SEARCH ROOM

May 23, 1950 G. E. HULSTEDE 2,508,573

ULTRA HIGH FREQUENCY OSCILLATOR CIRCUIT

Filed April 30, 1946

FIG. 1

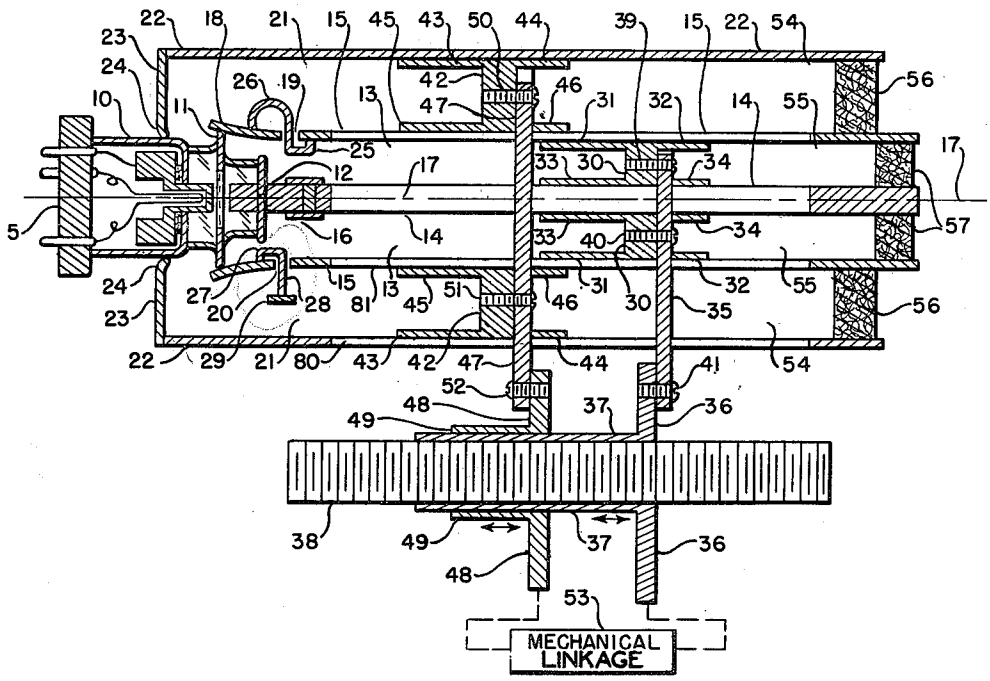
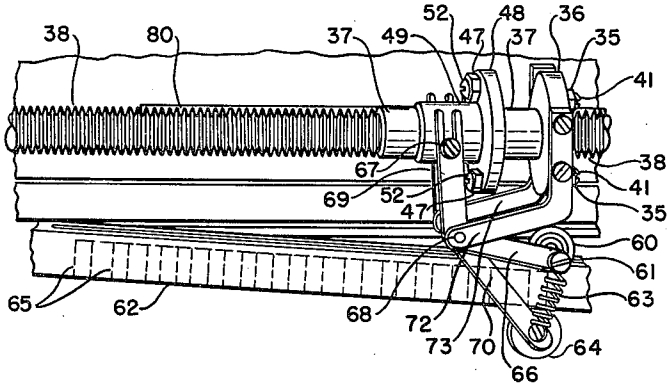


FIG. 2



INVENTOR
GEORGE E. HULSTEDE
BY
William D. Hall
ATTORNEY

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ULTRA HIGH FREQUENCY OSCILLATOR CIRCUIT

George E. Hulstede, Belmont, Calif., assignor to the United States of America as represented by the Secretary of War

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9 Claims. (Cl. 250—27.5)

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This invention relates in general to electrical apparatus, and more particularly to thermionic tube circuits employing cavity resonators as the resonant elements thereof.

