

June 22, 1948.

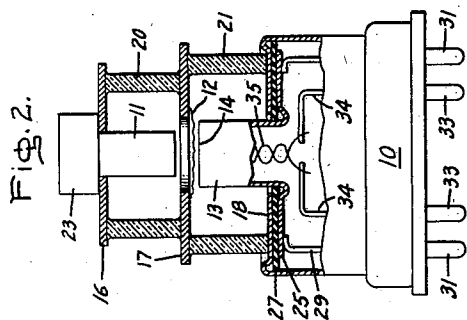
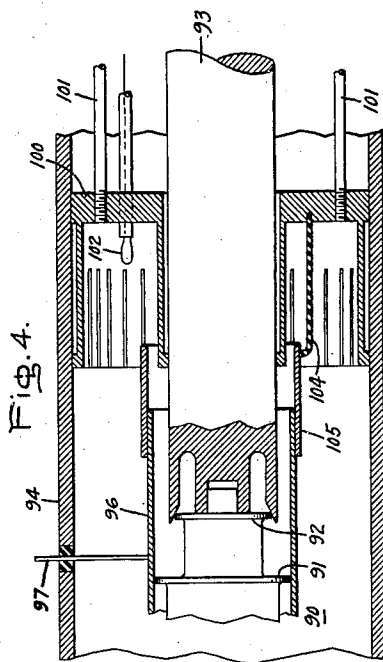
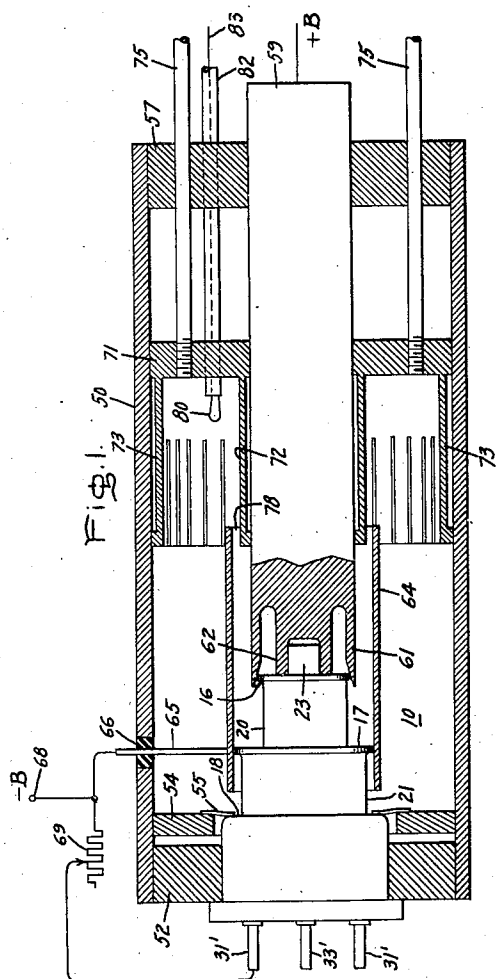
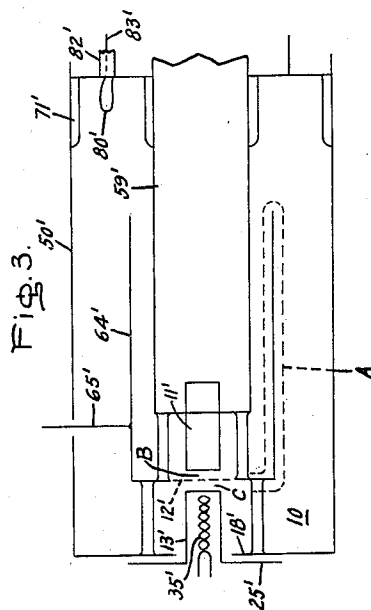
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2,443,907

HIGH-FREQUENCY CAVITY RESONATOR APPARATUS

Filed Jan. 11, 1943

4 Sheets-Sheet 1



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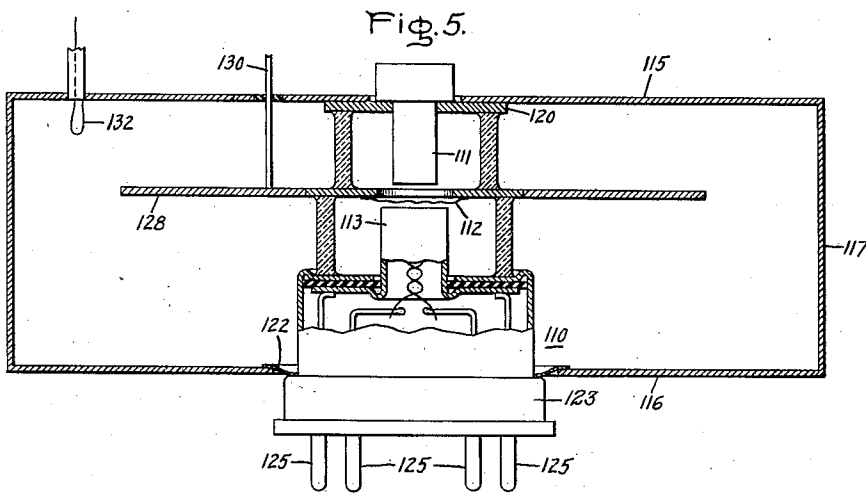
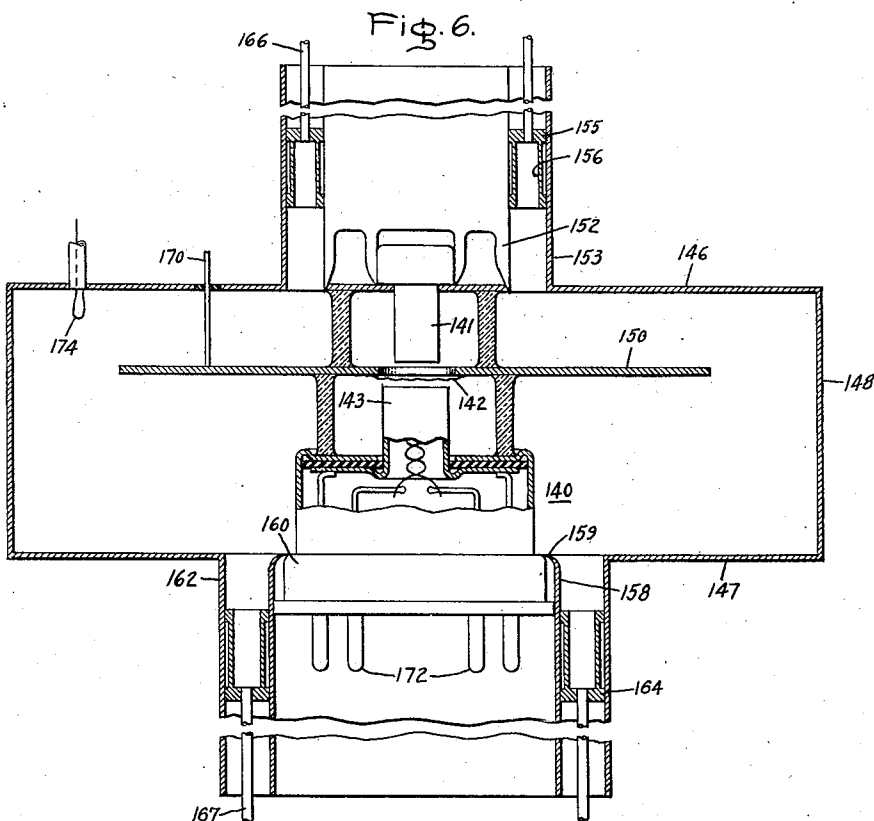
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HIGH-FREQUENCY CAVITY RESONATOR APPARATUS

