July 1, 1947. J. M. LAFFERTY 2,423,327

ULTRA HIGH FREQUENCY OSCILLATOR OF THE CAVITY RESONATOR TYPE

Filed Oct. 2, 1942

Fig. 1.

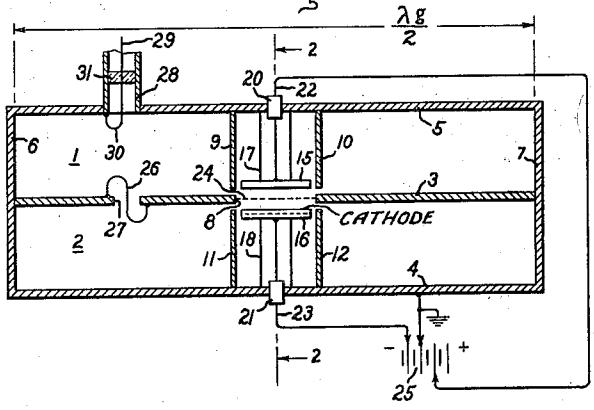


Fig. 2.

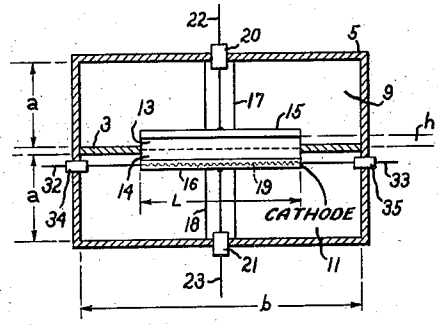
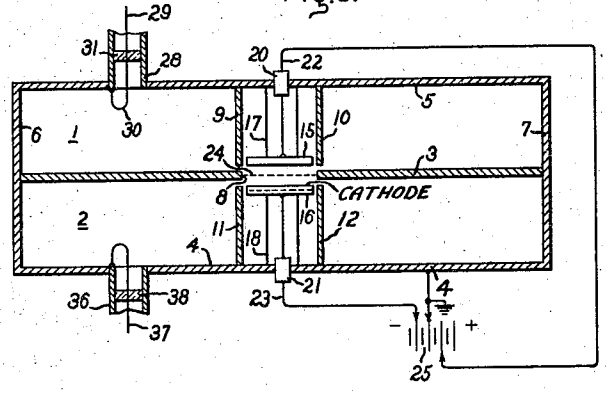


Fig. 3.



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His Attorney.

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UNITED STATES PATENT OFFICE

2,423,327

ULTRA HIGH FREQUENCY OSCILLATOR OF THE CAVITY RESONATOR TYPE

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Application October 2, 1942, Serial No. 460,524

14 Claims. (Cl. 315—6)

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My invention relates to electric discharge devices and more particularly to ultra high frequency electric discharge devices of the space resonant type.

With the ever increasing demand for electric discharge apparatus and devices for use in the ultra high frequency field, it has become apparent that many of the prior art arrangements are not satisfactory due primarily to the prohibitive decrease in the input impedance thereof as the operating frequency is increased. In accordance with the teachings of my invention described hereinafter, I provide a new and improved electric discharge device which is capable of operation satisfactorily within the ultra high frequency field, and which obviates many of the disadvantages of the prior art arrangements.

It is an object of my invention to provide a new and improved electric discharge device.

It is another object of my invention to provide a new and improved high frequency oscillator and amplifier of the space resonant type.

It is a further object of my invention to provide a new and improved ultra high frequency triode oscillator or amplifier of the space resonant type comprising a space resonant cavity, or cavities, which may be considered as comprising isolated sections of a dielectric wave guide.

It is a still further object of my invention to provide a new and improved ultra high frequency triode oscillator of the space resonant type comprising a plurality of adjoining and metallically bound tuned space resonant cavities, and which includes means therein for effecting a concentration of the potential differences due to the electromagnetic waves within the respective cavities and which is provided with an electric discharge path which maintains the discharge device in oscillation.

Briefly stated, in accordance with the illustrated embodiment of my invention, I provide a new and improved high frequency electric discharge device, such as a high frequency triode oscillator, which comprises a pair of adjoining, metallically bound, space resonant cavities which are dimensioned to support electromagnetic waves of predetermined frequency. The cavities have a metallic boundary in common and this boundary is provided with a communicating opening. Means, such as a resonant aperture or slot, is provided in transverse wall sections in each of the cavities to effect a concentration of the potential difference due to the electromagnetic waves, or the standing electromagnetic waves, in each of the cavities, and electric discharge means

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is associated with the opening in the metallic boundary and the resonant apertures to produce and maintain oscillation of the electric discharge device as a whole, so that energy may be derived from either one of the cavities.

