

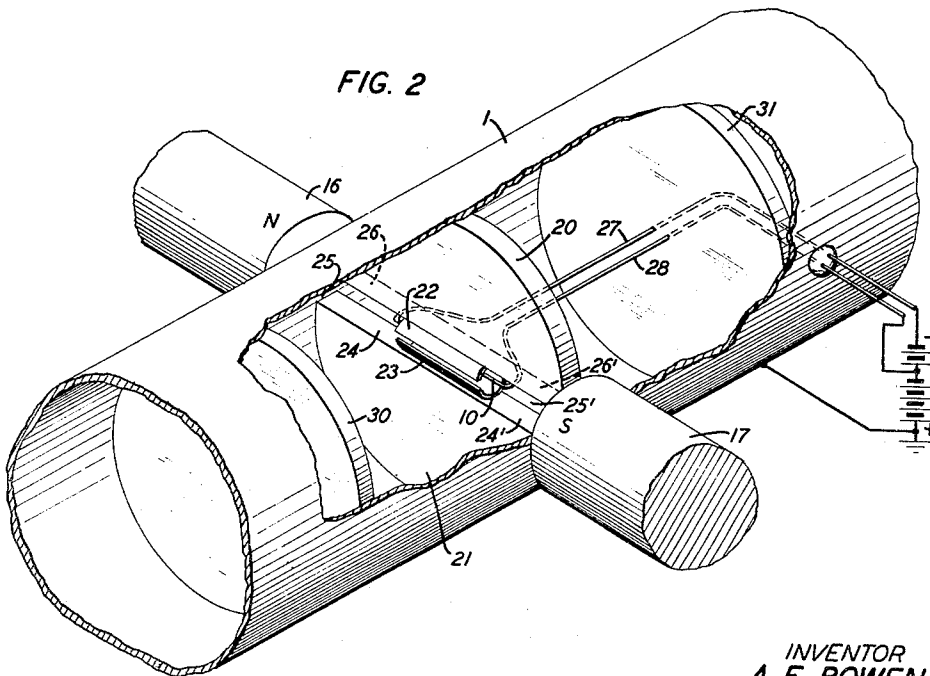
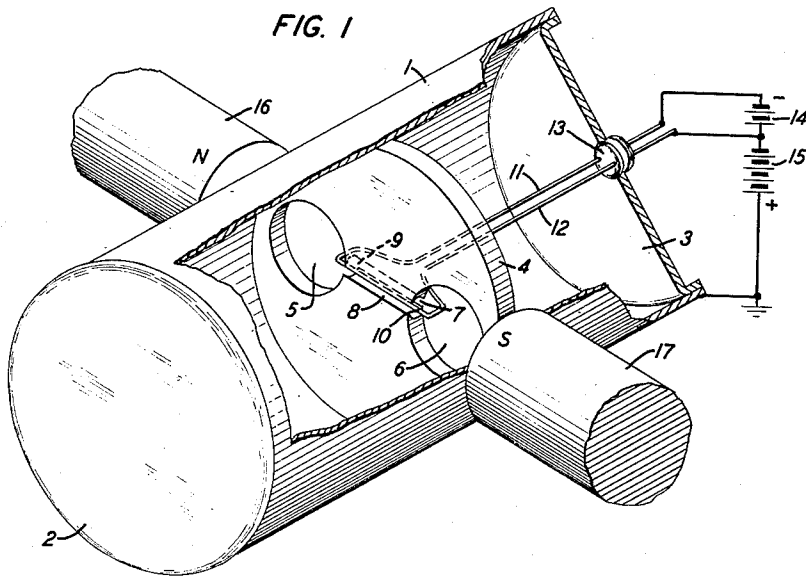
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A. E. BOWEN
ULTRAHIGH FREQUENCY RESONATOR