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4 Sheets-Sheet 2



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HIGH-FREQUENCY CAVITY RESONATOR APPARATUS

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Fig. 7.

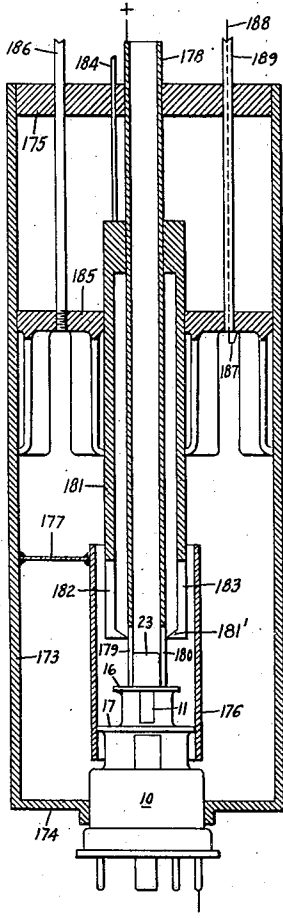
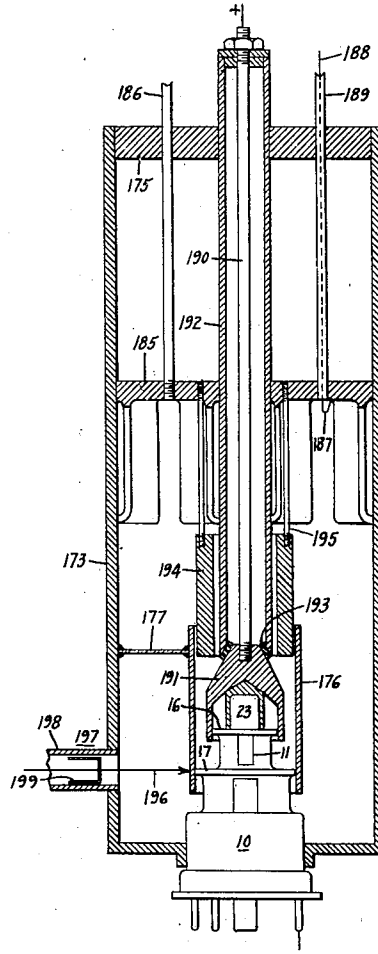


Fig. 8.



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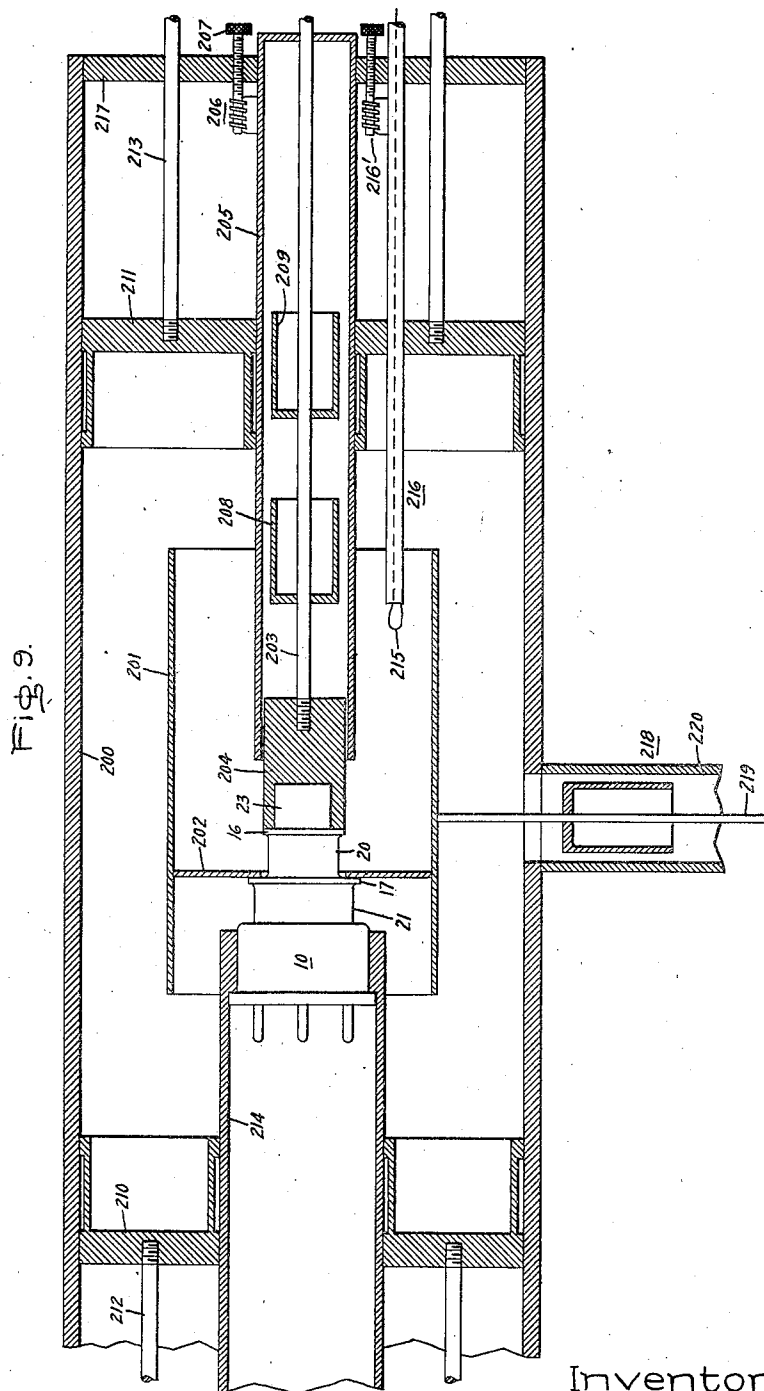
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HIGH-FREQUENCY CAVITY RESONATOR APPARATUS