In accordance with another feature of my invention, I provide a new and improved high frequency amplifier of the space resonant type which comprises two tuned cavities or sections of a hollow-pipe type dielectric wave guide each of which includes means, such as a resonant aperture or slot, for concentrating the voltage difference due to the electromagnetic waves and associated controlled discharge path. Input electrode means are associated with the grid-cathode cavity and output electrode means are associated with the anode-grid cavity.

The subject matter of this application relates to improvements in electric discharge devices of the space resonant type of the nature disclosed and broadly claimed in my copending U. S. patent application, Serial No. 460,523, filed concurrently herewith and which is assigned to the assignee of the present application.

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. Fig. 1 diagrammatically illustrates a longitudinal cross sectional view of a high frequency triode oscillator built in accordance with my invention; Fig. 2 is a cross-sectional end view particularly relating to the transverse wall sections including the resonant apertures and the associated anode and cathode which constitute an electric discharge path; and Fig. 3 is a modification of my invention as applied to a high frequency amplifier of the space resonant type.

As stated above, the space resonant cavities employed in the electric discharge device which I provide may be considered as isolated or tuned sections of a dielectric wave guide of the hollow-pipe type. Accordingly, it is believed that it may be helpful in the description of my invention to review briefly certain fundamental aspects of dielectric wave guides of the hollow-pipe type.

It is now somewhat generally appreciated that high frequency electromagnetic waves may be transmitted through or supported by dielectric wave guides of the hollow-pipe type, such as wave guides constructed of a highly conductive material or metal such as copper or brass, where the frequency at which the guide is excited is greater than the critical or cut-off frequency. The types

of waves which may be transmitted dielectrically through guides of this type are manifold and heretofore have been generally classified into the E and H types. Although my invention may be applied to electromagnetic waves of a variety of types, in the following description particular reference will be made to the H_{01} type of wave inasmuch as it is of less complex order and mode and inasmuch as it is easier to produce this type of wave and utilize it than some of the higher order waves.

Where the dielectric wave guide or a section thereof is excited at a frequency greater than the critical or minimum frequency, the wave will be propagated through the dielectric guide having a rectangular cross section of height a and base b, and will have a phase constant β which may be expressed as follows:

$$\beta=\left[\omega^2\mu_1\epsilon_1-\left(\frac{n\pi}{a}\right)^2-\left(\frac{m\pi}{b}\right)^2\right]^{\frac{1}{2}} \quad (1)$$

where ω is the angular velocity of the wave propagated through the medium; that is, ω is equal to $2\pi f$, where f is the frequency of the wave, or in the case of a cavity it is the natural frequency of the cavity, μ_1 is the permeability of the medium within the guide or cavity; ϵ_1 is the effective dielectric constant of the medium, and n and m are, respectively, the order and mode of propagation of the electromagnetic wave under consideration.

It will be noted that in Equation 1 ϵ_1 is defined as being the effective dielectric constant of the medium. As will be described presently, the electric discharge devices which I provide include as an element thereof an electric discharge path, that is a region of charged electrical particles, which affect the dielectric constant of the medium within the cavities. More particularly, the presence of the charged electrical particles, such as electrons, effect a reduction in the magnitude of the dielectric constant of the medium and as a result affect the phase constant β and the phase wave length of the electromagnetic waves supported by the respective cavities. Accordingly, it is necessary in the computation of the phase constant and the phase wave length to employ the effective value of the dielectric constant of the medium as modified by the presence of the region of charged particles. Generally speaking, it may be said that the effective dielectric constant of the medium is a function of the difference of the dielectric constant of the medium with no charged particles present, a quantity which is directly proportional to the number of charged particles per unit volume, the square of the unit charge of each particle, and inversely proportional to the mass of each charge and some function of the frequency.

