July 16, 1946. J. R. WHINNERY 2,404,261

ULTRA HIGH FREQUENCY SYSTEM

Filed Oct. 31, 1942 2 Sheets-Sheet 1

Fig.1.

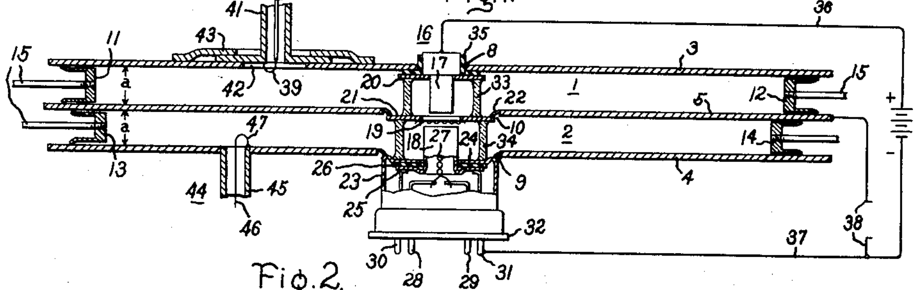


Fig.2.

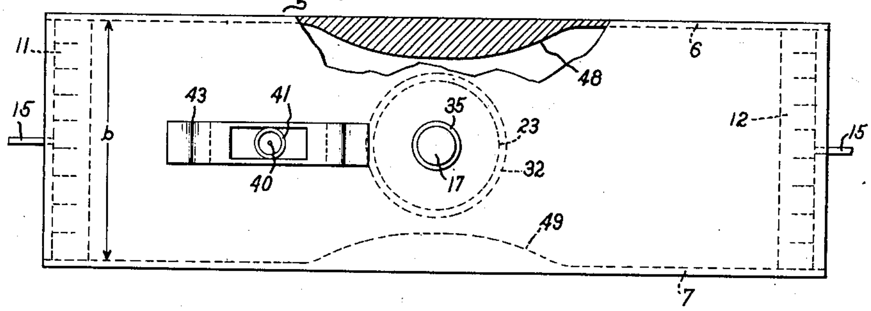


Fig.3.

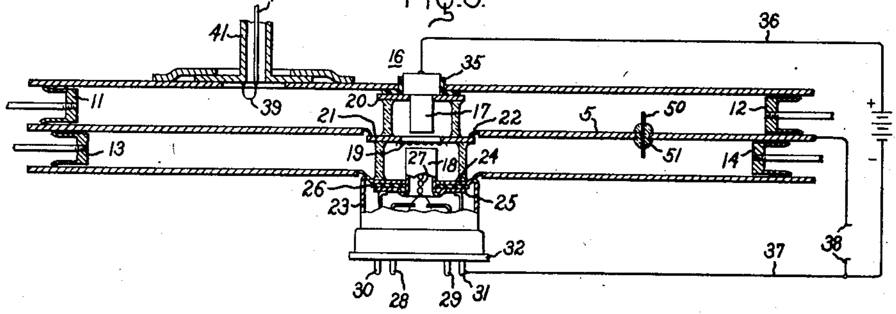
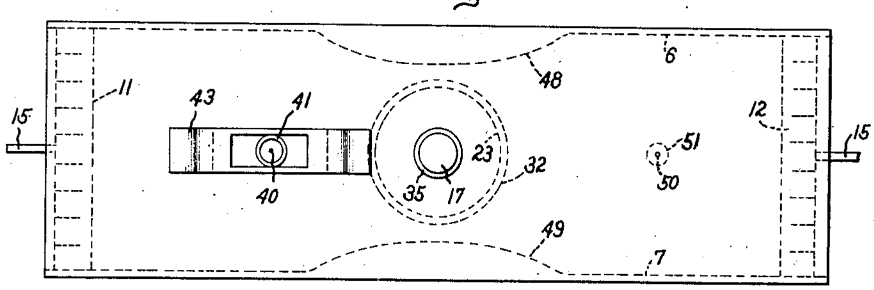


Fig.4.



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July 16, 1946. J. R. WHINNERY 2,404,261
ULTRA HIGH FREQUENCY SYSTEM
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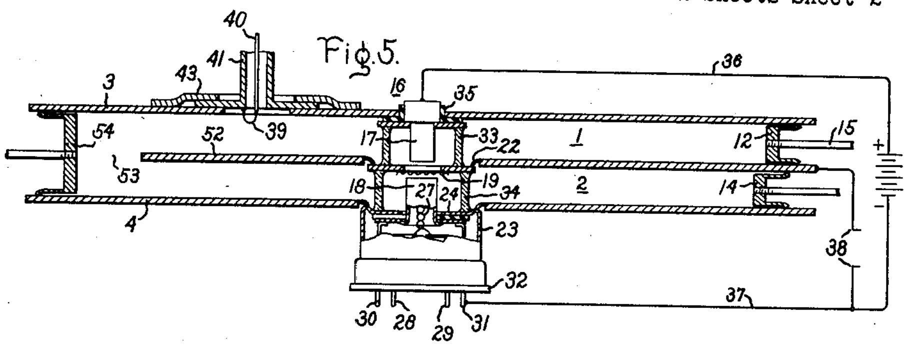


Fig. 5.