Among the objects of the present invention, therefore, are:

1. To provide a tunable oscillator for use at ultra-high and super-high frequencies:

2. To provide such an oscillator adapted for use with the lighthouse tube; and

3. To provide such a lighthouse tube oscillator in which the tuning is accomplished by keeping each of the cavities embodied therein tuned to substantially optimum conditions at all frequencies over the tuning range.

In accordance with the present invention, there is provided a concentric coaxial cavity oscillator for use with a lighthouse triode in which both cavities are tunable by means of plungers. These plungers are mechanically coupled together by means of a cam arrangement, which is capable of motion alongside the axis of the cavities by means of a tuning screw. The cam structure is such that as the tuning screw is turned, both plungers move at different velocities, with the position of each plunger in its respective cavity being at all times such that substantially optimum resonant conditions are maintained in the two cavities.

This invention will best be understood by reference to the accompanying drawings, taken in connection with the appended claims and this specification, and in which:

Fig. 1 is a functional diagram representing the working parts of one practical form of the oscillator circuit itself, with a portion of the mechanical arrangement for moving the plungers shown; and

Fig. 2 is a drawing of one embodiment of the mechanical linkage coupling the two plungers.

Referring now to a description of one embodiment employing the principles of the present invention and specifically to Fig. 1, there is represented a lighthouse type of triode thermionic tube 5 showing the cathode collar 10, grid disc 11 and plate cap 12. These parts are made of a conducting material and are electrically connected, within the tube, to the cathode, grid and plate respectively. This showing of the tube is intended only to be representative, in general, of the lighthouse type triode. There are a number of ways of utilizing the lighthouse triode in an oscillator circuit, but the one chosen, by way of an example, to indicate the principles of the present invention employs a tuned circuit between grid and plate and a tuned circuit between grid and cathode. Both of these tuned circuits are made to be cylindrical, coaxial cavity resonators having annular cross sections perpendicular to the axes of the cylinders. In particular, cavity 13, in which the inner wall is conducting rod 14 and the outer wall is cylindrically-shaped, conducting member 15, couples the plate of the tube to the grid for radio frequencies through the electromagnetic field existing in this cavity. Members 14 and 15 are substantially rotationally symmetrical about center line 17. About the tube end of the rod 14 is fitted sleeve member 16, also of a conducting material, with a large fraction thereof overhanging or extending beyond the end of the rod. Into this overhanging portion is fitted the plate cap 12 of the tube 5. This sleeve 16 may be slotted along a fraction of its length in a direction parallel in space to center line 17 so that a more highly conducting fit may be accomplished between plate cap 12 and sleeve 16. Cylinder 15 has the tube end thereof flared out slightly, and this flared portion 18 may be slotted in much the same manner as sleeve 16, so that a number of fingers, not shown, are formed. The cylinder 15 is preferably made of a springy, conducting material. The triode 5 is forced into the cavity resonator portion of the oscillator until the fingers in the flared portion 18 are pressing tightly onto the grid disc 11. There are a number of small holes, two of which are 19 and 20, equally spaced about the circumference of the tube 15. These do not interfere appreciably with the flow of surface currents along tube 15.

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The cavity resonator 21, which is connected between grid and cathode of tube 5, comprises the outer surface of tube 15 as the inner wall thereof, and the inner surface of tube 22 as the outer wall thereof. The tube end of cavity 21 is closed by means of the annular disc 23, which has its inner portion 24 flared slightly in the direction of the cavity. This flared portion 24 may be slotted in a radial direction, so that a plurality of fingers may be formed therefrom. When the tube 5 is pressed into the cavity structure, its cathode collar 10 should make good contact with disc 23. Thus it is seen that, at the tube end, cavity 13 is terminated by only the plate-grid capacitance of the triode tube, and cavity 21 is terminated only by the grid-cathode capacitance of the tube.