The critical frequency f_0 may be defined as follows:

$$f_0=\frac{1}{2\sqrt{\mu_1\epsilon_1}}\left[\left(\frac{n}{a}\right)^2+\left(\frac{m}{b}\right)^2\right]^{\frac{1}{2}} \quad (2)$$

Consequently, the phase wave length of the electromagnetic waves propagated through the guide, or the phase wave length of the electromagnetic waves within a cavity, may be defined as:

$$\lambda_g=\frac{2\pi}{\beta} \quad (3)$$

Referring now to Fig. 1 of the accompanying drawing, I have there diagrammatically illustrated my invention as applied to an electric discharge device, such as a high frequency triode oscillator which comprises a pair of tuned or space resonant cavities 1 and 2 of the hollow-pipe type. The space resonant cavities 1 and 2 are metallically bound, preferably by metal such as copper which has a relatively high electrical conductivity. The cavities 1 and 2 may be formed to have a common metallic boundary, such as a plate 3, and the other longitudinal boundaries of the cavities 1 and 2 may be provided by a metallic base plate 4 and a top plate 5. The ends of the cavities may be defined by metallic plates 6 and 7, and the sides shown in Fig. 2 may all be welded or soldered to form a hermetically sealed region.

The longitudinal dimension of the space resonant cavities 1 and 2 is established to be an integral multiple, either odd or even, of a half-wave length of the electromagnetic wave which would be propagated through the cavities if these cavities constituted sections of a dielectric wave guide of the hollow-pipe type. Consequently, one value of longitudinal dimension chosen may be

$$\frac{\lambda g}{2}$$

where λ_g is defined by Equation 3 above.

The common metallic boundary 3 is provided with an opening 8 which serves as a communicating path between the cavities and which permits the establishment of an electric discharge to be described presently.

Within each of the tuned cavities 1 and 2, I provide means for accentuating or concentrating the potential difference due to the electromagnetic waves within the respective cavities. This means may comprise a wall structure which provides tuned or resonant apertures, such as resonant slots, tuned substantially to the natural frequency of the cavities. For example, I provide within cavities 1 and 2 a transverse wall section comprising metallic walls or partitions 9, 10, 11 and 12, also shown in Fig. 2, which in conjunction with the metallic boundary plate 3 define resonant apertures or slots 13 and 14 having a height h and a principal dimension or length L. The apertures, in any case, should have an appreciable dimension substantially transverse to the electric component of the electromagnetic field within the cavities and by virtue of their dimensions are resonant, that is, have an effective distributed inductance and capacitance thereby establishing natural resonance frequencies thereof corresponding to the natural frequencies of the respective cavities.

There is a definite relationship between the height h and length L of the resonant apertures in order to obtain this resonant condition, which is important not only from the standpoint of obtaining concentration of the voltage or potential due to the waves within the cavities, but is also of importance in maintaining the transverse wall structures substantially reflectionless so as not to disturb the tuned or resonant characteristics of the cavities. The total impedance Z_0 of a dielectric wave guide or a rectangular cavity comprising a section of a dielectric wave guide, using the dielectric medium may be defined as follows:

$$Z_0=\frac{\epsilon_1\pi c}{2}\frac{\lambda_g}{\lambda}\frac{a}{b} \quad (4)$$

where ϵ_1 is the effective dielectric constant of the medium and c is the velocity of light. If this total impedance is constant along the guide, the wave

will not be reflected. To maintain this impedance constant for changes in dimensions a and b, one must have at any particular wave length or frequency the following relationship:

$$\frac{a}{b}\lambda_g = \text{constant} \equiv k \qquad (5)$$

As stated above, the apertures 13 and 14 are resonant. It will be appreciated that the natural frequency or the resonance frequency, or frequencies, of the apertures or slots 13 and 14 will be affected by the dielectric constant of the medium within which these slots are placed. Furthermore, the natural or resonance frequency, or frequencies, of these apertures will vary as a function of the effective dielectric constant of the medium as modified and established by the presence in the region of charged electrical particles, such as electrons, which constitute the beam transmitted from cathode 16 to anode 15. This variation in the dielectric constant will be appreciated by considering the fact that the effective distributed capacitance of the slots 13 and 14 with an electron beam present is less than that when no beam is present. As a result, in the computation of the dimensions h and L of the slots 13 and 14, the effect of the region of charged particles must be taken into consideration. Viewed as a general matter, it may be said that for a slot of given height and length, the establishment of a region of charged particles will effect a reduction or decrease in the magnitude of the distributed capacitance of the slot, inasmuch, as is well known, the capacitance is directly proportional to the dielectric constant and inversely proportional to the distances between the surfaces involved. Consequently, if a slot is designed to be resonant to an electromagnetic wave of particular frequency with no region of charged particles present, upon the establishment of such a region the effective height or dimension h of the slot must be decreased in order to effect a resultant capacitance to resonate with the distributed inductance. Stated in other words, the ratio of the dimension h to the length L will be decreased due to the presence of the region of charged particles.