Fig. 6.

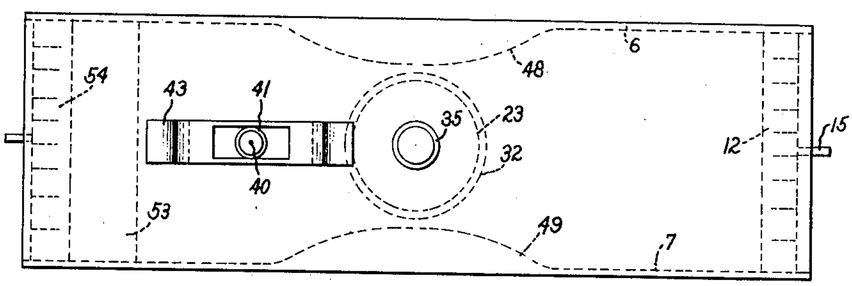
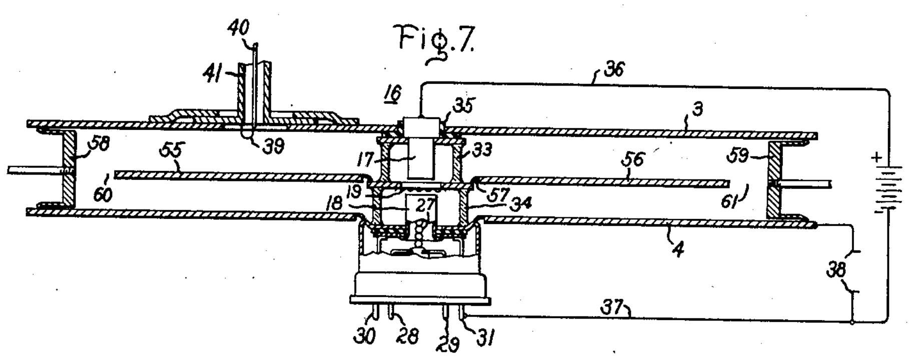


Fig. 7.



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Patented July 16, 1946

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UNITED STATES PATENT OFFICE

2,404,261

ULTRA HIGH FREQUENCY SYSTEM

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Application October 31, 1942, Serial No. 464,037

15 Claims. (Cl. 315—39)

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My invention relates to ultra high frequency systems and more particularly to electric discharge devices and associated space resonant cavities, or regions, for the production and utilization of ultra high frequency energy.

Energy may be transmitted dielectrically through wave guides of the hollow-pipe type when the frequency at which the guide is excited is greater than a critical minimum or cut-off frequency, the energy being transmitted through the dielectric of the medium within the guide and conductive or metallic defining members or walls of the guide serving to direct the propagation of the electromagnetic wave.

The types of waves which may be transmitted dielectrically through guides of this nature are manifold and have been classified in the early stages of the development of this art into E and H type waves. At a somewhat later date, the terms "transverse magnetic" (TM) and "transverse electric" (TE) have been used to define the E and H type waves, respectively. In the E type wave, or the transverse magnetic type, the electromagnetic waves have both longitudinal and transverse components of electric field, but only a transverse component of magnetic field. By the use of the word transverse is meant transverse to the direction of wave propagation through the guide. In the H type waves, or the transverse electric type waves, the electromagnetic waves have both a longitudinal and a transverse component of magnetic field, but only a transverse component of electric field. Waves transmitted through guides of this nature have been identified by the use of the subscripts, as indicated, $E_{n,m}$ and $H_{n,m}$. The subscript n indicates the order and the subscript m indicates the mode of propagation. For example in circular guides, the order of the waves is determined by the manner in which the field intensity varies circumferentially around the axis of the guide, whereas the mode is determined by the manner of its variation with distance from the axis of the guide. Although hereinafter in the discussion of my invention an H_{01} type wave in a rectangular guide will be referred to, it is to be appreciated that my invention is applicable with equal facility to other H type waves as well as E type waves.

It is an object of my invention to provide new and improved ultra high frequency space resonant devices.

It is another object of my invention to provide new and improved dielectric wave guides for use in connection with high frequency electric discharge devices.

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It is another object of my invention to provide new and improved space resonant regions, or cavities, employing electric discharge devices.

It is a further object of my invention to provide new and improved space resonant oscillators.

It is a still further object of my invention to provide new and improved ultra high frequency space resonant amplifiers.