2,660,667

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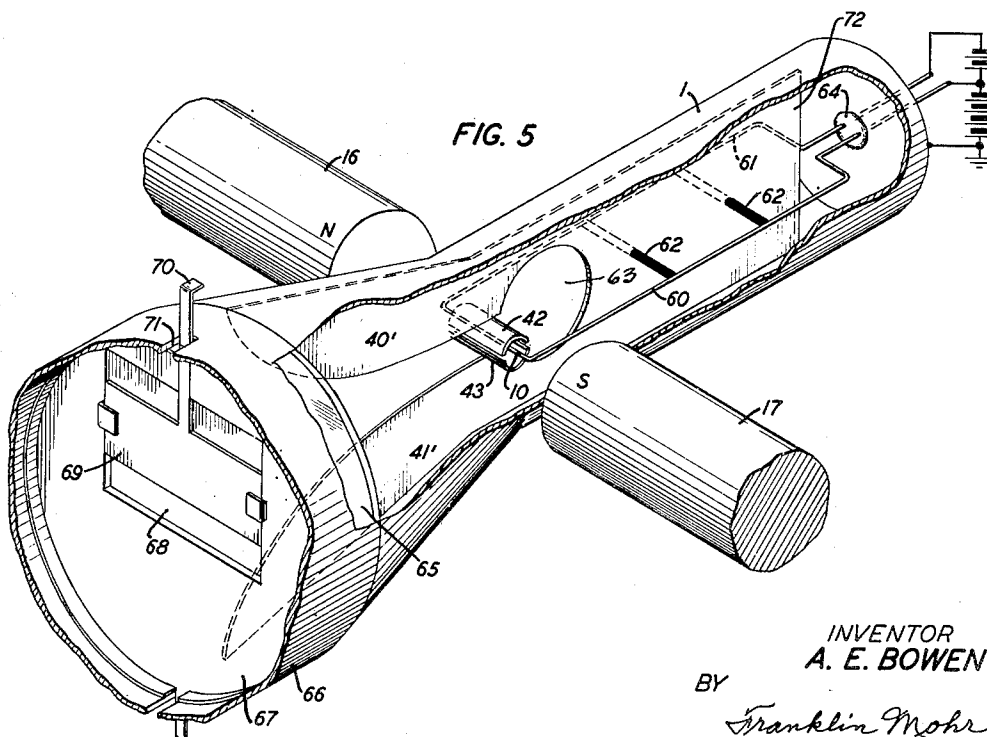
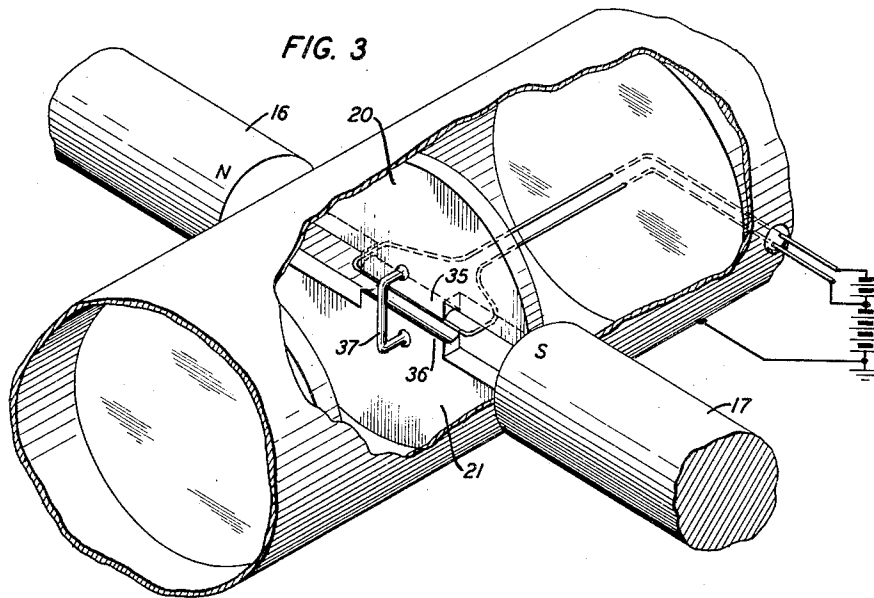


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ULTRAHIGH FREQUENCY RESONATOR