If the change in guide dimensions is made in a very small fraction of a wave length λ_g, there will be a reflection from the discontinuity so produced, but this reflection is ineffective because of a reflection from a second discontinuity a very short phase distance along the guide or cavity from the first discontinuity. By the use of a rectangular resonant slot, or the equivalent thereof, the total impedance of the slot itself is made to be exactly equal to the total impedance of the guide or cavity, since the reflection produced at the entrance of the slot is just cancelled by the reflection at the exit.

The above stated relationships relative to the dimensions h and L to maintain the slot in a resonant condition obtains irrespective of the position of the slot in the transverse partition. In the embodiment of my invention shown in Figs. 1 and 2, the resonant apertures 13 and 14 are adjacent to and partially defined by the metallic boundary plate 3.

I provide electric discharge means for establishing a region of charged particles, such as an electron beam, for maintaining the electric discharge device as a whole in oscillation. The electric discharge device may comprise an anode 15 and a thermionic cathode 16 on opposite sides of the boundary plate 3 and in alinement with the opening 8. An anode 15 and cathode 16 may be maintained in spaced relation with respect to each other and from partitions 9, 10 and 11, 12, respectively, by means of vitreous or glass insulators 17 and 18 which may be of cylindrical cross section. Cathode 16 is provided with a cathode heating element 19; and anode 15 and cathode 16 are positioned so that the faces thereof constitute a longitudinal boundary for the resonant slot assembly, the outside surfaces of these elements being substantially parallel with the defining edges of the openings or partitions 9–12, inclusive.

Anode 15 and cathode 16 are electrically insulated not only from the partitions 9–12 but are also electrically insulated from the defining walls of the cavities and I provide sealing glass insulators 20 and 21 which extend through top plate 5 and bottom plate 4, respectively. These seals, of course, are important in order to maintain the cavities at the desired low pressure which facilitates the establishment and control of the electric discharge path. Conductors 22 and 23 extend through the insulators 20 and 21 and are connected to the anode 15 and cathode 16, respectively.

As a means for modulating or controlling the electron beam, I provide electrostatic control or grid means 24 which may comprise a grid wire or mesh in spaced relation with respect to anode 15 and cathode 16, and which is preferably conductively connected to the boundary plate 3.

As a means for supplying power to the electric discharge device as a whole, I may employ a source of unidirectional voltage, such as a battery 25, the positive terminal of which is connected to anode 15 and the negative terminal of which is connected to cathode 16. The entire metallic defining structure of the discharge device may be connected to ground, in which case the high frequency anode potential and cathode potential may be considered as being in time-phase with respect to each other, the potential of the grid remaining fixed by virtue of the ground connection.

I provide means for coupling the cavities 1 and 2 in order that energy may be derived from the anode-grid cavity 1 and delivered to the grid-cathode cavity 2 to maintain the discharge device in oscillation. Where the electrostatic control member or grid 24 is maintained at grid potential, causing the anode and cathode potentials to vary in time-phase with respect to it, the coupling means between the anode-grid and grid-cathode cavities may comprise a phase-reversing coupling device, such as a double loop 26, which extends through an opening 27 in the metallic boundary plate 3. In this manner, the proper phase between the anode-grid and grid-cathode cavity voltages is obtained.

Energy may be extracted from the cavities of the discharge device by a variety of electrode means and for the purpose of illustrating one form of such means I have diagrammatically illustrated the electrode means as comprising a concentric or coaxial transmission line including a tubular conductor 28 and a concentric conductor 29, the latter of which forms a loop 30 within the anode-grid cavity 1. Of course, a sealing insulator, such as a vitreous or glass insulator 31, may be placed in conductor 28 and sealed to both conductors 28 and 29.

The cathode heating element 19 of cathode 16 may be provided with externally accessible terminal conductors 32 and 33 which are supported by glass insulators 34 and 35.

The embodiment of my invention illustrated in

Figs. 1 and 2 operates to supply high frequency electromagnetic waves, the energy of the device being extracted from one of the resonant cavities, such as cavity 1, through the concentric transmission line comprising conductors 28 and 29. The energy for the operation of the electric discharge device is derived from battery 25 by the anode-cathode circuit of the electric discharge path including anode 15 and cathode 16. The cyclic or periodic voltages for exciting and maintaining the resonant cavities 1 and 2 in oscillation are produced by virtue of the control or modulation of the electron beam of the discharge path produced principally by the cyclic variations in the potential of the electrostatic control grid 24.