It is a still further object of my invention to provide new and improved space resonant cavities, or regions, having a particular configuration to facilitate the use therewith of electric discharge devices wherein the space resonant regions are formed by employing tuned sections of a dielectric wave guide of the hollow-pipe type and wherein the transverse dimensions of the section of the wave guide are chosen in order to compensate for the capacitance effect of the electric discharge device so that electromagnetic waves may be propagated therethrough or sustained in a manner substantially unaffected by the presence of the discharge device.

It is a still further object of my invention to provide a new and improved ultra high frequency system wherein an ultra high frequency triode is positioned within a section of a dielectric wave guide and wherein the wave guide is foreshortened in its width within the vicinity of the electric discharge device in order that the impedance of the guide is substantially uniform along its longitudinal axis.

Briefly stated, in the illustrated embodiments of my invention I provide ultra high frequency space resonant systems comprising a tuned section of a dielectric wave guide of the hollow-pipe type which may be used for various purposes, such as for the production of electromagnetic oscillations, or for the amplification of electromagnetic waves of high frequency. The transverse dimensions of the guide are chosen within the vicinity of the electric discharge device so that the guide offers a substantially uniform impedance along its longitudinal axis. More specifically, the transverse dimension or width of the guide is restricted within the region of the electric discharge device to compensate for the capacitance effect of the device, thereby maintaining the desired relationship between the effective distributed inductance and capacitance of the guide not only at points removed from the position of the discharge device but within the vicinity thereof.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims. Figs. 1 and 2 diagrammatically illustrate an embodiment of my invention as applied to an ultra high frequency space resonant system which may be used either as an ultra high frequency oscillator, or as an ultra high frequency amplifier. Figs. 3 and 4 represent a further modification which is provided with coupling means interposed between the anode-grid and the grid-cathode space resonant cavities. Figs. 5 and 6 represent a further modification of my invention as applied to a high frequency space resonant system of the re-entrant type, and Fig. 7 represents a modification of the arrangement shown in Figs. 5 and 6 wherein a double reentrant feature is employed.

Referring now to Figs. 1 and 2 jointly, I have there illustrated my invention as applied to an ultra high frequency space resonant system comprising a pair of space resonant regions, or cavities, 1 and 2 which are defined by sections of a dielectric wave guide of the hollow-pipe type. These sections may be defined by conductive or metallic members constructed of copper or brass and, of course, may assume various cross sectional configurations. For the purpose of illustrating my invention, I have chosen to employ dielectric wave guides of rectangular cross section, which may be defined by metallic outer plates or members 3 and 4, and having an intermediate common metallic member 5 which defines a common metallic boundary between the two regions. Members 3—5 are positioned so that the heights a of regions 1 and 2 are preferably equal, and the width b may be established by means of lateral wall members 6 and 7 which, of course, are conductively connected to members 3, 4 and 5.

In order to facilitate the employment of an electric discharge device, to be described presently, in the space resonant system, plates 3, 4 and 5 are provided, respectively, with apertures, preferably circular apertures, 8, 9 and 10 which are substantially coaxial, the axis of which lies substantially perpendicular to the longitudinal axes of the cavities 1 and 2.

As a means for establishing the longitudinal dimensions of the cavities 1 and 2, and as a means for tuning these cavities with respect to the electromagnetic waves established therein, I employ a plurality of adjustable end-wall members which may take the form of plungers 11, 12, 13 and 14 which may be actuated by any suitable mechanical expedient, such as rods 15. It will be observed that plungers 11 and 12 engage the metallic walls of members 3 and 5 which define space resonant cavity 1, and that the plungers 13 and 14 engage the walls of metallic members 4 and 5 which define the space resonant cavity 2.

Prior to a further description of the system, it is believed that at this time it will be helpful to point out certain fundamental aspects of dielectric wave guides of the hollow-pipe type, with particular attention to rectangular guides. As stated above, there is a critical minimum or cut-off frequency for each mode in a dielectric guide, which is determined by the mode, the dielectric constant of the medium within the guide through which the electromagnetic waves are propagated, and the transverse dimensions of the guide. Below this minimum or cut-off frequency the electromagnetic waves are rapidly attenuated and the energy thereof is not transmitted an appreciable distance along the guide. Above the critical frequency, the electromagnetic waves are propagated with an attenuation and velocity determined by the propagation constant of the guide. The propagation constant h may be expressed as follows:

$$h=\alpha+i\beta \qquad (1)$$

where α is the attenuation constant and β is the phase constant and both are real quantities whose magnitudes depend upon frequency.