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,443,907

HIGH-FREQUENCY CAVITY RESONATOR
APPARATUSAnatole M. Gurewitsch, Schenectady, N. Y., as-
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Application January 11, 1943, Serial No. 471,973

10 Claims. (Cl. 315—39)

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The present invention relates to high frequency apparatus and is primarily concerned with the provision of an improved oscillator of the type which employs a discharge device or tube, such as a vacuum triode, as an exciting element.

This application is a continuation-in-part of my copending patent application Serial No. 452,945, filed July 30, 1942, and which is assigned to the assignee of the present application and which now stands abandoned.

One aspect of satisfactory oscillator design consists in so adjusting the parameters of the system that the level of operation toward which the oscillator tends is one at which satisfactory output and high efficiency are concurrently obtained and at which no excessive loading of any of the oscillator components occurs. A further desired condition is that of stability at the intended operating frequency, and a still further desideratum is the possibility of adjustment for operation over a range of frequencies.

In the ultra high frequency range, especially at frequencies corresponding to wave lengths of the order of a few centimeters, the simultaneous fulfillment of all the indicated conditions becomes extremely difficult because of the relative inflexibility of the circuit elements with which one is obliged to work. Instead of being able to use the easily variable condensers, inductances, etc. which are available at low frequencies, the desired results must be accomplished by such devices as resonant cavity structures, which, for obvious mechanical reasons, are less readily adjustable as to their electrical properties.

It is an object of my invention to provide new and improved ultra high frequency space resonant systems wherein a new and improved re-entrant type of coupling means is provided with the anode-grid and the grid-cathode circuits of an electric discharge device employed therein.

It is another object of my invention to provide new and improved methods of operating ultra high frequency space resonant systems.

It is a further object of my invention to provide new and improved frequency controlling means and coupling means for space-resonant type oscillators wherein not only the magnitude but also the phase of the anode-grid voltage is readily determinable.

It is still another object of my invention to provide a new and improved variable impedance path in a re-entrant type ultra high frequency space resonant oscillator wherein the magnitude or intensity of the electromagnetic radiations delivered to the grid-cathode region are controllable.

It is a still further object of my invention to provide new and improved frequency controlling and coupling means for ultra high frequency space resonant systems wherein the tuning operation

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and control of the coupling means may be effected concurrently or simultaneously.

It is a still further object of the present invention to provide an improved form of high frequency oscillator which is capable of stable operation, high efficiency, and good output and which may be readily adjusted for operation over an appreciable frequency range. In this connection, an important feature of the invention consists in the use of a construction in which the required feedback between the input and output sections of the oscillator is accomplished by the guided propagation of waves established and maintained within a relatively simple form of space resonant cavity. In a particular case, the desired results are obtained by arranging a vacuum triode within a cavity-forming structure and by providing in connection with the grid of the triode a conductive member which is adapted to form a continuous wave-guiding path between the grid-anode gap of the triode and its grid-cathode gap. By making this path of appropriate length and proportions the feedback effects attributable to it are readily fixed at the proper phase and amplitude to assure the efficient generation of self-sustained oscillations.

The features of the invention desired to be protected herein are pointed out in the appended claims. The invention, itself, together with its further objects and advantages may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 is a longitudinal sectional view of a high frequency oscillator suitably embodying the invention. Fig. 2 is a sectional view of the triode which is incorporated in the structure of Fig. 1; Fig. 3 is a schematic representation of the structure of Fig. 1; Fig. 4 is a modification of Fig. 1; Figs. 5 and 6 illustrate alternative applications of the invention; Figs. 7 and 8 illustrate further modifications of my invention wherein variable impedance means are provided and associated with the re-entrant type space resonant systems for controlling the electromagnetic radiations emanating from the anode-grid regions; and Fig. 9 is a still further modification wherein there is provided a pair of adjustable tuning members or plungers longitudinally displaced at the ends of the space resonant region for tuning the space resonant system and for controlling the grid-cathode voltage.

Referring particularly to Fig. 1, there is shown an oscillator having as its central element a high frequency electric discharge device, such as a triode 10, which is of a type particularly described and claimed in application Serial No. 436,633, filed March 28, 1942, issued as Patent Number 2,416,565 on February 25, 1947, in the name of James E. Beggs and assigned to the General Electric Company, a corporation of New York.

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As appears more clearly in Fig. 2 this tube comprises a cylindrical anode 11, a grid 12 and a cylindrical cathode 13, the latter element having its emissive part in the form of a flat disk 14 which faces the grid. The envelope within which these electrodes are enclosed comprises a series of three circular metal parts 16, 17 and 18 which are supported in spaced relation by glass cylinders 20 and 21 sealed between them. The part 17 provides a terminal for the grid 12, and a terminal for the anode is provided by a cylindrical enlargement 23 which is welded or soldered against the upper surface of the part 16.

The cathode 13 is provided at its lower extremity with a flange 25 which parallels the under surface of the part 18 but which is separated from that part by an insulating spacer 27 (e. g. a mica washer). With this arrangement the part 18 has a high frequency connection with the cathode through the capacity existing between this part and the flange 25 but is effectively insulated from the cathode as far as direct current is concerned. Separate direct-current connections are made to the cathode by means of lead-in wires 29 secured to the under surface of the part 25 and terminally connected to prongs 31 which depend from the base of the discharge tube. Additional prongs 33 and lead-in wires 34 are provided for the purpose of supplying heating current to a coiled filament 35 arranged within the cathode cylinder 13.