Due to the fact that the transverse wall assembly comprising partitions 9–10, inclusive, and the associated electric discharge path are located within the vicinity of the potential-maximum or the potential loop, the modulation of the electron beam is effective to produce electromagnetic waves within cavity 1 which may be considered, for the purposes of elementary analysis, as being generated across the horizontal edges of the resonant slot 13. By virtue of the tuned or resonant nature of cavity 1, a standing electro-magnetic wave is maintained therein.

The feed-back or coupling between cavities 1 and 2 is obtained by virtue of loop 26; that is, energy is derived from anode-grid cavity 1 and supplied to grid-cathode cavity 2 in order to maintain the latter mentioned cavity in oscillation. The oscillations which are established within cavity 2 produces a standing electromagnetic wave, the potential-maximum or potential loop of which is in the vicinity of the transverse partitions 11 and 12, thereby concentrating by the action of resonant slot 14 the potential difference due to the wave to utilize most effectively this potential difference in the control or modulation of the electron beam by virtue of the electrostatic effect of grid 24. The variation in the potential of grid 24 occasioned by the variation in voltage across the horizontal dimensions of slot 14 modulate the electron beam which, in turn produces cyclic variations of potential across the horizontal dimensions of slot 13, thereby maintaining, by the above described sequence of phenomena, both cavities 1 and 2 in oscillation.

As stated above, where the entire metallic cavity structure, that is the boundary structure, is connected to ground potential, the grid 24 may be considered as fixed in potential, and the anode and cathode potentials may be considered as varying in time-phase with respect to grid 24. Consequently, when such an arrangement is utilized, the double loop 26 produces the desired reversal in phase so that the grid-cathode and the anode-grid cavity voltages have the desired phase relationship necessary to maintain the discharge device, as a whole, in oscillation.

In Fig. 3, I have diagrammatically illustrated a modification of my invention as applied to a high frequency amplifier of the space resonant type which is similar in many respects to the arrangement illustrated in Fig. 1, and corresponding elements have been assigned like reference numerals. In the arrangement of Fig. 3, it will be noted that the metallic boundary 3 is continuous except for the opening 8, and that additional or separate coupling means need not be provided between the space resonant cavities 1 and 2. In the arrangement of Fig. 3 I provide means for establishing within the grid-cathode

cavity 2 electromagnetic waves of predetermined frequency to which the cavity 2 is tuned or resonant. This means may comprise a high frequency concentric or coaxial transmission line comprising an outer conductor 36 and an inner conductor 37 provided with a sealing insulator 38. In this modification of my invention, the electrode means comprising conductors 28 and 29 constitute an output electrode means.

The embodiment of my invention illustrated in Fig. 3 operates as an amplifier of high frequency voltages or signals supplied by the input electrode means comprising conductors 36 and 37. The operation of the embodiment of my invention from an elementary point of view may be considered in the following manner. The excitation of the grid-cathode cavity 2 by the input electrode means 36 and 37 establishes within the cavity 2 a standing electromagnetic wave due to the tuned or resonant condition of the cavity to the frequency of the input excitation. Resonant slot 14 effects a concentration, of the potential difference due to the standing wave in cavity 2, across its boundaries and consequently modulates the electron beam transmitted between cathode 16 and anode 15, so that amplified voltages appear across the horizontal dimensions of the resonant slot 13 in the anode-grid cavity 1. As a result thereof, a standing electromagnetic wave is established within the cavity 2 of amplified value which is delivered to an output or utilization circuit which may be connected to the output electrode means comprising conductors 28 and 29.

It will be obvious to those skilled in the art that the high frequency amplifier shown in Fig. 3 may be employed in a variety of ways. For example, the device may be employed to amplify weak high frequency signals. In addition, the system may be modified for use as a regenerative amplifier wherein a predetermined component of the output voltage derived from conductors 28 and 29 is fed back to the input electrode means comprising conductors 36 and 37.

While I have shown and described my invention as applied to a particular system 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 high frequency electrical apparatus comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure defining a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators, a cathode in the other of said resonators and a grid interposed therebetween, said anode, cathode and grid being mounted in alignment through said opening.

2. A high frequency electrical apparatus comprising a pair of wave guides having a common

metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure defining a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators adjacent the said wall structure therein, a cathode in the other of said resonators adjacent the said wall structure therein and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening.