If the frequency is sufficiently large, α is very small compared to β and the waves are propagated without appreciable attenuation at a phase velocity

$$\frac{\omega}{\beta}$$

which is a function of the transverse dimension of the guide. When the excitation frequency is below the critical frequency, the Equation 1 may still be used but α and β both become imaginary with the result that β determines the attenuation and α determines the extent of wave action. Physically, this means that the transmission of waves through the guide is virtually non-existent at frequencies below the cut-off frequency.

The phase constant β may be expressed:

$$\beta=\left[\omega^2\mu\epsilon-\left(\frac{n\pi}{a}\right)^2-\left(\frac{m\pi}{b}\right)^2\right]^{1/2} \qquad (2)$$

where ω is the angular velocity of the wave propagated through the guide ($\omega=2\pi f$ where f is the frequency of the wave), μ is the permeability of the medium and ϵ is the dielectric constant of the medium in consistent units, such as rational m. k. s. The quantities n and m are the order and mode of the particular wave being transmitted through the guide.

Furthermore, it can be shown that the critical frequency f_0 may be defined as follows:

$$f_0=\frac{1}{2\sqrt{\mu\epsilon}}\left[\left(\frac{n}{a}\right)^2+\left(\frac{m}{b}\right)^2\right]^{1/2} \qquad (3)$$

The wave length λ_g of the electromagnetic waves propagated through the guide may be defined as:

$$\lambda_g=\frac{2\pi}{\beta} \qquad (4)$$

In order to simplify still further the presentation of the subject matter relative to a rectangular dielectric wave guide, it will be assumed that the dielectric is air and that the system is arranged for the transmission of an H_{01} type wave where the electric component of the field is perpendicular to the base b. With these assumptions, Equations 2 and 3 become:

$$\beta=\left[\left(\frac{\omega}{c}\right)^2-\left(\frac{\pi}{b}\right)^2\right]^{1/2} \qquad (5)$$

$$f_0=\frac{c}{2b} \qquad (6)$$

where c is the velocity of light.

A concept of total impedance useful in matching wave guides suggests that the impedance of the guide remain substantially constant along its longitudinal dimension, and it will of course be observed that there must be a fixed or predetermined relationship or ratio between the height a and the base b. This concept may be put into equation form as follows:

$$Z=\frac{\mu\pi c}{2}\frac{\lambda_g}{\lambda}\frac{a}{b} \qquad (7)$$

where Z represents the impedance; μ is the permeability of air, and c is the velocity of light. If the guide impedance is constant, the wave will be propagated or sustained uniformly and to maintain this impedance constant for changes in guide dimensions or changes in guide characteristics, one must have at any particular wave length the following relationship:

$$\frac{a}{b}\lambda_g = \text{constant} = k \qquad (8)$$

Returning now to Figs. 1 and 2, the longitudinal and transverse dimensions a and b of the space resonant cavities 1 and 2 are chosen so that the cavities are tuned or substantially resonant to an electromagnetic wave of a predetermined frequency. For example, the dimension b should be chosen to have a value which is somewhat greater than a free-space half-wave length, or multiples thereof, of the electromagnetic wave sustained within cavity 1 or 2. Furthermore, by the adjustment of plungers 11—14, the cavities may be adjusted to have longitudinal dimensions equal to a half-wave length, measured in terms of λ_g, or multiples thereof, so that standing electromagnetic waves are established within these cavities. That is, upon adjustment of plungers 11—14 the standing potential and current curves of the electromagnetic waves assume positions fixed in space but undergoing sinusoidal time variations. More particularly, voltage nodes of the potential curves occur at the end of the cavities, and a current node occurs at a point midway between the ends of the cavities, the voltage and current standing waves being in time quadrature.

I position within the apertures 8, 9 and 10 an electric discharge device 16 of the type disclosed and claimed in copending patent application Serial No. 436,633 of James E. Beggs, filed March 28, 1942, and which is assigned to the assignee of the present application. This discharge device is peculiarly adapted for the utilization of ultra high frequency energy and comprises a plurality of enclosed electrodes including a cylindrical anode 17, a cylindrical cathode 18 and a grid 19 maintained in spaced relation between the anode and the cathode. Anode 17 and grid 19 are supported by metallic discs 20 and 21, the latter of which is conductively connected to the intermediate plate member 5 through resilient fingers or an annular metallic collar 22. Cathode 18 is supported by a cylindrical member 23 having a flat disc part 24 substantially parallel to disc 21. Members 21 and 23 provide externally accessible high frequency terminals for grid 19 and cathode 18. Cathode 18 is provided with a flanged part 25 substantially parallel to the lower surface of part 24 and is spaced therefrom by means of an insulator 26 so that the cathode is electrically insulated therefrom, so far as direct current potentials are concerned, but effectively connected thereto with reference to high frequency current, by virtue of the electrostatic coupling between the parallel surfaces. Cathode 18 is also provided with a coiled heating element 27 to which current may be supplied through suitable conductors terminated in contact pins 28 and 29. Unidirectional potential may be applied to the cathode 18 through other conductors terminated in contact pins 30 and 31. Contact pins 28—31 are supported by a base 32 which encloses a metallic header (not shown) and in which the various conductors for the cathode heating element and the cathode are sealed.