3 Sheets-Sheet 2



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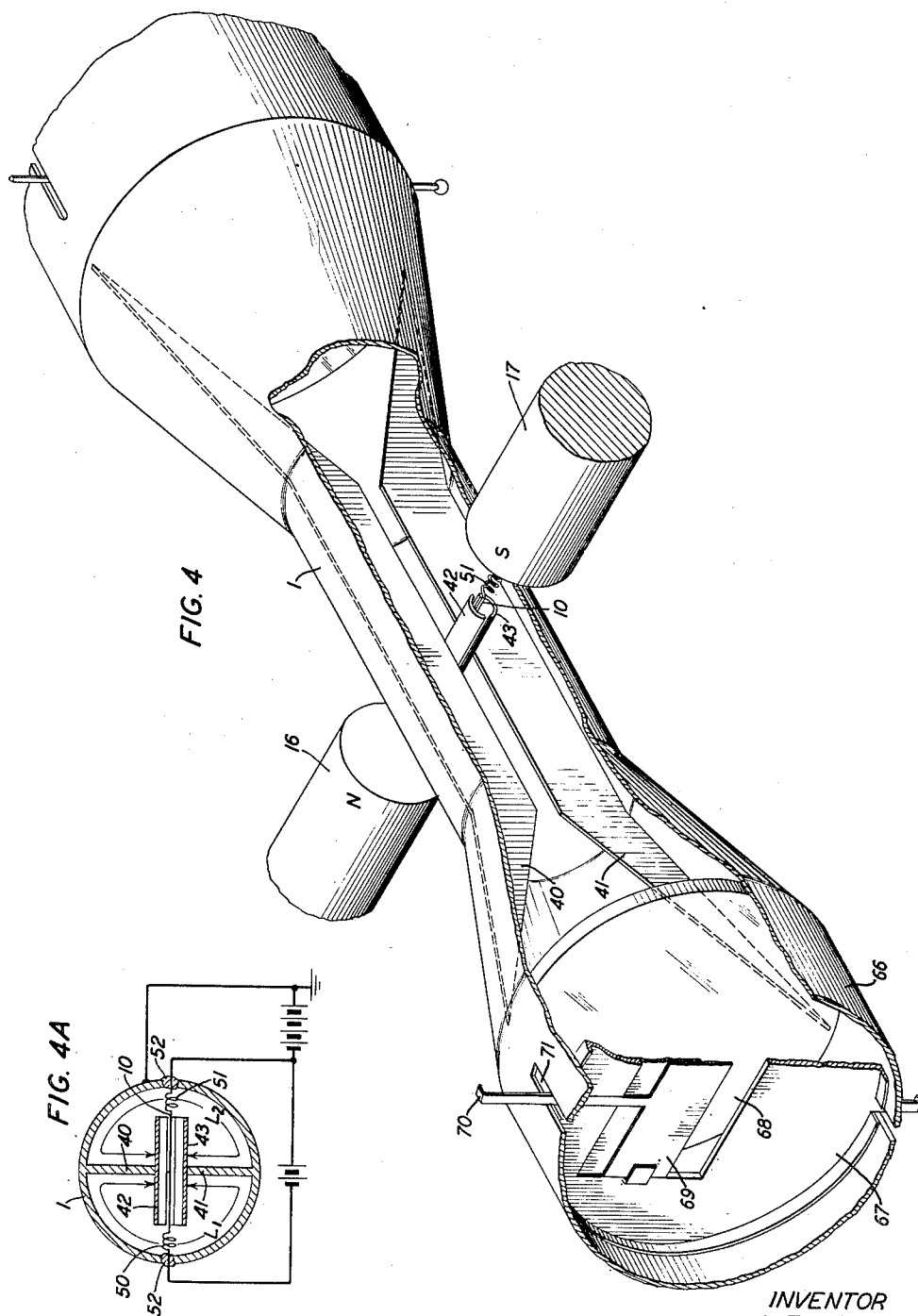
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ULTRAHIGH FREQUENCY RESONATOR

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3 Sheets-Sheet 3



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2,660,667

ULTRAHIGH FREQUENCY RESONATOR

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30 Claims. (Cl. 250-17)

1 This invention relates to the generation and transmission of ultra-high frequency electromagnetic waves and more particularly to means for resonating such waves.

The resonator of the invention may be of the open or radiating type. It is particularly adapted for use with the type of transmission system commonly known as a dielectric wave guide and in combination with such a guide may form part of a substantially closed system for supporting a standing wave pattern. In accordance with the invention the resonator comprises a structure inserted in a wave guide to form a partial obstruction to the passage of waves therethrough. In one embodiment, the resonant structure comprises a transverse conductive partition containing an aperture comprising in its bounding surfaces a circuit which is resonant to a frequency freely transmissible by the wave guide structure. The resonator is useful in a variety of ways, for example, as a combination resonator and radiator for an oscillation generator or a repeater contained within the wave guide. The resonator may also serve as a filter for the selective transmission of a particular frequency. It may also serve as a frequency selective coupling between two portions of a wave guide. With proper modification, the resonator may serve to selectively absorb waves of the resonant frequency. The device may transmit waves into a connecting section of wave guide or it may launch the waves into space either directly or through a horn.

