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HIGH-FREQUENCY APPARATUS

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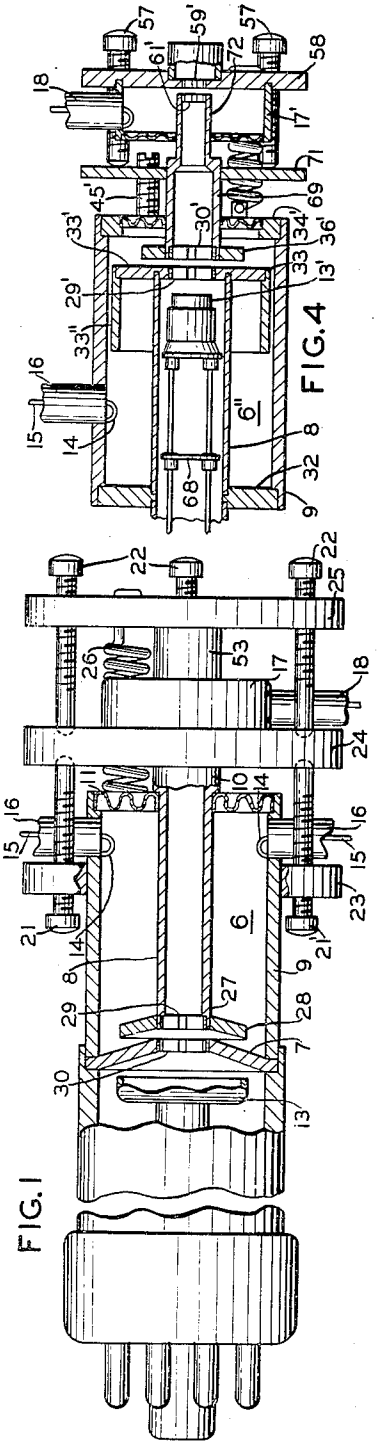


FIG. 1

FIG. 4

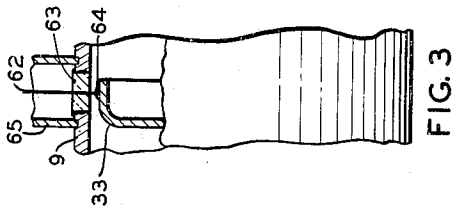


FIG. 3

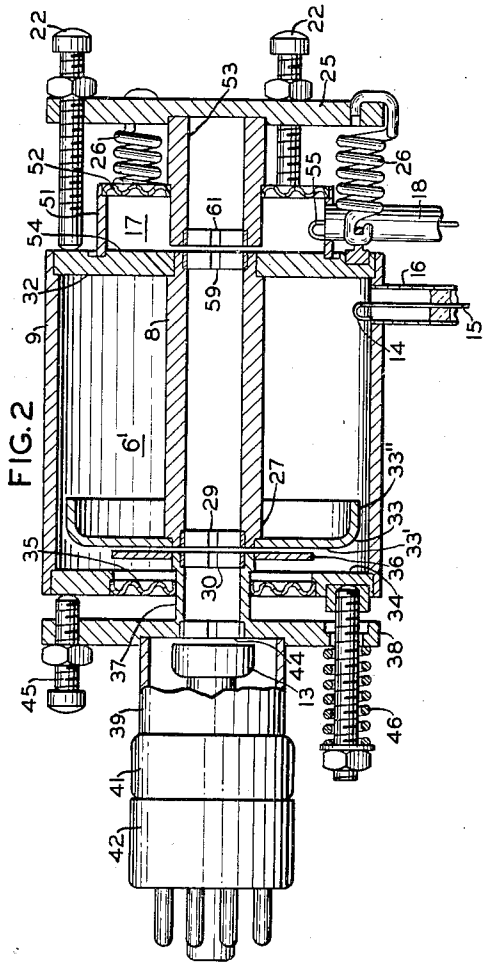


FIG. 2

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HIGH-FREQUENCY APPARATUS

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31 Claims. (Cl. 315—6)

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The present invention relates to the art including ultra high frequency electron discharge tubes, and is more particularly concerned with such tubes wherein cavity resonators are used to vary the velocity of an electron beam, and the electrons are thereafter bunched.

In prior U. S. Patent No. 2,281,935, issued May 5, 1942, to R. H. Varian and W. W. Hansen, and in U. S. Patent application Serial No. 416,170, filed October 23, 1941, in the names of W. W. Hansen, J. R. Woodyard, S. F. Varian and R. H. Varian, and now Patent No. 2,425,738, issued August 19, 1947, there are disclosed vacuum tubes of the above type used as frequency multipliers, in which an electron beam, velocity bunched by the action of an input resonator tuned to and excited at a first frequency, excites an output resonator tuned to a harmonic of the energizing frequency and spaced a predetermined distance from the input resonator.

It is an object of the present invention to provide an improved cavity resonator suitable for use in such frequency multiplier vacuum tubes, and having smooth and stable frequency characteristics.

It is a further object to provide an improved cavity resonator having an effective fixed lumped capacitance and an effective variable tuning capacitance.

Another object is to provide an improved electron discharge device having a cavity resonator embodying an inner cylinder rigidly positioned with respect to the outer shell of said resonator.

A further object is to provide an improved frequency multiplier or harmonic generator having an input resonator embodying an inner cylinder rigidly positioned with respect to the outer shell of said resonator.

Still a further object is to provide an improved velocity variation frequency multiplier or harmonic generator having an input resonator embodying an inner cylindrical conductor forming an electron drift tube rigidly positioned within an outer shell of said resonator.