The oscillating system in which the tube 10 is incorporated comprises a cavity-forming structure having as a principal component an elongated conductive (e. g. copper or brass) preferably silver plated cylinder 50. This surrounds the tube 10 and is symmetrical with respect to the axis of alignment of the electrodes of the tube. A conductive wall part 52 extends across one end of the cylinder 50 and provides a mount for the base of the tube. Near this part there is provided an annular ring 54 which extends inwardly from the interior wall surface of the cylinder 50 and which is provided at its inner periphery with a ring of spring fingers indicated at 55. These bear upon the exposed surface of the part 13 and are thus effectively connected with the cathode 13 as far as high frequencies are concerned by capacity coupling through the insulating spacer 27 (Fig. 2). A corresponding connection to the anode is made by a solid longitudinal cylindrical conductor 59 which is supported within the cylinder 50 by means of a transverse wall part 57 and which is provided at its inner extremity with contact fingers 61 and 62 arranged to engage the anode end of the tube 10 both at the terminal cap 23 and at the periphery of the disk 16. The grid terminal 17 is peripherally connected to a tubular conductor 64, whose function will be stated at a later point, and through this connects with a terminal wire 65 which extends through an insulating bead 66 provided in the wall of the cylinder 50.

The D.-C. connections for the triode 10 may be made in various ways. In the arrangement illustrated, the anode is assumed to be at ground potential (i. e. at the potential of the conductive structure as a whole) while the cathode is insulated (in a D.-C. sense) from the main conductive structure by the spacer 27 (Fig. 2) and is made negative with respect to the anode by an appropriate connection to the contact prong 31'. The grid connection is made through the conductor 65 and if a cathode bias arrangement is to be employed, the connection should be made to the ter-

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minial 68 and the resistor 69 adjusted to give the bias which is required for most effective operation.

Like any confined space bounded by a conductive medium, the chamber enclosed by the cylinder 50 provides a system which may be made to resonate electrically at a particular frequency determined by the dimensions and configuration of the chamber and of the elements enclosed by it. This means that under appropriate conditions, electromagnetic waves may be caused to exist within the chamber in a space distribution fixed by the nature and location of the exciting source and by the boundary conditions set by the form of the conductive structure. Such waves may be either traveling waves or standing waves (waves corresponding to a fixed distribution of the magnetic and electric fields within the chamber) or a combination of traveling and standing waves.

The effective electrical impedance and inductance loss ratio of a space-resonant structure of the type under consideration are high enough so that a structure of this kind can be made to serve as a tank circuit for an oscillator having an intended operating frequency which is the same as, or is harmonically related to, the resonant frequency of the space enclosed by the structure (taking into account the effect on resonance of the reaction produced by the exciting tube or other exciting agency). Since resonant frequency is a direct function of the dimensions of the resonator in question, it may be varied within reasonable limits by appropriate adjustment of these dimensions. To permit such adjustment in connection with the structure of Fig. 1 there is provided a plunger 71 having two sets of contact fingers 72 and 73 which respectively bear upon the opposed surface of the parts 50 and 59. This plunger may be moved back and forth by externally accessible actuating rods 75, and by this means the size of the resonant cavity may be adjusted as desired.

Viewing the structure of Fig. 1 as a device for generating sustained oscillations it may be noted that the triode 10 comprises a means for exciting the resonant system provided by the cylinder 50. If voltage variations can be caused to occur between the grid and anode of the tube 10 at the resonant frequency of cylindrical structure 50 (as modified by the presence of the tubular conductor 64, the solid cylinder 59 and the tube itself), electromagnetic waves of the frequency in question will be established in the cavity-forming space. Such waves may be considered as being initiated in the vicinity of the grid-anode gap and as being propagated from this point throughout the remainder of the cavity. Their path of propagation is governed in the first instance by the presence of the conductive tube 64 which necessarily tends to confine or guide the waves along the annular space between this tube and the outer surface of cylinder 59. At the extremity of the tube, however, the waves are free to pass through the gap indicated at 78. Viewing the mechanism of wave propagation as being a condition of energy flow, it will be seen that wave energy issuing from the gap 78 can flow in the reverse direction along the outside of the conductor 64 toward the vicinity of the cathode to grid gap of the triode 10. At this point (as at all other points to which the waves extend) a variable electric field will be established in accordance with the properties of waves of the type under consideration. Assuming a proper orientation of the electric field axis (actually the only probable orientation with a structure such as that

being discussed), potential variations consistent with the variations of the electric field will be set up between the cathode and grid of the triode. Provided these variations bear a proper phase relationship to those previously assumed to exist between the grid and anode, it will be seen that a mechanism exists for producing regenerative oscillations.

The desired phase relationship under the conditions postulated is that in which the cathode and anode both have the same sign of potential with respect to the grid at any instant. This is a condition which can evidently exist if the length of the propagating path from the grid-anode gap to the grid-cathode gap is a full wave length (or an integral number of wave lengths) at the operating frequency. Since the dimensions of this path are fixed mainly by those of the tubular conductor 64, it is indicated that the length of this conductor should be approximately a half wave length, so that a wave which traverses the interior of the tube in one direction and its exterior in the other direction, will have progressed substantially a full wave length. It should be recognized, however, that in calculating the proper length of the tube 64, one must take into account the various end effects caused by inter-electrode impedances and related factors. The importance of these factors can usually best be determined by empirical means and the length of the tube 64 adjusted accordingly.

In addition to a proper phase relationship, which may be obtained in the manner just indicated, it is further necessary that the amplitude of the input voltage of the triode 10 bear a particular relationship to its output voltage. In general, and for reasons which are well known, the voltage variation at the cathode-grid gap should be less than the anode-cathode variation by a factor which is determined mainly by the amplification factor of the triode. The amplitude relationship obtainable by a construction such as that of Fig. 1 is a function of the degree of feedback and may be adjusted by proper design of the elements of the oscillator structure. The possibility of controlling the relative amplitude of the voltage variation at the grid-anode gap and the cathode-grid gap of the triode depends in part upon the consideration that the opening 73 through which feedback occurs represents a discontinuity in the path of propagation of waves originating at the former gap. In accordance with principles well understood in the electronics art, some reflection of wave energy will occur at this discontinuity and the relative amplitude of the waves developed in the remaining parts of the resonant cavity will be fixed accordingly. By changing the size and configuration of the structural elements involved, almost any desired relationship can be obtained.

