, 10, and 11 of said patent.

[*Official Gazette September 19, 1950.*]