When a resonator of this type is used within a wave guide the resonant frequency is found to be influenced to a marked extent by the presence of reflecting surfaces or apertured partitions and the system as a whole may be tuned by adjusting the position of a partition to form a resonant chamber.

The invention is described hereinafter as embodied in a magnetron oscillator contained within a hollow pipe wave guide of circular cross-section; other uses and applications of the invention will readily occur to any one skilled in the art.

In the drawings:

Fig. 1 shows the resonator of the invention embodied in a magnetron oscillator within a hollow pipe wave guide of circular cross-section;

Figs. 2 and 3 show structural modifications of the arrangements of Fig. 1;

Figs. 4 and 4A show a further modification in which the diameter of the wave guide may be reduced in the neighborhood of the magnetron so that a shorter magnetic path may be employed; and

2 Fig. 5 shows a modification of the arrangement of Figs. 4 and 4A.

In Fig. 1 the reference numeral 1 refers to a length of hollow conductive non-magnetic pipe, comprising a wave guide and may be hermetically sealed by a window 2 of dielectric material at one end and a conductive disc 3 at the other. The disc 3 may be flanged and welded to the wall of the pipe 1. Within the guide 1 is a conductive partition wall 4 containing circular apertures 5 and 6 connected by a slot 7. The slot may be bored out with a cylindrical contour, the lower of the cylindrical surfaces being indicated at 8. The other cylindrical surface of the slot which is hidden in the figure, is indicated by dotted lines at 9. The surfaces 8 and 9 comprise a two segment anode for a magnetron oscillator the cathode of which may be a filament 10 lying on the axis of the cylinder common to the surfaces 8 and 9. The conductive surfaces bounding the apertures 5 and 6 form inductive loop circuits connecting the anode segments 8 and 9. The capacity comprised between the surfaces 8 and 9 is effectively in parallel connection with the inductive loops surrounding the apertures 5 and 6 to form therewith a parallel resonant circuit. Filament heating leads 11 and 12 from the respective ends of the filament 10 are preferably brought out close to the axis of the guide 1 through a glass bead 13 or other suitable seal to a heating source represented by a battery 14. To minimize coupling between the high frequency system and the filament circuit, the filament leads are preferably placed in a plane which includes the filament. The partition 4 is preferably in good electrical contact with the inner surface of the guide 1. The wall of the guide may be grounded as shown and the anode may be energized by any suitable source such as a battery 15 connected between the cathode circuit and the outer surface of the guide 1. The whole interior of the guide 1 is evacuated to permit thermionic action. A substantially uniform and constant magnetic field is provided within the space between the anode segments 8 and 9 with the magnetic vector directed along the axis of the filament 10, by means of any suitable source of magnetomotive force such as a pair of magnets 16 and 17. To effect a progressive motion of electrons along the filament axis the magnetic axis may be tilted slightly, usually 5 to 10 degrees, as is common in magnetron practice. Accordingly, the magnets 16 and 17 may be mounted at the desired small angle with the filament axis. The magnets may be poled as shown or

else the polarity of both magnets may be reversed.

In the operation of the system of Fig. 1, the generation of oscillations occurs in the manner of any split anode magnetron oscillator to cause electric charges to alternate between the segments 8 and 9 at an ultra-high frequency rate which is determined primarily by the resonant frequency of the system comprising the segments 8 and 9 together with the bounding surfaces of the apertures 5 and 6. The latter surfaces take the place of the usual inductive wire connection between the anode segments.

The electric field appears mainly between the segments 8 and 9 and radiates energy from the slot 7 towards either end of the guide 1. The resultant wave in the guide is of the H_{11} type with the electric vector mainly in the direction mutually perpendicular to the filament 10 and to the longitudinal axis of the guide 1. The spacing between the partition 4 and the disc 3 may be made of such value that the wave radiating to the right is reflected by the plate 3 to the partition 4 in such phase as to reinforce the oscillations. The reinforced waves may be projected through the dielectric window 2 into space in the form of a beam or they may be utilized in any other suitable manner.

For calculating suitable dimensions for the resonator, I have found the following formula useful:

$$\lambda_a = 6\pi \cdot 10^{10} \sqrt{LC}$$

where

λ_a is the wave-length in air, in centimeters,

L is one-half the inductance of one circular aperture, and

C is the capacitance between the upper and lower anode segments.