To complete the enclosure for the electrodes

of the discharge device and for maintaining the electrodes in spaced relation, there is provided cylindrical vitreous insulators 33 and 34 immediately surrounding the anode 17 and cathode 18 and which are sealed to members 20, 21 and part 24. Anode 17 is electrically insulated from the metallic or conductive structure of the space resonant cavities, and particularly from plate 3, so far as direct current potentials are concerned, by means of an insulator 35, so that a suitable potential may be applied across the anode 17 and cathode 18 through conductors 36 and 37. The anode is effectively connected to the top of cavity 3 for high frequency currents by the electrostatic coupling between plates 3 and 20.

Where it is desired to impress a unidirectional biasing potential on the grid 19, I may employ a circuit 38 connected to conductor 37 or cathode 18 through contact pin 31, and to the intermediate plate member 5. For example, this biasing means may comprise a high resistance grid lead connected in circuit 38.

Energy may be extracted from the anode-grid space resonant cavity 1 by suitable electrode means which may take the form of a loop 39 constituting an extension of an inner conductor 40 of a coaxial or concentric transmission line comprising the inner conductor 40 and an outer tubular conductor 41, the latter of which is conductively connected to outer member 3 and is arranged to slide along the outer surface thereof. Plate 3 is provided with an opening 42 of appreciable longitudinal dimension, thereby permitting adjustment of the position of loop 39 to that optimum position wherein maximum energy may be extracted from the space resonant region 1. Any suitable mechanical arrangement may be provided for adjusting loop 39, and such an arrangement is diagrammatically illustrated as constituting a plate 43 welded or soldered to the outer surface of member 3 and which positions and guides the flanged part of outer conductor 41.

Where the arrangement illustrated in Figs. 1 and 2 is employed as an amplifier, the input excitation for the grid-cathode space resonant cavity 2 may be provided by means of input electrode means 44 constituting an outer tubular conductor 45 and an inner conductor 46 terminated in a loop 47 which projects into the space resonant region 2. It will be understood that other forms of electrode means, such as probes or the equivalent, may be employed for this purpose.

In order to maintain the impedance of the guide constant along its length and particularly to arrange cavities 1 and 2 so that the cavities offer substantially no discontinuity due to the presence of the discharge device 16, I provide means within the respective cavities for restricting the transverse dimension b within the vicinity of the discharge device, thereby compensating for the capacitance effect of the discharge device in order that the waves within the respective cavities are substantially unaffected by the presence of the discharge device. More particularly, the transverse dimension within the vicinity of the electric discharge device 16 is foreshortened so that the guide at this point is substantially resonant to the electromagnetic waves which it is desired to sustain. In other words, inasmuch as the electric discharge device 16 offers an appreciable capacitance by virtue of its configuration and presence, the dimension b is foreshortened so that the resultant or effective distributed capitance and the capacitance of the discharge device 16 resonate with the distributed inductance of this portion of the guide or cavities. One way in which this desired symmetry of the longitudinal impedance of the respective cavities may be obtained is by restricting the transverse dimension *b* and by providing the lateral wall members 6 and 7 with appropriately enlarged wall thicknesses or protuberances 48 and 49 having a curvature and a configuration so that no abrupt discontinuity is encountered as the wave progresses along the longitudinal axis. For example, the protuberances 48 and 49 may be formed integral with the lateral wall members 6 and 7, or may be constituted separately and inserted in the proper position. Of course, it is required that these protuberances 48 and 49 be conductive and be conductively connected to the wall members 6 and 7. Where the protuberances are constructed separately, these parts may be welded or soldered to the lateral wall members 6 and 7.

Upon the application of a suitable potential, such as a unidirectional potential, to the anode 17 and cathode 18, the space resonant system shown in Figs. 1 and 2 are initiated in operation. Each of the cavities 1 and 2 is tuned or resonant to the desired frequency, and energy is supplied to an external utilization circuit from the anode-grid cavity through loop 39 and the concentric transmission line comprising conductors 40 and 41. In the arrangement of Figs. 1 and 2, when used as an oscillator, the coupling between the anode-grid cavity 1 and the grid-cathode cavity 2 is obtained principally by virtue of the inter-electrode capacitance effects of the electric discharge device 16, whereby the system is maintained in oscillation by virtue of the cyclic variations in the potential impressed between grid 19 and cathode 18. Inasmuch as the grid and the boundary member 5 are common to the two cavities, it may be considered that the anode and cathode voltages vary substantially in that phase relationship with respect to the grid, necessary to maintain the discharge device 16 and the space resonant system as an entirety in oscillation.