A necessary element in this type of oscillator is a means of feedback from the plate-grid cavity, in this case cavity 13, to the grid-cathode cavity,

in this case cavity 21. In this particular embodiment, feedback is provided by two different types of coupling, magnetic field coupling and electric field coupling. The magnetic field type of coupling utilizes a conducting wire bent into the form of a loop 25, one end of which is firmly connected to the inner wall of tube 15. The free end of this loop extends through the hole 19 in the wall of tube 15 and forms another, larger loop 26, the end of which is firmly connected to the outer wall of tube 15. The electric field type of coupling utilizes a loop 27 in cavity 13, one end of this loop being soldered to the inner wall of tube 15. The free end of loop 27 is brought through hole 20 in the wall of tube 15 and extends into cavity 21 in the form of a probe 28. At the end of this probe 28 is soldered a small flat plate 29, the plane of the surface of which is normal to the plane of the drawing. This flat plate may take any one of a number of shapes, with one preferable design employing a circular shape. One desirable embodiment of this apparatus may use a number of coupling loops and probe-flat plate arrangements distributed over the circumference, using one method and then the other, alternately.

Both cavity 13 and cavity 21 have their ends opposite to the tube ends short-circuited for radio frequency by means of conducting movable plungers, the conducting material being phosphor bronze or, preferably beryllium copper. Cavity 13 is terminated by plunger 30 which is mounted so as to be slidably associated with the wall of tube 15 and with rod 14.

The plunger 30, in a plane normal to axis 17, is annular in shape. It is desirable for efficient operation of the oscillator that the plunger 30 make very good contact at all times with tube 15 and rod 14. To provide this, a number of front spring fingers 31 are attached to the plunger 30 and allowed to press firmly against the inner wall of tube 15. It is desirable that these fingers also be made of beryllium copper. Back fingers 32 are also desirable at certain frequencies. Front fingers 33 strengthen the contact between the plunger 30 and the rod 14, and back fingers 34 are also provided for this purpose. Each group of spring fingers extends over the whole circumference of the cylindrical surface with which it is making contact. Plunger 30 contains a suitable bypass condenser structure so that plate potential may be applied to conductor 14.

The translational motion of the plunger 30 is affected by motion transmitted through yoke 35, flange 36, sleeve 37 and screw 38. It should be understood that the arrangement of coupling these various motion-transmitting means that is illustrated in Fig. 1 is given merely as a functional example to explain the operation of the present device. Yoke 35 extends through thin slots 80 and 81 in the walls of tubes 22 and 15, respectively, is held against the back surface of plunger 30 by screws 39 and 40, and is connected to flange 36 by means of screws 41, only one of which is shown.

Cavity 21 is terminated by movable plunger 42 in a manner similar to that in which cavity 13 is terminated. This plunger 42 is annular in shape, looking in a direction parallel to axis 17, and has an outside diameter substantially equal to the inside diameter of tube 22, and has an inside diameter substantially equal to the outside diameter of tube 15. Front fingers 43 and back fingers 44 assure that the plunger 42 makes good electrical contact with tube 22, while front

fingers 45 and back fingers 46 strengthen the electrical contact with tube 15, analogously to the structure in association with plunger 30. Plunger 42 has motion transmitted to it, in a manner similar to that used in connection with plunger 30, by means of yoke 47, flange 48 and collar 49. Yoke 47 extends through thin slot 80 in the wall of tube 22, is held against the back of plunger 42 by means of screws 50 and 51, and is coupled to flange 48 by means of screws 52, only one of which is shown. Collar 49 is adapted to slide easily on the surface of collar 37 and receives its motion through a mechanical linkage 53, which is described in detail in connection with Fig. 2.

It is seen upon inspection of Fig. 1 that there are two more cavity resonators 54 and 55, formed by the extension of tubes 15 and 22 beyond the plungers. These cavities are bounded at one end by the backs or near surfaces of the plungers, and they are terminated by annular members 56 and 57. These latter-mentioned members are made of a material consisting of a large number of thin strips of steel, tightly packed together. This material is often referred to as "steel wool." Member 57, similar to plunger 30, has a bypass condenser structure to isolate conductor 14 with respect to the plate potential applied thereto.