The values of L and C are determined as follows:

$$L = \frac{0.00987}{2} \frac{D^2 K}{l'} \cdot 10^{-6} \text{ henries}$$

$$C = \frac{2.56l}{\pi^2} \cdot 10^{-12} \log_{10} \frac{4d}{h} \text{ farads}$$

where

D is the diameter of aperture 5 or 6;

l' is the thickness of the partition 4;

K is a constant depending upon the ratio of D to l' ;

l is the length of the anode segments;

d is the diameter of the cylindrical anode surface; and

h is the separation of the anode segments at their closest approach; all lengths expressed in centimeters.

The formula for L is derived from formula (153) of Circular No. 74 of the Bureau of Standards, 2nd edition, March 10, 1924, page 252. The values of the constant K are given in Table 10, page 283 of the circular.

Using the above formulae to design a resonator for a wave-length of approximately 3.5 centimeters, I have found the following a suitable set of dimensions by way of example:

Dimensions	Centimeters
D	0.46
d	0.127
l'	0.147
l	0.254
h	0.0127

A resonator of the above tabulated dimensions may conveniently be mounted in a wave guide comprising a one-inch copper tube. It will be evident, of course, that in general the inside diameter of the wave guide must be sufficiently large to insure that the cut-off frequency of the wave guide will be below the frequency of the resonator if the fundamental frequency of the oscillator is to be freely transmitted along the wave guide. The design formulae for the resonator permit of some leeway in the choice of ratios of D to l' and d to h and in the length l .

Fig. 2 shows a modified form of magnetron oscillator. Compared with Fig. 1 the modified arrangement has two nearly semicircular transverse conductive septa 20 and 21 in place of the partition 4. A pair of approximately semicylindrical anode segments 22 and 23, respectively, are conductively attached to the upper and lower septa 20 and 21, respectively, in a central position. The inductive circuit provided in Fig. 1 by the boundary surface of aperture 5 is replaced in Fig. 2 by surfaces designated 24, 25 and 26. The numeral 24 refers to the left-hand portion of the upper edge of the septum 21, and 25 represents a portion of the inner wall of the guide 1 between the septa, while 26 comprises the left-hand portion of the lower edge of the septum 20. The inductance associated with the aperture 5 in Fig. 1 is replaced by the inductance of similarly located surfaces 24', 25' and 26' at the right of the anode segments, the surface 25' being cut away in the drawing. The filament 10 is supported and electrically supplied by leads 27 and 28 which pass through a dielectric sealing disc 31. The vacuum chamber enclosing the magnetron assembly and resonator may be sealed off by means of the dielectric disc 31 and a similar disc 30 which permit the transmission of electromagnetic waves therethrough in either direction along the longitudinal axis of the guide. Sources of electromotive force and magnetomotive force may be supplied in any suitable manner, for example, as illustrated in Fig. 1.

The operation of the system of Fig. 2 is similar to that of the system of Fig. 1. Resonance takes place between the capacitance of the anode segments 22 and 23 and the inductance of the circuits 24, 25, 26 and 24', 25' and 26'. The waves radiated by the magnetron oscillator may be transmitted in a single direction by providing a reflecting plate as in the system of Fig. 1 or, if desired, waves may be transmitted in both directions through the dielectric closures 30 and 31.

Fig. 3 shows a further slight modification compared with the arrangement of Fig. 2. In Fig. 3 anode segments 35 and 36 are formed as integral portions of the septa 20 and 21, respectively. The inductance of the resonant system is supplemented by a conductive bridge 37 connecting the septa 20 and 21 and lying in a plane perpendicular to both the septa and the cathode. The bridge 37 provides additional inductive coupling between the resonator and the portion of the wave guide to the left of the septa.

The operation of the arrangement of Fig. 3 is similar to that of the systems of Figs. 1 and 2.

Fig. 4 shows a modification which results in a shortening of the magnetic path between the magnets 16 and 17. The magnetron structure is placed in a portion of the guide 1 that has been tapered down to a smaller cross-section than that of the main portion of the guide. In order to permit electromagnetic waves to be propagated to and through the restricted por-

tion of the guide a pair of fins 40 and 41 are mounted in a plane which is perpendicular to the cathode 10 and contains the longitudinal axis of the guide 1.

The fins 40 and 41 are tapered at either end as shown and serve to provide a two-conductor transmission line which will support the desired wave. The tapered portions of the fins provide a transition between conditions in the main portion of the guide 1 and the two-conductor transmission line in the neighborhood of the magnetron element. The use of the fins 40 and 41 is generally similar to the use of converting arrangements for passing from waves of one type to those of another type as described in my United States Patent 2,253,503 of August 26, 1941, Figs. 7, to 14, inclusive.