If the side walls 6 and 7 were not shortened by use of protuberances 48 and 49, that is, if the transverse dimension *b* is uniform throughout the cavities, resonance is then determined by an electromagnetic wave traveling essentially in the transverse direction within the vicinity of the discharge device 16, due to the fact that the capacitance loading effect thereof tends to lower the natural resonance frequency within that region to a frequency for which the width *b* is less than a half-wave length. Consequently, the lowest order wave H_{01} is then below cut-off in the regions removed from the vicinity of the discharge device, that is where the tube capacitance loading effects have disappeared. Attempts to tune such an arrangement by plungers far removed from the discharge device or to couple the electromagnetic fields of the cavities by loops or lines in regions of the cavities far from the discharge device are not effective under those conditions.

By the restriction of the transverse dimension, or dimensions, of the cavities within the vicinity of discharge device 16, the tendency to establish a localized wave region, or a wave propagated along the transverse axis within the vicinity of the discharge device is reduced or substantially eliminated, and the electromagnetic waves will be sustained symmetrically throughout the entire length of the respective space resonant cavities. Furthermore, tuning and coupling may be obtained with facility.

The arrangement of Fig. 1 may also be employed as an amplifier of ultra high frequency voltages or currents, in which case the input electrode means, and particularly loop 47, is energized through the concentric transmission line 44, establishing within the grid-cathode space resonant region 2 an electromagnetic oscillation. In this case, of course, the cavity 2 being tuned to the frequency of the input excitation sustains a standing electromagnetic wave and, by virtue of the fact that the electric discharge device 16 is positioned within the vicinity of the potential maximum of this standing wave, the grid and the cathode undergo cyclic variations of potential to modulate the electron beam transmitted between anode 17 and cathode 18, consequently effecting energization of the anode-grid cavity 1 and maintaining this cavity in oscillation. Energy is extracted from the anode-grid cavity 31 by loop 39 and the associated concentric transmission line. The amplification of the input signal is obtained by virtue of the amplification effect due to the electric discharge device 16 which couples the respective cavities.

Figs. 3 and 4 show a further embodiment of my invention similar in many respects to that shown in Figs. 1 and 2, and corresponding elements have been assigned like reference numerals. In the arrangement of Figs. 3 and 4, there is provided separate coupling means, such as a probe 50, supported by the intermediate metallic member 5, but spaced electrically therefrom by means of insulating glass bead or seal 51. Other suitable forms of coupling means may be employed and, of course, positioned at that point to obtain the maximum or desired coupling effect.

Figs. 5 and 6 represent a further modification of my invention which is similar in many respects to that shown in Figs. 1 and 2, and corresponding elements have been assigned like reference numerals. In the arrangement of Figs. 5 and 6, I provide a space resonant oscillator of the re-entrant type wherein an intermediate member 52, defining the common boundary between the anode-grid and the grid-cathode space resonant cavities, does not extend the entire longitudinal dimension of the respective cavities, so that there is afforded a re-entrant coupling path 53 between the anode-grid cavity 1 and the grid-cathode cavity 2 thereby constituting a feed-back connection between these two cavities. When such a construction is employed, the corresponding end walls of the respective cavities may comprise a single tuning plunger 54 which engages the inner surfaces of the metallic defining members 3, 4, 5 and 6.

In the arrangement of Figs. 5 and 6, the length of the member 52 is preferably chosen so that the desired phase relationship between the anode-grid and the grid-cathode voltages is maintained. For example, since the grid 19 is at the common potential, in order that the anode and cathode vary in the proper phase relationship, the axial or longitudinal dimension of the member 52 should be substantially equal to a half-wave length of the electromagnetic waves sustained within the respective cavities. Of course, actually the physical length of the part 52 is somewhat less than a half-wave length due to the end effects.

In the arrangement of Fig. 7 there is illustrated a still further modification of my invention as applied to a space resonant system, such as an ultra high frequency oscillator employing a double re-entrant feature. That is, the anode-grid and the grid-cathode cavities are defined by a metallic member having parts 55 and 56 which may be constituted by a single member having therein an aperture 57 through which the discharge device 16 extends. Members 55 and 56 extend axially the longitudinal dimension of the system, but do not engage the metallic end walls defined by plungers 58 and 59, thereby affording coupling paths 60 and 61 between the anode-grid and the grid-cathode space resonant regions. Energy is fed back from the anode-grid cavity to the grid-cathode cavity, and the axial dimensions of the parts 55 and 56 are chosen in order that the grid-cathode voltage have the desired phase relationship to maintain the system in oscillation.