As a result of the considerations stated in the foregoing, it will be seen that the illustrated construction provides a wave-guiding system which is symmetrical about the central axis of the resonator and which directs high frequency waves initiated between the grid and anode of the tube 10 toward the grid-cathode region of the tube. The length of the wave-guiding path is such that the waves arrive in the right phase to maintain oscillations, and the propagating properties of the path are such that a desired amplitude relationship is maintained between the input and output voltages of the tube.

In a sense the system provided may be thought of as one in which the coupling or feedback is

complete so that the entire resonator is a single space-resonant cavity having a first region of strong electric field at the anode-grid gap of the enclosed tube and a second such region at the cathode-grid gap of the tube. It may also be considered as an arrangement in which the wave-guiding system by which feedback is produced is itself the resonator which yields the desired impedances across the tube terminals. A system thus constituted is found to be characterized by excellent efficiency in operation and by a high degree of frequency stability.

In order that high frequency energy may be taken from the oscillator for utilization in an external circuit, there is provided a coupling loop 80 which extends into the cavity and which is supported from a hollow tubular conductor 82 extending outwardly through the plunger 71. A wire 83 which connects with one extremity of the coupling loop 80 is arranged within the conductor 82 and forms with it a coaxial transmission line.

The operation of the invention will perhaps be more readily understood by reference to Fig. 3 which shows the oscillator of Fig. 1 in a diagrammatic representation. In this figure elements which may be identified with corresponding parts already described in connection with Fig. 1 are indicated by similar numerals differentiated by priming.

Fig. 3 particularly illustrates the mechanism by which feedback of the proper character is obtained. Specifically, the dotted line A represents the path of propagation of wave energy which originates in the vicinity of the grid-to-anode gap B. It will be seen that such wave energy is directed along the annular channel provided between the tubular conductor 64' and the solid cylindrical conductor 59', and then traverses a reversed path along the outside of the conductor 64' toward the cathode-grid gap C. As has been previously stated, it is desired that the effective electrical length of the path be one full wave length at the operating frequency or some integral number of such wave lengths. When this condition is fulfilled, a proper phase relationship for sustained oscillations exists between the voltage variations at B and the voltage variations between the grid and cathode which result from the feedback described.

Referring again to Fig. 1, it will be understood that tuning of the oscillator may be obtained by adjusting the location of the tuning plunger 71. Alternatively, some degree of tuning may also be obtained by changing the length of the grid cylinder 64, thus to vary the effective length of the feedback path between the anode-grid gap and the cathode-grid gap. In view of the fact that both the plunger 71 and the tubular conductor 64 conjointly govern the operating frequency of the oscillator, it is not wholly satisfactory to attempt to tune over any appreciable range by adjustment of either one of these elements alone. It is found, however, that effective concurrent adjustment of them may be obtained by an arrangement such as that illustrated in Fig. 4.

The last named figure illustrates only the terminal portion of an oscillator which as to its remaining parts is assumed to correspond to the construction illustrated in Fig. 1. This comprises a tube 90 of which only the grid and anode terminals are illustrated, these being respectively indicated at 91 and 92. As in the construction of Fig. 1, the anode terminal is connected to a solid cylindrical conductor 93 which extends axially with-

in a hollow cavity-forming cylinder 94. A tubular conductor 96 having an externally accessible terminal 97 for the application of D.-C. bias serves to control feedback in accordance with principles previously stated herein.

In order to adjust the resonant frequency of the cavity formed within the cylinder 94 there is provided a tuning plunger 100 which is movable by means of externally accessible actuating rods 101 and which bears an output loop 102 which is movable with it. This plunger is connected by an insulating link 104 with a cylindrical conductive sleeve 105 which is telescoped over the outer surface of the tubular conductor 96. By virtue of this arrangement, movement of the plunger 100 in either direction produces a concurrent motion of the sleeve 105 and a resultant shortening or lengthening of the feedback path of the oscillator depending upon the direction of the motion involved. It is found that the two tuning controls, i. e., the plunger 100 and the sleeve 105, track very well in the arrangement illustrated and that practically level output may be obtained over a tuning range of several centimeters in an oscillator having a median operating wave length of about ten centimeters.

A further factor which tends to affect the operation of an oscillator of the type under consideration is the location of the grid terminal wire 65 (Fig. 1). Since the magnitude of the effect caused by the wire is not readily predictable or controllable it is advisable to place the wire at a point which corresponds to a voltage node for the resonator and at which its disturbing influence is minimized. In certain cases satisfactory operation has been obtained with the grid and the cylinder 64 floating (i. e. with no D.-C. connections), but this is not preferable in most instances.

Internal tube capacitance, especially the capacitance between cathode and anode, also has a bearing on the production of oscillations in that it provides feedback in parallel with that produced by the wave-guiding provisions described in the foregoing. This factor is of more or less importance depending on the form of the tube employed and must ordinarily be taken into consideration in the design of apparatus of the type under consideration.

While the invention has so far been described by reference to a construction in which substantially all of the operative parts are of cylindrical configuration, it should be understood that this is not an essential condition. For example, in an arrangement such as that of Fig. 1, the cylinder 50 and the grid cylinder 64 can alternatively be made of outwardly flared, or frusto-conical construction, without seriously modifying the operation of the oscillator. Many other variations of shape are possible.

A distinctive modification within the scope of the invention is that illustrated in Fig. 5. In the latter figure, there is shown partly broken away a three-element discharge tube 110 which may be assumed to be identical in its internal construction with the tube illustrated in Fig. 2 and which includes an anode 111, a grid 112, and a cathode 113.

The tube 110 is arranged within a rotationally symmetrical cavity formed by the combination of two parallel metallic disks 115 and 116 and an annular metal cylinder 117 which closes the gap between the disks at their peripheries. The anode terminal disk 120 is in direct contact with the surface of the disk 115 and a spring finger

arrangement indicated at 122 provides a symmetrical connection between the disk 116 and the envelope part 123 which serves as a high frequency terminal for the cathode 113. D.-C. potential is applied to the cathode and heating current is supplied to its filament through contact prongs 125 which depend from the lower extremity of the tube.