The resonant circuit in the arrangement of Fig. 4 has its inductances formed in part by the lateral surfaces of the fins 40 and 41 and the inner wall of the guide 1, as indicated diagrammatically by L_1 and L_2 in the cross-sectional view Fig. 4A. The above-mentioned surfaces correspond in a general way to the bounding surfaces of the apertures 5 and 6 of Fig. 1. In the arrangement of Fig. 4, however, the tuning is dependent to a marked degree upon the position of slidable partitions 67 which define a resonant chamber within the wave guide. Either partition may contain a coupling aperture 68 of variable size controlled by an adjustable closure 69. A rod or handle 70, extending through a slot 71 may be provided to enable adjustment both of the axial position of the partition 67 and of the effective size of the opening 68. Control of the frequency and coupling are thus provided. Capacitance, as in the other embodiments, is provided between the anode segments 42 and 43.

In this embodiment the filament 10 is supported and electrically supplied by spring members 50 and 51 which pass through insulating beads 52 at diametrically opposite points in the wall of the guide 1, as shown most clearly in Fig. 4A.

It is found that the fins 40 and 41 form good conducting paths for carrying heat away from the anode and thus that this type of construction is conducive to increased output.

The operation of the arrangement of Fig. 4 is similar to that of the preceding figures except that the generated waves are guided initially by the fins 40 and 41.

Fig. 5 shows a modification of the arrangement of Figs. 4 and 4A which lends itself to ease of manufacture. It is single-ended and in this respect resembles the embodiment shown in Fig. 1. An advantage of the single-ended construction is that the fins, magnetron segments and cathode system may be formed as a subassembly and inserted into the tapered pipe structure from the open end, the cathode leads then being sealed through a glass bead in a small hole at the closed end of the pipe. The corresponding parts in Figs. 4 and 5 are similarly numbered. The fins 40' and 41' in Fig. 5 are modified in shape to accommodate the change to a single-ended structure and the tapered edges in a given case were curved to give a smooth transition with a minimum of reflection of waves as shown by measurements of the transmission efficiency of trial devices. The fins 40' and 41' are formed by cutting out a portion of a single conductive sheet 72 and the cut-out portion includes an inductive loop 63

which may be of circular contour as shown. The filament 10 is supplied by leads 60 and 61 supported by insulating posts 52 fastened to the sheet 72. The capacity of the resonant system is mainly that between the segments 42 and 43. The cathode leads are sealed through the bead 54. The flaring end of the pipe, which is sealed by a dielectric disc 55, may be shaped, as desired, to form a horn or to give a smooth transition for connection to a wave guide 66 of suitable diameter. As described in connection with Fig. 4, it is particularly advantageous to place a slidable partition 67 in the guide 66 as it is found that the frequency of the oscillations and the efficiency of operation at a particular frequency may be adjusted by varying the position of this partition and the size of the coupling aperture. Similarly to the arrangement of Fig. 4, the partition 67 may have an aperture 68 with an adjustable closure 69 to regulate the transmission of waves. The closure 69 may be manipulated by a handle 70 projecting through a slot 71, the handle 70 also serving for axial adjustment of the partition 67.

In an oscillator of this type shown in Fig. 5 which was built and operated in the three-centimeter wave-length range it was found that the wave-length could be readily adjusted over a range from 2.6 to 3.6 centimeters by varying the position of the partition 67.

What is claimed is:

1. A hollow pipe wave guide, a conductive partition wall therein, said wall containing an aperture comprising in its bounding surfaces a circuit resonant to a frequency freely transmissible by said wave guide.

2. A wave guide structure divided longitudinally into two sections by a transverse conductive partition, said sections being selectively coupled at a particular frequency by means of an aperture in said partition, the outline of said aperture defining a circuit resonant to said frequency.

3. A hollow pipe wave guide containing a conductive partition wall, said partition wall containing an aperture comprising edges that are relatively close together in one region to provide high electric intensity in said wave guide and far apart in another region to provide high magnetic intensity.

4. Oscillator apparatus comprising a conductive planar resonator diaphragm having a relatively small aperture therein, said diaphragm by virtue of said aperture having a capacitive portion and an inductive portion, and a linear electrode of a space discharge device mounted within said capacitive portion of said aperture, and substantially parallel to the plane of said diaphragm.