It will be understood that only the broad aspects of the lighthouse tube and resonator structure have ben described hereinabove, and that there are many details not required for an understanding of the invention which have not been specifically shown or described and which would be required in the proper operation of the device, such as the plate power supply connections, various condensers and chokes needed in the system, the bias arrangement, etc. It is believed, however, that such details are well known in the art and so do not need to be included here.

In Fig. 2 there is shown the oscillator of Fig. 1 looking in a direction parallel to, and from bottom to top of, the plane of the paper of Fig. 1, with the mechanical linkage 53 together with certain other members shown in detail, but with the main electrical portion of the oscillator omitted for the sake of clarity. From a comparison of Fig. 2 with Fig. 1, there may be recognized the screw 38, threaded around which is collar member 37. Flange 36, which may be cut from the same stock as collar 37 is recalled to be one of the means of transmitting motion to the plate-grid plunger 30 through yoke 35, a portion of which may be seen in Fig. 2. Screws 41 may also be discerned in Fig. 2. Sliding collar 49 together with flange 48 is shown fitted over collar 37. A portion of yoke 47 may be seen, with screws 52 holding it to the flange 48. It will be recalled that collar 49 is used to transmit motion to the grid-cathode plunger 42. It is seen that the turning motion of the screw 38 gives a translational motion to collar 37, while collar 49 is moved by motion transmitted through the coupling network to be described below.

In the cam arrangement, follower 60 is made to run in a narrow track 61 in cam 62, the follower 60 being held in track 61 by a first spring 63 and a second spring, not shown, which are attached to a roller 64. The second spring is connected to the other sides of follower 60 and roller 64. The cam 62 is made to have a straight track originally, but the contour of the track may be varied slightly by the adjustment of set screws 65. Sliding links 66 and 69, comprising flat

angular strips of metal, rotate at one end about the axle of follower 60, and rotate and slide at the other end about a pin which may be formed by screw 67. At the vertices of the angle formed by the links 66 and 69 is a pin 68 to which is connected straight links 70, only one of which is shown. To pin 68 is also connected two fixed links 72 and 73, the other end of these two links being fixedly connected to the flange 36.

Referring now to a description of the electrical and mechanical operating characteristics and principles of the present device, and to Fig. 1, it is seen that the circuit here represented may be made to oscillate by virtue of feedback between plate and grid of the tube. The ordinary interelectrode capacitance between plate and grid of a lighthouse triode tube is normally too small to provide sufficient feedback for oscillation to occur. In the present device, the feedback is accentuated by coupling an amount of energy from the plate-grid cavity 13 to the grid-cathode cavity 21. Energy is extracted from the electromagnetic field existing in the plate-grid cavity by means of small loops, one of which is loop 25, which link the magnetic field and couple this energy to the magnetic field in the grid-cathode cavity by means of larger loops, one of which is loop 26. Energy is also extracted from the plate-grid cavity electromagnetic field by small coupling loops, one of which is loop 27, and is coupled to the electric field in the cathode-grid cavity by means of probes and flat plates, one such combination being probe 28 and flat plate 29. Two different types of feedback are necessary because of the very wide frequency range of this oscillator. The combination of the two is effective because the loop 26 provides more efficient feedback at the lower end of the frequency range, and the probe and plate arrangement is more useful in providing feedback at the higher end of the frequency range.

An effective parallel resonant circuit must appear between plate and grid, and between grid and cathode in this oscillator. The characteristics of the parallel resonant circuits are fulfilled by the two cavity resonators if they are made to be effectively an odd number of quarter-wavelengths long at the operating frequency of the oscillator, and if the cavities are short-circuited at the ends other than the tube ends. One preferable mode of oscillation occurs when the cavities are effectively ¾ wavelength long. The short-circuit terminations are provided by the two plungers 30 and 42 together with their associated fingers. The fingers on the front, fingers 45 and 43, in association with plunger 42, and fingers 31 and 33 in association with plunger 30, are made to be, when possible, about a quarter of a wavelength long at the highest operating frequency. The back fingers, fingers 44 and 46, in association with plunger 42 and fingers 32 and 34 in association with plunger 30, have their lengths usually limited by space requirements and are relatively short.