While I have shown and described my invention as applied to particular systems and as embodying various devices diagrammatically shown, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, 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 space resonant system comprising a section of a dielectric wave guide of the hollow-pipe type including conductive defining walls, said section being dimensioned to support electromagnetic waves of predetermined frequency, an electric discharge device comprising a plurality of enclosed electrodes connected to oppositely disposed walls of said guide and being positioned substantially transverse to the longitudinal axis of said section and enclosing structure for said electrodes, and means for restricting a transverse dimension of said guide within the vicinity of said device to compensate for the capacitance effect of said discharge device in order that the electromagnetic wave of said predetermined frequency is substantially unaffected by the presence of said discharge device.

2. A space resonant system comprising a section of a dielectric wave guide of the hollow-pipe type including conductive walls, said section being excited at a frequency greater than the cut-off frequency and having dimensions so that said section is tuned substantially to the excitation frequency, an electric discharge device comprising a plurality of enclosed electrodes connected to oppositely disposed walls of said section, an enclosing structure for said electrodes, and means for restricting a transverse dimension of said guide to compensate for the capacitance effect of said discharge device in order that the wave of said excitation frequency is substantially unaffected by the presence of said discharge device.

3. A space resonant system comprising a section of a dielectric wave guide of the hollow-pipe type including a metallic defining member, said section being dimensioned to support electromagnetic waves of a predetermined frequency and having dimensions so that said section is tuned substantially to said frequency, an electric discharge device comprising a pair of enclosed electrodes, an enclosing structure immediately surrounding said electrodes and providing externally accessible high frequency terminals connected to oppositely disposed points of said member, means for restricting a transverse dimension of said section to compensate for the capacitance effect of said discharge device in order that the electromagnetic wave of said predetermined frequency is substantially unaffected by the presence of said discharge device, and electrode means associated with said section for supplying energy to or extracting energy therefrom.

4. A space resonant oscillator comprising a section of a dielectric wave guide of the hollow-pipe type including a conductive defining member, said section being dimensioned to support electromagnetic waves of a predetermined frequency and having dimensions so that said section is tuned substantially to the excitation frequency, an electric discharge device comprising a plurality of enclosed electrodes connected to oppositely disposed walls of said conductive member, an enclosing structure immediately surrounding said electrodes, means for restricting a transverse dimension of said guide to compensate for the capacitance effect of said discharge device in order that the electromagnetic wave of said predetermined frequency is substantially unaffected by the presence of said discharge device, and output electrode means connected to said section.

5. An ultra high frequency space resonant system comprising a section of a dielectric wave guide of the hollow-pipe type defined by longitudinal and lateral conductive members, said section being excited at a predetermined frequency correlated to the dimensions of said section, and an electric discharge device including a plurality of electrodes comprising an anode, a cathode and a grid, transverse discs for supporting said members and for providing high frequency terminals between two of said electrodes and the conductive members of said section and an enclosing structure for said electrodes, the transverse dimension of said section being restricted within the vicinity of said electric discharge device in order to compensate for the capacitance effect of said discharge device.

6. A high frequency space resonant system comprising a section of a dielectric wave guide of the hollow-pipe type including a conductive member for defining a space resonant region, said space resonant region being excited at a frequency corresponding to the natural frequency thereof, and an electric discharge device including an electric discharge path provided by a pair of electrodes and an enclosing structure therefor, said discharge device being connected transversely across said guide along the longitudinal axis thereof within the vicinity of the potential maximum of the standing electromagnetic wave within said region, means for restricting the section of said electric wave guide within the vicinity of said discharge device to compensate for the capacitance effect of said electric discharge device.

7. A high frequency space resonant system comprising a pair of space resonant cavities defined by a pair of sections of a dielectric wave guide and having a common metallic boundary, an electric discharge device comprising a plurality of enclosed electrodes including an anode, a cathode and a grid and an enclosing structure therefor, said discharge device being positioned within said cavities and having the cathode and grid thereof connected to oppositely disposed transverse points of one of said cavities, and means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof.

8. An ultra high frequency space resonant system comprising a pair of space resonant cavities

defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type including conductive outer defining members and having a common metallic boundary, said members being provided with alined apertures the axis of which is substantially perpendicular to the longitudinal axis of said cavities, an electric discharge device positioned within said apertures and comprising a plurality of enclosed electrodes including an anode, a cathode and a grid and an enclosing structure for said electrodes, said anode being electrically insulated from one of the outer members and said grid and said cathode being connected respectively to the common metallic boundary and the other outer member, means for applying a potential across said anode and said cathode, and means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof so that said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes.

9. An ultra high frequency space resonant oscillator comprising a pair of space resonant cavities defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type including conductive outer defining members and having a common metallic boundary, said members being provided with apertures alined substantially perpendicularly to the longitudinal axis of said cavities, an electric discharge device positioned within said apertures and comprising a plurality of enclosed electrodes including an anode, a cathode and a grid and an enclosing structure immediately surrounding said electrodes and having externally accessible high frequency terminals, said anode being electrically insulated from one of the outer members and said grid and said cathode being connected respectively to the common metallic boundary and the other outer member, means for applying a potential across said anode and cathode, means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof whereby said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes, and output electrode means connected to the cavity associated with the anode-grid circuit of said discharge device.