5. Oscillator apparatus comprising a conductive planar resonator diaphragm having a relatively small aperture therein, said diaphragm by virtue of said aperture having an inductive portion and another portion having substantially parallel spaced edges relatively close together to provide a region of concentrated capacitance, and a linear electrode of a space discharge device mounted within said region of concentrated capacitance and extending parallel to the plane of the diaphragm and to the said parallel spaced edges of the diaphragm in said region.

6. Oscillator apparatus comprising a conductive planar resonator diaphragm having a relatively small aperture therein, said diaphragm by virtue of said aperture having an inductive

portion and another portion defining a pair of semicylindrical anode segments providing a relatively concentrated capacitance therebetween, and a linear cathode mounted on the common cylindrical axis of said anode segments, said axis lying substantially in the plane of said diaphragm.

7. Oscillator apparatus comprising a conductive planar resonator diaphragm having two relatively small substantially circular apertures therein connected by a narrow slot, and a linear electrode of a space discharge device mounted within said slot and extending in the direction parallel to the plane of said diaphragm and to the edges of said slot.

8. A wave guide, an oscillator structure positioned within said wave guide, said oscillator structure having a plurality of anode segments arranged symmetrically about an axis perpendicular to the longitudinal axis of said wave guide, and an inductive loop circuit connecting a pair of said anode segments, said loop circuit lying substantially in a plane containing the oscillator structure axis, said plane being perpendicular to the longitudinal axis of said wave guide.

9. A wave guide, a magnetron structure positioned within said wave guide, said magnetron structure comprising means to maintain a substantially uniform and constant magnetic field having its magnetic vector in a direction perpendicular to the longitudinal axis of said wave guide, a pair of anode segments adapted to be immersed in said magnetic field and symmetrically positioned with respect to an axis parallel to the direction of the magnetic field and an inductive loop circuit connecting said anode segments and lying substantially in a plane containing said axis of symmetry, said plane being perpendicular to the longitudinal axis of said wave guide.

10. A wave guide oscillation generator comprising hollow conductive pipe portions of different inside diameters joined by a tapered section, a bifurcated axial partition of conductive material placed in a diametral plane of said wave guide structure with the forked portion of said partition in the tapered section and the body portion of said partition in the hollow pipe portion of smaller diameter, said partition having an inductive aperture in the body portion thereof opening into the space between the branches of the forked portion, a pair of anode segments mounted on the respective branches of said forked portion near the entrance to said inductive aperture and symmetrically disposed about an axis perpendicular to said partition, a cathode located between said anode segments on the axis of symmetry thereof, and means to actuate said cathode and said anode segments conjointly as components of a magnetron generator to sustain electromagnetic wave oscillations in said wave guide.

11. A combination in accordance with claim 10, in which the branches of the forked portion of the said partition are tapered toward the ends.

12. A combination in accordance with claim 10, in which reflecting closures are mounted in the said hollow pipe portions of different diameter, said reflecting closures bounding a resonant chamber for electromagnetic waves sustainable by said magnetron generator.

13. A combination in accordance with claim 10, in which reflecting closures are mounted in

the said hollow pipe portions of different diameter, one of said reflecting closures being adjustable in axial position, said reflecting closures bounding a tunable resonating chamber for electromagnetic waves.

14. A combination in accordance with claim 10, in which reflecting closures are mounted in the said hollow pipe portions of different diameter, the reflecting closure in said pipe of larger diameter having an aperture of adjustable size, and said reflecting closures bounding a resonating chamber adjustably coupled for wave transmission into the main portion of said pipe of larger diameter.

15. A combination in accordance with claim 10, having a conductive end closure for the said pipe of smaller diameter, and having cathode heating leads insulatingly mounted upon the body portion of the said partition and insulatingly sealed through a central hole in said end closure.

16. A combination in accordance with claim 10, having cathode heating leads insulatingly supported in a plane containing the said cathode and the axis of the said wave guide structure.

17. In combination, a conductively sheathed wave guide for the transmission of electromagnetic waves, a partition transversely disposed at a point in said guide and an aperture in said partition, the height of said aperture in the direction of polarization of the electric field of the waves transmitted by said guide and the width of said aperture in a direction perpendicular thereto being proportioned with respect to each other to provide at said point an impedance branch which is resonant at a certain frequency transmitted by said guide.

18. The combination in accordance with claim 17 in which said partition has a pair of oppositely disposed projections extending into said aperture to reduce its height in the vicinity of its center.