In connection with the grid 112, there is provided a radially extending conductive disk or partition 128 which may be formed integrally with the grid terminal, or which may be separately appended to it. This disk, which is of smaller diameter than the disks 115, 116, connects with a terminal wire 130 by means of which appropriate bias may be applied to the grid.

In the operation of the oscillator, the disk 128 performs a function analogous to that of the conductive tube 64 of Fig. 1. That is to say, it provides a feedback path of fixed length between the anode-grid gap of the tube 110 and its cathode-grid gap, the length and proportions of this path being chosen in such a way as to assure the occurrence of sustained oscillations.

The considerations which govern the propagation of waves in a parallel disk system are set forth in E. D. McArthur Patent No. 2,284,405, granted May 26, 1942. In general, it may be said that such waves propagate radially between the opposed disk surfaces in a manner which suggests that each elementary radial sector of the propagating system may be regarded as a form of parallel wire transmission line. In the arrangement illustrated, the course of energy flow as far as the feedback action is concerned is outwardly between the upper surface of the disk 128 and the disk 115 and then inwardly between the lower surface of the disk 128 and the opposed surface of the disk 116. Obviously, the radius of the disk 128 determines the length of the feedback path and thus serves in part to determine the operating frequency of the oscillator. This latter quantity is additionally determined, however, by the overall dimensions of the cavity provided by the combined parts 115, 116 and 117.

When the oscillator is in operation, high frequency energy may be extracted from the enclosed space by a coupling loop or probe inserted at an appropriate point, a loop of suitable character being indicated at 132.

Fig. 6 represents a modification of the construction of Fig. 5 in which provisions are made for adjusting the resonant system in such fashion as to obtain optimum operating conditions. The structure illustrated comprises a vacuum triode 140 which contains an anode 141, a grid 142 and a cathode 143 and which is arranged centrally within a radial wave system formed by two parallel metal disks 146 and 147, the outer edges of the disks being connected by a metallic annulus 148. A smaller metal disk 150 which is connected to the grid of the triode partially subdivides the resonant cavity and provides a re-entrant feedback path between the anode-grid gap of the triode and its cathode-grid gap.

Connection is made to the anode 141 by means of a cylindrical conductor 152 which is arranged concentrically within a second cylindrical conductor 153, a bridging connection being made between the two cylinders by means of a conductive ring 155 which bears appropriately formed contact fingers 156. A somewhat similar arrangement used in connection with the cathode comprises an inner conductive cylinder 158 having inwardly directed contact fingers 159 which

bear upon the metal tube part 160 and a second conductive cylinder 162 which surrounds the first cylinder. A conductive plunger 164 which is arranged between the cylinders 158 and 162 provides an adjustable connection between them. The plungers 155 and 164 are connected with externally accessible actuating rods 166 and 167 and may be moved in the axial direction by means of these rods. Motion of the plungers tends to modify the resonant frequency of the cavity structure as a whole and also changes the effective length of the feedback path between the output and input gaps of the triode 140. By correlated adjustment of both plungers it is possible to adjust both the phase and amplitude of the feedback to assure most effective operation of the oscillator as a whole.

In using the construction of Fig. 6 a D. C. connection is made to the grid through a terminal wire 170 and corresponding connections are made to the cathode through contact prongs 172. As in the constructions previously described the anode is grounded to the main structure of the resonant cavity. An output loop for the oscillator is indicated at 174.

In accordance with a still further feature of my invention, I provide in ultra high frequency space resonant systems, and particularly space resonant systems wherein re-entrant type feedback means are employed, arrangements for controlling the degree of coupling between the anode-grid and the grid-cathode circuits of the discharge device which may be employed as a central element in such instances. More specifically, I provide in certain of the arrangements described hereinafter means specifically adaptable for controlling the impedance which the electromagnetic waves, derived from the anode-grid regions, encounter in emanating from these regions and consequently in flowing to the grid-cathode regions.

Fig. 7 illustrates one form of my invention wherein such variable impedance means are employed in connection with a re-entrant type ultra high frequency oscillator. In the embodiment illustrated in Fig. 7, a space resonant region is defined principally by a cylindrical conductive member or metallic cylinder 173 having a flanged part 174 at one end which supports an electric discharge device or tube 10 illustrated in detail in Fig. 2. The other end of cylinder 173 may be terminated by an apertured disk 175.

A re-entrant type feedback means is employed and may comprise a metallic cylinder 176 electrically connected to disk 17 of tube 10 and extending an appreciable longitudinal distance within the space resonant region. Cylinder 176 may be supported from the inside of cylinder 173 by a suitable mechanical support which may comprise a dielectric rod 177 sealed to the inside of cylinder 173 and the outer surface of grid cylinder 176.

Anode part 23 of tube 10 is connected to a tubular conductor 178 which affords an externally accessible terminal for the application of voltage to the anode 11 and is provided at the end which engages the anode part 23 with a plurality of longitudinal slots 179 and 180.

As a means for controlling the effective impedance encountered by the electromagnetic waves generated within the anode-grid region, and hence for controlling the magnitude or intensity of the electromagnetic waves established within the region between cylinders 173 and 176, I provide a longitudinal cylinder or sleeve 181, pref-

erably of a conductive nature, which extends in spaced relation between conductor 178 and cylinder 176. Sleeve 181 may be provided with a plurality of openings or longitudinal slots 182 and 183 which control the impedance encountered by the waves in progressing from the anode-grid region. Within the slotted region of the sleeve 181, the sleeve is provided with a restricted region 181' which establishes contact with the longitudinal conductor 178. Of course, the effective impedance is determined in a substantial measure by the relationship between the inside diameter of cylinder 176 and the outside diameter of sleeve 181. More particularly, it may be stated that the impedance offered by such a concentric arrangement of conductive members is a function of the logarithm of the ratio of the inside diameter of cylinder 176 to the outside diameter of sleeve 181. Generally speaking, it may be said that the amount of energy which emanates from the anode-grid region depends upon the relative impedances of the anode-grid region and the impedance at the top of cylinder 176. As the latter impedance approaches the impedance of the anode-grid region, the amount of energy transmitted to the main space resonant region, or the region between cylinders 176 and 173, is increased, due to the fact that as these impedances are made to approach each other the reflection is lessened or reduced.