Even though the fingers provide very good contact between the plungers and the sides of the cavities, there still may be a small amount of electromagnetic energy leaking through these contacts into the back cavities 54 and 55. Even though there is no apparent reason, with respect to size, why oscillation of the fields should occur in these back cavities, nevertheless under certain conditions it does. It is found by experience that unless provision is made to absorb most of this energy, and thereby prevent resonance behind the plungers, there will be points in the tuning band of the oscillator at which no oscillation will occur. Cartridges of thin strips of steel closely packed, used at the ends of these back cavities to absorb a large amount of the electromagnetic energy existing therein have been found to prevent an undesirable amount of oscillations in these back cavities.

Since the effective length of each of the cavities must be an odd multiple of a quarter of a wavelength at the desired frequency of oscillation for satisfactory operation to take place, it is seen that the resonant structure must be tuned by the linear motion of each of the plungers along the length of the cavities. It is found that for the cavities to be of optimum length over the tuning range, the plungers should not be kept a fixed linear distance apart, but should have their separation increase approximately linearly as the frequency is increased, that is, as the lengths of the cavities are decreased. The plate-grid cavity plunger 30 has motion transmitted to it through yoke 35, which moves through narrow slots in the walls of tubes 22 and 15. This yoke is a thin rod over the portion which extends through the wall of tube 22, through cavity 54 and through the wall of tube 15. The yoke then branches into two parts in cavity 13 so that a firm connection can be made to the back of plunger 30. This yoke 35 is seen to extend through the extension, cavity 54, of the grid-cathode cavity, which does not enclose the oscillations belonging to the lighthouse tube circuit. In a similar manner, yoke 47 is used to transmit motion to the grid-cathode plunger 42. This yoke is in the form of a thin rod in the portion that passes through the wall of tube 22, using the same slot as that used by yoke 35. Yoke 47 branches into two parts in cavity 21, a circular-like shape being preferable so that a strong connection can be made to the back of plunger 42. Mechanical linkage 53 connects collar 37 to collar 49 which thus mechanically couples plunger 30 to plunger 42.

This linkage is shown in detail in Fig. 2. As the long screw 38 is turned, collar 37 and flange 36, which are mechanically coupled to the plate-grid plunger 30, move along screw 38 and the length of the plate-grid cavity 13 is varied. Motion is transmitted through fixed links 72 and 73 and through pin 68 to movable links 66 and 69, which causes follower 60 to rotate and move along the track 61, which is a part of the cam 62. Let us assume that screw 38 is turned in such a direction that the whole mechanical linkage 53 is moved to the left. Since the long axis of cam 62 is placed at a small acute angle with respect to the long axis of screw 38, motion of follower 60 to the left simultaneously brings this follower, and hence this end of movable links 66 and 69, nearer to screw 38, which increases the separation of the slidable ends of links 66 and 69 from the flange 36. Since flange 48 is connected to these slidable ends through collar 49, and is mechanically coupled to the grid-cathode plunger 42, the separation of these two plungers is also increased.

If the cam 62 has a straight track 61, this separation is increased linearly. Certain lighthouse tubes have properties, however, such that a slight departure from this straight-line variation is desired. For that end adjustment screws 65 are provided. These screws change the contour of the cam slightly, and so control to a small extent the variation of the relative motion of the two plungers. Link 70 and its counterpart positioned

behind it, spring 63 and its twin, and roller 64 keep follower 60 in the track 61.

Since proper cooling of the tube must take place for the oscillator to function efficiently, care must be taken in assuring good heat transmission away from the plate cap 12 of the tube. It is desirable to use some form of efficient heat dissipator at the open air end of rod 14.