19. In combination, a conductively sheathed wave guide for the transmission of electromagnetic waves, a partition transversely disposed at a point in said guide and an aperture in said partition, the height of said aperture in the direction of polarization of the electric field of the waves transmitted by said guide and the width of said aperture in a direction perpendicular thereto being proportioned with respect to each other to provide parallel resonance at said point for a certain frequency transmitted by said guide.

20. The combination in accordance with claim 19 and means within said guide for establishing a point of zero potential, said means being spaced from said partition approximately a quarter of a wavelength at said certain frequency.

21. In combination, a conductively sheathed wave guide for the transmission of electromagnetic waves and a partition transversely disposed in said guide, said partition having an aperture therein which is resonant at the frequency of said waves and said aperture comprising a comparatively narrow central opening and a wider opening at each end thereof.

22. In combination, a hollow-pipe type wave guide for transmitting electromagnetic waves dielectrically and a partition positioned relative to said guide to be substantially transverse to the direction of propagation of waves through said guide and having therein a tuned aperture comprising a central elongated slit and an enlarged opening at each end of the slit.

23. In combination, a hollow-pipe type wave guide for transmitting electromagnetic waves dielectrically, exciting means for establishing elec-

tromagnetic waves in said guide, and means including a wall member associated with said guide provided with an aperture tuned to the frequency of said exciting means and having an appreciable dimension perpendicular to a transverse component of electric field for effecting a concentration of the potential due to said waves and for effecting current flow in said wall member thereby producing in effect a dipole for radiation purposes.

24. In combination, a hollow-pipe type wave guide for transmitting electromagnetic waves dielectrically, exciting means for establishing electromagnetic waves in said guide, and a wall member positioned relative to said guide to be substantially transverse to the direction of propagation of waves through said guide and having therein a tuned aperture comprising a central elongated slit and an enlarged opening at each end of the slit.

25. In combination, a hollow-pipe type wave guide for transmitting electromagnetic waves dielectrically, exciting means for establishing electromagnetic waves in said guide, and means including a conductive member associated with said guide and provided with an aperture tuned to the frequency of said exciting means and having an appreciable dimension perpendicular to a transverse component of electric field for effecting a concentration of the potential due to said waves and for effecting current flow in said conductive member thereby producing in effect a dipole for radiation purposes, said conductive member having a phase extension in the direction of wave propagation within said wave guide which is a small portion of a wavelength of said waves.

26. In combination, a dielectric wave guide of the hollow-pipe type and filtering means selectively responsive to an electromagnetic wave of predetermined frequency comprising a wall within said guide lying in a plane substantially transverse to the direction of wave propagation therethrough and having an aperture tuned substantially to said frequency and means associated with said aperture for establishing a region of charged electric particles.

27. In combination, a dielectric wave guide of the hollow-pipe type, and means for controlling the wave propagating characteristics of said guide comprising a wall lying in a plane substantially transverse to the direction of wave propagation therethrough and having therein an aperture tuned to a resonance frequency, and means associated with said aperture for establishing within the vicinity thereof a region of charged electric particles.

28. In combination, a dielectric wave guide of the hollow-pipe type, and means for controlling the wave propagating characteristics of said guide comprising a conductive member having therein an aperture tuned to a resonance frequency, said member having a phase extension in the direction of wave propagation through said guide

which is a small portion of a wavelength at said resonance frequency, and means associated with said aperture for establishing within the vicinity thereof a region of charged electric particles.

29. A device for use at high radio frequencies and including an elongated envelope having at one end an electron source and a cavity resonator positioned adjacent said source to be excited by electrons therefrom, said resonator having an aperture therein, said envelope having an elongated flared out portion extending from said one end and registering with the aperture in said resonator, said flared out portion having a conducting inner surface and providing a reflecting surface and waveguide for electromagnetic waves generated in said resonator, the end of said flared out portion being closed by a member permeable to electromagnetic wave energy.

30. An electron discharge device for use at ultra high frequencies and comprising an elongated envelope, one end of said envelope being provided with a constricted portion and the remainder of said envelope being formed into an elongated cone-like portion closed at the outer end, a magnetron electrode assembly within the constricted portion of said envelope and including an anode member forming a cavity resonator and an electron source adjacent to said anode member for energizing said cavity resonator, said cavity resonator having an aperture opening into the interior of the cone-like portion of said envelope, said cone-like portion of said envelope having an inner conducting surface.

ARNOLD E. BOWEN.

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