The magnitude of the impedance offered by sleeve 181 in cooperation with cylinder 176 may be controlled or adjusted by positioning the longitudinal sleeve 181. A suitable mechanical expedient may be employed for this purpose and I have chosen to show one form which may comprise an actuating rod 184 to which a suitable screw-thread device (not shown) may be connected for accurate positioning of sleeve 181.

As a means for controlling the natural resonant frequency of the system, I provide an adjustable end-wall member such as an annular plunger 185 which may be arranged to be in slidable engagement with the inner surface of cylinder 173 and the outer surface of sleeve 181. Plunger 185 may be actuated by a rod 186, and energy may be derived from the space resonant region by means of suitable output electrode means which may take the form of a loop 187 constituting an extension of an inner conductor 188 comprising part of a concentric transmission line including that conductor and an outer tubular conductor 189.

In the operation of the device shown in Fig. 7, the sleeve 181 and plunger 185 may be independently or concurrently adjusted to predetermine the operating frequency of the system as a whole, and to control the impedance of the feedback path. From an elementary point of view, it may be considered that the position of the sleeve 181 controls the magnitude of the oscillations established in the regions between cylinders 173 and 176 and the position of plunger 185 controls the phase and frequency of the electromagnetic oscillations established in this region. Of course, there is some interrelation between the two adjustments and the setting of the device for operation at a predetermined frequency may be accomplished by first adjusting one of the members and subsequently adjusting the other to obtain the desired operating frequency and power output. Adjustment of plunger 185 controls the effective electrical length of the space resonant region and consequently determines to some extent the phase of the grid-cathode voltage which

is derived from the anode-grid region within cylinder 176.

In Fig. 8 there is illustrated a further modification which is similar in many respects to the system shown in Fig. 7, and corresponding elements have been assigned like reference numerals. In this modification of my invention there is shown an alternative arrangement for controlling the magnitude of the electrical oscillations established in the region between cylinders 173 and 176 by controlling the effective impedance to the flow of the oscillations or waves from the anode-grid region. In this arrangement, a longitudinal conductor 190 is connected to the anode part 23 by means of an adaptor construction 191 which is electrically insulated from a longitudinal tubular conductor or sleeve 192 by means of an interspaced insulator 193 at one end thereof. The sleeve 192 serves to define with grid cylinder 176 one boundary of the anode-grid region at one end thereof. An annular impedance controlling member 194, preferably of a conductive material, extends into and is in spaced relation with sleeve 192 and cylinder 176. The spacing between the outer surface of annular member 194 and the inner surface of cylinder 176 controls principally the magnitude of the electromagnetic oscillations which are generated in the anode-cathode region and which are transmitted to the region defined between cylinders 173 and 176. Annular member 194 may be mechanically coupled and supported by plunger 185 by means of a plurality of circumferentially spaced rods 195.

A constant or controllable unidirectional biasing potential may be impressed on the grid cylinder 176 and hence upon the grid of tube 10 by means of a radially extending conductor 196 which constitutes an extension of an inner conductor comprising one part of a coaxial transmission line 197, the outer conductor comprising a tubular member 198. Suitable filtering means offers a high impedance to the frequency of the electromagnetic oscillations within the space resonant region and may take the form of a tuned metallic cup-like member 199.

The operation of the embodiment shown in Fig. 8 is substantially the same as that described above relative to the embodiment shown in Fig. 7. The adjustment of the plunger 185 not only controls the operating frequency of the system, but also concurrently positions the annular member 194, thereby controlling the coupling between the anode-grid and the grid-cathode circuits. Initially, the member 194 may be positioned relative to plunger 185 so that the optimum coupling effect for a desired range of operating frequencies is obtained and thereafter, upon actuation of rod 186, the tuning and the coupling adjustments are effected concurrently or simultaneously.

A still further modification of my invention is illustrated in Fig. 9 and is also shown as applied to an ultra high frequency space resonant oscillator of the reentrant type wherein the space region is defined principally by means of a metallic or conductive cylinder 200, and wherein the electric discharge device or tube 10 comprises a central control element placed within the space resonant region. A re-entrant type coupling means comprising a conductive or metallic cylinder 201 is placed longitudinally within the space resonant region and extends appreciable distances in both directions from the plane of the grid member 17. Cylinder 201 may be connected to the grid member 17 by means of an apertured transverse disk 202, the latter of which

defines one boundary of the anode-grid and the grid-cathode regions. Longitudinal anode conductor 203 provides an externally accessible terminal for anode part 23 and is connected thereto by means of an adaptor 204. As a means for minimizing the leakage of high frequency electromagnetic energization present within the space resonant region, I provide an adjustable longitudinal member 205 which at one end surrounds the adaptor 204 and may be spaced therefrom. This member may be moved longitudinally by a suitable screw-thread device 206 having an externally accessible knurled thumb-screw 207. Suitable filtering means comprising tuned sections 208 and 209 of concentric-type transmission lines are interposed in the region between conductor 203 and member 205 to offer a high impedance to the operating frequency of the device and thereby prevent the loss of appreciable energy within this region.

I provide a pair of adjustable or positionable end-wall members such as annular tuning plungers 210 and 211 at each end of the space resonant regions and which may be respectively actuated by suitable mechanical expedients such as actuating rods 212 and 213. Plunger 210 is adapted to be in slidable engagement with the inner surface of cylinder 200 and the outer surface of a cylindrical supporting member 214 for the electric discharge device 10. Plunger 211 is also adjustable or in slidable engagement with cylinder 200 and member 205.

As a means for extracting energy from the space resonant system, I provide suitable output electrode means when extends into the anode-grid region and which may assume the form of a loop 215 constituting a part of a concentric transmission line 216 being externally accessible through an end wall 217. The outer tubular conductor of concentric transmission line 216 is in slidable engagement with plunger 211 and extends through an aperture therein. The position of the loop 215 may be controlled by a suitable screw-thread device 216' which is arranged to move the concentric transmission line 216 longitudinally. Of course, after initial adjustment of the optimum position of the loop 215, the plunger 211 and the concentric transmission line 216 may be mechanically coupled so that upon movement of the plunger 211 a corresponding adjustment in position of loop 215 is obtained.