The losses in the oscillator circuit and in the vacuum tube are found to be greatest at the high-frequency end of the tuning range. With a constant plate potential and cathode bias, the plate current increases with the strength of oscillations. Thus if a plate potential is chosen which provides satisfactory operation at the higher frequencies, the plate current at the lower end of the range would be excessive. It is, therefore, desirable to use a type of plate power supply which has substantially constant-current characteristics, which results in lower plate potentials being supplied at the lower frequencies where the efficiency is the highest.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention, and it is, therefore, intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A tunable concentric double-coaxial cavity resonator circuit comprising a thermionic tube having an anode, control grid and cathode electrodes therein, a first cavity resonator connected between a first pair of said electrodes, a second cavity resonator connected between a second pair of said electrodes, a first slidable plunger positioned in the end of said first cavity resonator for the tuning thereof, a second slidable plunger positioned in the end of said second cavity resonator for the tuning thereof, a moving device mechanically coupled between said resonators and one of said slidable plungers for moving said one plunger at a first velocity with respect to said resonators, and adjustable mechanical linkage means coupling said first and said second plungers together and adapted to vary the spacing between said plungers as a function of the position of said one plunger relative to said resonators for simultaneously moving the other of said slidable plungers at a different velocity from said first velocity.

2. An oscillation generator comprising a tube having an anode, control grid and cathode electrodes, a first concentric line cavity resonator connected between a first pair of said electrodes, a second concentric line cavity resonator connected between a second pair of said electrodes, said cavity resonators being coaxial and having slots, a slidable tuning plunger positioned within each of said cavity resonators, and means for simultaneously tuning each of said cavity resonators comprising a screw, the axis of which is substantially parallel in space to the axis of said concentric resonators, a substantially straight cam the axis of which is at an acute angle with respect to the axis of said screw, a first yoke member extending through the slot in one of said resonators, a threaded collar mechanically coupled to a first of said slidable plungers through said first yoke, said threaded collar adapted to be screwed onto said screw, a second yoke member extending through the slot in one of said resonators, a smooth collar mechanically coupled to the second of said slidable plungers through said second yoke member, said smooth collar slidably mounted with said threaded collar, a follower for running along said cam, a pin, a non-rotatable link connected at one end to said threaded collar and at the other end to said pin, and a rotatable link slidably connected at one end to said smooth collar and connected at the other end to said follower and at an intermediate point to said pin, whereby the turning of said screw causes movement of said first plunger at a first velocity and movement of said second plunger at a second velocity.

3. A tube having an anode, control grid and cathode electrodes, a first concentric line cavity resonator connected between a first pair of said electrodes, a second concentric line cavity resonator connected between a second pair of said electrodes, said cavity resonators being coaxial and having slots, a slidable tuning plunger positioned within each of said cavity resonators, and means for simultaneously tuning each of said cavity resonators comprising a screw the axis of which is substantially parallel in space to the axis of said concentric coaxial cavity resonators, a substantially straight cam the axis of which is at an acute angle with respect to the axis of said screw, a threaded collar mechanically coupled to a first of said slidable plungers and adapted to be screwed onto said screw, a smooth collar mechanically coupled to the second of said slidable plungers and slidably mounted with said threaded collar, a follower for running along said cam, a pin, a non-rotatable link connected at one end to said threaded collar and at the other end to said pin, and a rotatable link slidably connected at one end to said smooth collars and connected at the other end to said follower and at an intermediate point to said pin, whereby the turning of said screw causes movement of said first plunger at a first velocity and movement of said second plunger at a second velocity.

4. A tube having an anode, control grid and cathode electrodes, a first concentric line cavity resonator connected between a first pair of said electrodes, a second concentric line cavity resonator connected between a second pair of said electrodes, said cavity resonators being coaxial and having slots, a slidable plunger positioned within each of said cavity resonators, and means for simultaneously tuning each of said cavity resonators comprising a guiding means the axis of which is substantially parallel in space to the axis of said concentric coaxial cavity resonators, a substantially straight cam the axis of which is at an acute angle with respect to the axis of said guiding means, a first yoke member extending through the slot in one of said cavity resonators, a first guided means mechanically coupled to a first of said plungers through said first yoke member, said first guided means being adapted to be controlled by said guiding means, a second yoke member extending through the slot in one of said cavity resonators, a second guided means mechanically coupled to the second of said plungers through said second yoke member, said second guided means being adapted to move in a direction parallel in space to the axis of said guiding means, a follower for running along said cam, a pin, a non-rotatable link connected at one end to said first guided means and at the other end to said pin, and a rotatable link slidably connected at one end to said second guided means, and connected at the other end to said follower