10. An ultra high frequency space resonant oscillator comprising a pair of space resonant cavities defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type including conductive outer defining members and having a common metallic boundary, said members being provided with substantially concentric apertures alined perpendicular to the longitudinal axis of said cavities, an electric discharge device positioned within said apertures and comprising a plurality of enclosed electrodes including an anode, a cathode and a grid and an enclosing structure immediately surrounding said electrodes and having externally accessible high frequency terminals, said anode being electrically insulated from one of the outer members and said grid and said cathode being connected respectively to the common metallic boundary and the other outer member, means for applying a potential across said anode and cathode, means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof whereby said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes, output electrode means connected to the cavity associated with the anode-grid circuit of said discharge device, and means for tuning at least one of said cavities.

11. An ultra high frequency space resonant amplifier comprising a pair of space resonant cavities defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type including conductive outer defining members and having a common metallic boundary, said members being provided with concentric apertures the axis of which is substantially perpendicular to the longitudinal axis of said cavities, an electric discharge device positioned within said apertures and comprising a plurality of electrodes including an anode, a cathode and a grid and an enclosing structure immediately surrounding said electrodes and affording externally accessible high frequency terminals thereto, said anode being electrically insulated from one of said outer members and said grid and said cathode being connected respectively to the common metallic boundary and the other outer member, means for applying a potential across said anode and said cathode, means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof whereby said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes, input electrode means associated with the cavity connected to said grid and said cathode, and output electrode means associated with the other cavity.

12. An ultra high frequency space resonant system comprising a pair of space resonant cavities defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type including outer defining members and having throughout an appreciable longitudinal length thereof a common metallic boundary of the re-entrant type whereby energy may be transferred between said cavities, an electric discharge device positioned within apertures of said outer members and said common metallic boundary and comprising a plurality of enclosed electrodes including an anode, a cathode and a grid and an enclosing structure surrounding said electrodes, said anode being electrically insulated from one of the outer members and said grid and said cathode being connected respectively to the common metallic boundary and the other outer member, means for applying a potential across said anode and said cathode, means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof so that said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes thereof, means for tuning at least one of said cavities, and means for extracting energy from the anode-grid cavity associated with said discharge device.

13. An ultra high frequency space resonant system comprising an electric discharge device including a plurality of enclosed electrodes comprising an anode, a cathode and a grid and an enclosing structure surrounding said electrodes and providing externally accessible high frequency terminals thereto, a pair of space resonant cavities defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type

including outer defining members and an intermediate member, said intermediate member being connected to said grid through the associated terminal but not extending the entire axial length of said cavity thereby providing a re-entrant path for the transfer of energy from the anode-grid to the grid-cathode circuit of said discharge device, means for restricting the width of said cavities within the vicinity of said electric discharge device in order to compensate for the capacitance effect thereof so that said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes, and electrode means associated with one of said cavities.

14. An ultra high frequency space resonant system comprising an electric discharge device including a plurality of enclosed electrodes including an anode, a cathode and a grid and an enclosing structure surrounding said electrodes, a pair of space resonant cavities defined by two adjacent sections having a dielectric wave guide of the hollow-pipe type including conductive dedefining members, tuning means for said cavities comprising adjustable conductive end members, a conductive member intermediate the first mentioned members and connected to said grid and extending in one direction to engage an end wall and extending towards but not engaging the other end wall thereby constituting a re-entrant coupling path between the anode-grid and the grid-cathode circuits of said discharge device,

said first mentioned members being restricted within the vicinity of said electric discharge device in order to compensate for the capacitance effects thereof so that said cavities afford a substantially uniform impedance to electromagnetic waves of a predetermined frequency along the longitudinal axes of the cavities, and output electrode means associated with at least one of said cavities.

15. A space resonant system comprising a pair of space resonant cavities defined by two adjacent sections of a dielectric wave guide of the hollow-pipe type including outer defining members and having throughout an appreciable length thereof an intermediate boundary of the reentrant type, said intermediate boundary being provided with an aperture, an electric discharge device positioned within said aperture and comprising a plurality of enclosed electrodes including an anode, a cathode and a grid, said grid being connected to said intermediate boundary and said anode and cathode being connected for high frequency currents to respective points on said outer members located substantially along the axis of said aperture which is perpendicular to the longitudinal axis of said cavities, means for restricting the transverse dimensions of said cavities in the vicinity of said electric discharge device to compensate for the capacitance effect thereof, and means for applying a difference of potential across said anode and said cathode.

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