A suitable negative unidirectional biasing potential may be impressed on grid cylinder 201 from an external circuit by means of a concentric transmission line 218 comprising an inner conductor 219 and an outer tubular conductor 220 within which is placed a filtering means for offering a high impedance to the particular operating frequency or range of frequencies at which the system is operated.

In the operation of the device or system shown in Fig. 9 it may be considered that the electromagnetic oscillations are established within the anode-grid region, that is, within the grid cylinder 201 and to the right of the transverse disk 202. Consequently, the position of the loop 215 therein affords a ready means for extracting the high frequency energy and supplying it to a utilization circuit. The electromagnetic waves which supply the grid-cathode voltage for maintaining the system in oscillation, as explained above, may be considered as progressing first along the inside of cylinder 201 to the right, thence to the left

within the region between cylinders 200 and 201 and, lastly, to the right within the region defined by cylinder 201.

The natural resonance frequency or the operating frequency of the system is determined by the positions of plungers 210 and 211 inasmuch as both of these plungers are detrimental in the control of the effective electrical length of the space resonant region. Plunger 210 performs an additional function, namely that of controlling the reflected waves during the course of the waves traversing the re-entrant structure. By adjustment of the position of the plunger 210, there is offered a ready means for controlling the magnitude and the phase of the grid-cathode voltage and consequently a ready means for controlling the power output of the system as a whole. As will be readily understood by those skilled in the art, the position of plunger 210 controls the reflection of the electromagnetic waves which are present in the re-entrant portion and consequently permits control of the magnitude and the phase of the grid-cathode voltage.

While the invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. High frequency apparatus comprising a cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a conductive wall connected to said grid dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith, a conductive member positioned adjacent said conductive wall and a portion of said path, said member being movable to adjust the impedance of said path, and a tuning plunger for varying the dimensions of said resonator adjustably positionable along a dimension thereof, said conductive member being affixed to said plunger whereby said member moves in unison with said plunger.

2. High frequency apparatus comprising a generally cylindrical cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a generally cylindrical conductive wall connected to said grid dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith, and a generally cylindrical conductive member coaxial with and positioned ad-

jacent said conductive wall and a portion of said path, said member determining the impedance of said path and comprising an extension of said wall telescopically mounted with respect thereto and adjustably positionable longitudinally thereof whereby said impedance may be varied.

3. High frequency apparatus comprising a generally cylindrical cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a generally cylindrical conductive wall connected to said grid and extending longitudinally on either side thereof in the direction of said anode and cathode, said wall dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith.

4. High frequency apparatus comprising a generally cylindrical cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a generally cylindrical conductive wall connected to said grid dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith, a tuning plunger for varying the length of said resonator adjustably positionable along the length thereof, a generally cylindrical conductive member adjustably and coaxially positioned adjacent said conductive wall and a portion of said path for varying the impedance thereof whereby the phase and magnitude of said waves may be controlled, and means rigidly affixing said member to said plunger whereby said member moves in unison with said plunger.

5. High frequency apparatus comprising a generally cylindrical cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a generally cylindrical conductive wall connected to said grid dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith, a tuning plunger for varying the length of said resonator adjustably positionable along the length thereof, and a generally cylindrical conductive member adjustably and coaxially positioned adjacent said conductive wall and a portion of said path for varying the impedance thereof whereby the phase and magnitude of said waves may be controlled, said member comprising an extension of said plunger telescopically mounted with respect to said wall.

6. High frequency apparatus comprising inner

and outer concentric conductive cylinders defining a cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid and an anode defining cathode-grid and anode-grid gaps, a cylindrical conductive wall coaxial with said cylinders connected to said grid and dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode having high frequency connections to the outer and inner of said conductive cylinders respectively, a tuning plunger between said cylinders and adjustably positionable longitudinally thereof for tuning said resonator, and a cylindrical conductive member coaxially positioned adjacent said conductive wall and a portion of said path, said member being movable to vary the impedance of said path, and means connecting said conductive member to said plunger whereby said member moves in unison with said plunger.

7. High frequency apparatus comprising inner and outer concentric conductive cylinders defining a cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid and anode defining cathode-grid and anode-grid gaps, a cylindrical conductive wall coaxial with said cylinders connected to said grid and dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode having high frequency connections to the outer and inner of said conductive cylinders respectively, a tuning plunger between said cylinders and adjustably positionable longitudinally thereof for tuning said resonator, and a cylindrical conductive member coaxially positioned adjacent said conductive wall and a portion of said path, said member being slidably mounted upon the inner of said conductive cylinders in telescopic relation to said wall to vary the impedance of said path.

8. High frequency apparatus comprising inner and outer concentric conductive cylinders defining a cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid and an anode defining cathode-grid and anode-grid gaps, a cylindrical conductive wall coaxial with said cylinders connected to said grid and dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode having high frequency connections to the outer and inner of said conductive cylinders respectively, a tuning plunger between said cylinders and adjustably positionable longitudinally thereof for tuning said resonator, and a cylindrical conductive member coaxially positioned adjacent said conductive wall and a portion of said path, said member being slidably mounted upon the inner of said conductive cylinders in telescopic relation to said wall to vary the im-

pedance of said path and said member having a restricted portion at the end thereof nearer said anode engaging said inner cylinder.

9. High frequency apparatus comprising a generally cylindrical cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a conductive wall comprising a cylinder coaxial with said resonator connected to said grid dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith, and means for controlling the effective electrical length of each of said regions comprising a pair of adjustable end wall members, one at each end of said resonator and constituting portions of the end walls thereof.

10. High frequency apparatus comprising a generally cylindrical cavity resonator, an electric discharge device within said resonator having a plurality of electrodes including a cathode, a grid, and an anode defining cathode-grid and anode-grid gaps, a conductive wall comprising a cylinder coaxial with said resonator connected to said grid dividing said resonator into a cathode-grid region and an anode-grid region and defining with said resonator a continuous feedback path for guiding waves from said anode-grid gap to said cathode-grid gap in proper phase and magnitude to sustain oscillations in said resonator, said cathode and anode being connected respectively to different portions of said resonator in energy-exchanging relationship therewith, means for controlling the effective electrical length of each of said regions comprising a pair of adjustable end wall members, one at each end of said resonator and constituting portions of the end walls thereof, and a conductive cylindrical member adjustably and coaxially positioned adjacent said conductive wall for varying the impedance of said path and thereby the phase and magnitude of said waves.

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