and at an intermediate point to said pin, whereby movement of said first guided means at a first velocity causes movement of said second guided means at a second velocity.

5. A tube having an anode, control grid and cathode electrodes, a first concentric line cavity resonator connected between a first pair of said electrodes, a second concentric line cavity resonator connected between a second pair of said electrodes, said cavity resonators being coaxial and having slots, a slidable tuning plunger positioned within each of said cavity resonators, and means for simultaneously tuning each of said cavity resonators comprising a guiding means the axis of which is positioned substantially parallel in space to the axis of said concentric coaxial cavity resonators, a substantially straight cam the axis of which is at an acute angle with respect to the axis of said guiding means, a first guided means mechanically coupled to a first of said plungers and controlled by said guiding means, a second guided means mechanically coupled to the second plunger and adapted to move in a direction parallel in space to the axis of said guiding means, a follower for running along said cam, a pin, a non-rotatable link connected at one end to said first guided means and at the other end to said pin, and a rotatable link slidably connected at one end to said second guided means and connected at the other end to said follower and at an intermediate point to said pin, whereby movement of said first guided means at a first velocity causes movement of said second guided means at a second velocity.

6. A tube having an anode, control grid and cathode electrodes, a first concentric line cavity resonator connected between a first pair of said electrodes, a second concentric line cavity resonator connected between a second pair of said electrodes, said cavity resonators being coaxial and having slots, a slidable tuning plunger positioned within each of said cavity resonators, and means for simultaneously tuning each of said cavity resonators comprising a substantially straight cam, a follower adapted to run along said cam, a non-rotatable link mechanically coupling said follower to one of said plungers, and a rotatable link mechanically coupling said follower to the other of said plungers.

7. A tube having an anode, control grid and cathode electrodes, a first concentric line cavity resonator connected between a first pair of said electrodes, a second concentric line cavity resonator connected between a second pair of said electrodes, said cavity resonators being coaxial and having slots, a slidable tuning plunger positioned within each of said cavity resonators, and means for simultaneously tuning each of said cavity resonators comprising a substantially straight cam the axis of which is at an acute angle with respect to the axis of said concentric coaxial cavity resonators, a follower for running along said cam, a first guided means mechanically coupled to said first plunger and controlled by said follower, a mechanical structure connected to said follower, a second guided means mechanically coupled to said second plunger and controlled through said mechanical structure whereby movement of said first guided means at a first velocity causes movement of said second guided means at a second velocity.

8. A tunable lighthouse tube oscillator comprising an anode-grid cavity resonator, a first plunger situated at the end of said anode-grid cavity resonator for controlling the resonant frequency thereof, a grid-cathode cavity resonator, a second plunger situated at the end of said grid-cathode cavity resonator for controlling the resonant frequency thereof, a moving device mechanically coupled between said resonators and one of said plungers for moving said one plunger at a first velocity with respect to said resonators, and an adjustable mechanical linkage means between said plungers for varying the spacing between said plungers as a function of the position of said one plunger relative to said resonators for moving the other of said plungers at a different velocity from said first velocity.

9. A pair of concentric coaxial cylinders, slidable elements one movable within each of said cylinders, a moving device mechanically coupled between said cylinders and one of said slidable elements for moving said one element at a first velocity with respect to said cylinders, and adjustable means linking said elements together and varying the spacing between said slidable elements as a function of the position of said one element relative to said cylinders for simultaneously moving the other of said elements at a different velocity from said first velocity.

GEORGE E. HULSTEDE.

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