3. A high frequency electrical apparatus comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure defining a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators positioned adjacent the said wall structure therein within the region of said concentration of electric field therein, a cathode in the other of said resonators positioned adjacent the said wall structure therein with the region of said concentration of electric field therein, and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening.

4. A high frequency electrical apparatus comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure having therein an aperture adjacent said opening and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators, a cathode in the other of said resonators and a grid interposed therebetween, said anode, cathode and grid being mounted in alignment through said opening.

5. A high frequency electrical apparatus comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure having therein an aperture adjacent said opening and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators adjacent the said wall structure therein, a cathode in the other of said resonators adjacent the said wall structure therein, and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening.

6. A high frequency electrical apparatus comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure having therein an aperture adjacent said opening and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators positioned adjacent the said wall structure therein within the region of said concentration of electric field therein, a cathode in the other of said resonators positioned adjacent the said wall structure therein within the region of said concentration of electric field therein, and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening.

7. A high frequency electrical apparatus comprising a pair of wave guides of rectangular cross section having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a pair of transverse walls each having therein a rectangular aperture on opposite sides of said opening and defining thereby a resonator structure capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators between the said walls therein, a cathode in the other of said resonators between the said walls therein, and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening.

8. An electric discharge device comprising a pair of cavity resonators having a common metallic wall and each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said resonators having a transverse wall structure defining a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and an electric discharge path defined by principal electrodes on opposite sides of said common wall within the vicinity of said opening and an electro-static control means interposed in spaced relation between said principal electrodes.

9. An electric discharge device comprising a pair of cavity resonators having a common metallic wall and each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said resonators hav-

ing a transverse wall structure having therein an aperture and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, and an electric discharge path defined by principal electrodes on opposite sides of said common wall within the vicinity of said opening and an electro-static control means interposed in spaced relation between said principal electrodes.

10. An electric discharge device comprising a pair of cavity resonators having a common metallic wall and each being of the hollow pipe-type dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said resonators having a transverse wall structure having therein an aperture and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective electromagnetic waves therein, an electric discharge path defined by principal electrodes electrically insulated from said resonators and on opposite sides of said common wall in alignment with said opening and an electro-static control means interposed in spaced relation between said principal electrodes and conductively connected to said metallic wall, means connected to one of said resonators for extracting output power therefrom, means connected to said principal electrodes for applying a unidirectional potential therebetween, and coupling means connected between said resonators.

11. An electric discharge device comprising a pair of cavity resonators having a common metallic wall and each being of the hollow pipe-type dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said cavity resonators having a transverse wall structure having therein an aperture and defining thereby a resonator capable of resonance at substantially said predetermined frequency and adjacent said metallic wall in the vicinity of said opening for effecting a concentration of the electric field incident to the respective standing waves, an electric discharge path defined by principal electrodes on opposite sides of said common wall in alignment with said opening, electrostatic control means interposed in spaced relation between said principal electrodes and conductively connected to said common wall, and coupling means interconnecting said resonators.

12. A high frequency electrical oscillator comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure having therein an aperture adjacent said opening and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators adjacent the said wall structure therein, a cathode in the other of said resonators adjacent the said wall structure therein,

and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening, means intercoupling said resonators for interchanging energy therebetween, and means coupled to one of said resonators for extracting energy therefrom.

13. A high frequency electrical amplifier comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure having therein an aperture adjacent said opening and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electric field incident to the respective standing waves, means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators adjacent the said wall structure therein, a cathode in the other of said resonators adjacent the said wall structure therein, and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening, means coupled to said other of said resonators for introducing thereto a signal to be amplified, and means coupled to said one of said resonators for extracting an amplified signal therefrom.

14. A high frequency electrical amplifier comprising a pair of wave guides having a common metallic wall and defining a pair of cavity resonators each dimensioned to support standing electromagnetic waves of predetermined frequency, said common metallic wall having an opening therein, each of said wave guides including a transverse wall structure having therein an aperture adjacent said opening and defining thereby a resonator capable of resonance at substantially said predetermined frequency for effecting a concentration of the electrical field incident to the respective standing waves, means for sustaining high frequency electromagnetic waves in said resonators comprising an anode in one of said resonators adjacent the said wall structure therein, a cathode in the other of said resonators adjacent the said wall structure therein, and a grid conductively attached to said common wall, said anode, cathode and grid being mounted in alignment through said opening, means coupled to said other of said resonators for exciting said other of said resonators at its natural resonant frequency, and means coupled to said one of said resonators for extracting energy therefrom.

JAMES M. LAFFERTY.

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