Another object is to provide an improved input cavity resonator for a velocity variation frequency multiplier so constructed as to insure substantially coaxial relation between adjacent grids of said frequency multiplier input resonator.

Other objects will become apparent from the specification, taken in connection with the accompanying drawing, wherein the invention is embodied in concrete form.

In the drawing,

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Fig. 1 is an elevation, partly in cross-section, of a velocity-variation electron discharge device adapted to be used as a frequency multiplier;

Fig. 2 is a view partly in cross-section, of an improved velocity-variation frequency multiplier embodying the principal features of the present invention;

Fig. 3 is an elevation, partly in cross-section, of a portion of a velocity-variation frequency multiplier similar to that shown in Fig. 2, showing an alternative arrangement for excitation of the velocity-variation device of Fig. 2; and

Fig. 4 is an elevation, partly in cross-section, of a somewhat different arrangement of elements in a velocity-variation frequency multiplier embodying the present invention.

Like reference numerals are used throughout the four figures to refer to the similar portions thereof.

In Fig. 1 there is shown a velocity variation frequency multiplier embodying an input cavity resonator 6 of a type disclosed and claimed in pending application 416,170 referred to above. This input cavity resonator 6 comprises as its principal elements the cylindrical outer shell 9, a rigid slightly conical end wall 7, and an inner conductive cylinder 8 connected to outer shell 9 and movably supported therein by the flexible diaphragm 11 forming an end wall of the resonator opposite the rigid end wall 7.

As will be explained in detail below, the velocity variation frequency multiplier embodying input resonator 6 includes a cathode structure 13 positioned adjacent end wall 7 of the input resonator, an output cavity resonator 17, means for adjusting the dimensions within resonator 6 for tuning the input resonator to an excitation signal frequency, and means for tuning resonator 17 to a harmonic of this frequency.

As discussed in more detail in the above-mentioned patent, the velocity variation frequency multiplier is operated with the cathode electrically heated for electron emission and supplied with high negative potential with respect to resonator 6. With a resonant source of ultra high frequency energy coupled to resonator 6 through a coaxial line 15, 16 and coupling loop 14, a high-potential ultra high frequency electric field is developed between end wall 7 and the end 27 of inner cylinder 8 of resonator 6. Electrons are projected from cathode structure 13 through a central circular opening in end wall 7 to be propelled along through inner cylinder 8 into resonator 17, under the influence of

the high potential of the metal structure 7 with respect to the cathode structure 13.

On passage through the portion of this path encircled by the narow high-potential gap between end wall 7 and end 27 of inner cylinder 8, the electrons are velocity modulated by the ultra high frequency voltage field produced in this region.

During the travel of the stream of electrons from this region along the drift space bounded by inner cylinder 8, the velocity modulation results in distribution of the electrons in spaced bunches. These bunches pass through an ultra high frequency, high voltage field region of the output resonator 17, and impart thereto high harmonic energy. This ultra high frequency harmonic energy may be extracted from the output resonator 17 through coupling 18 and applied to a suitable utilization device connected thereto.

A pair of closely adjacent grids 29 and 30 may be provided in the end 27 of the inner cylinder 8 and in the opening in rigid end wall 7, respectively. Such a pair of grids, along with the closely adjacent metal areas of rigid wall 7 and inner cylinder 8, serve as an effective lumped or concentrated capacitance which, together with the distributed inductance and capacitance of input resonator 6, determines the frequency of resonant response of the resonator.

In practice, it is often found that in order to allow resonator 6 to be built as a compact unit, it is necessary to employ a large lumped capacitance at grids 29 and 30, which normally could be provided only by decreasing the spacing between the grids to less than a reasonable minimum value. In order to increase the lumped capacitance at this point, while retaining ample spacing between grids 29 and 30, a conductive slightly conical flange 28 was attached to the end 27 of the inner cylinder 8, as described in the pending application referred to above. The member 28 cooperates with rigid end wall 7 to provide additional capacitance, which acts in shunt with the capacitance between grids 29 and 30 to tune resonator 6 to a desired input frequency range.

The structure provided for tuning input resonator 6 comprises a flange 23 rigidly attached to outer shell 9, and a second flange 24 rigidly connected to an extension 10 of inner cylinder 8. A plurality of screws 21, 21' may be provided in suitably tapped holes through flange 23 for bearing against flange 24 to adjust the separation between the flanges. Although only two such screws are shown in the view of Fig. 1, there may be three input resonator tuning screws employed in suitable threaded holes symmetrically located at 120° intervals through flange 23.

If the input tuning screws are provided with righthand threads, clockwise rotation of the screws is used to produce movement of inner cylinder 8 axially away from rigid end wall 7, to decrease the capacitance therebetween and thus to tune resonator 6 to resonance at a higher frequency.

A similar structure for tuning harmonic output resonator 17 comprises a rigid metal plate 25 connected to the metal cylinder 53 extending within resonator 17 to form a movably supported part thereof. This plate, also may be provided with three tapped holes spaced at 120° intervals and accommodating output tuning screws 22 which have rounded ends adapted to bear against the rigid flange 24.

Three springs 26 interspaced among output resonator tuning screws 22 and also among the input tuning screws may be stretched between flange 23 and end plate 25, through clearance holes provided in flange 24. These springs provide axial tension for maintaining input tuning screws 21, 21' and output screws 22 firmly seated against the flange 24 which is common to the input and output tuning structures.

In practical operation of the device shown in Fig. 1, a cathode heating supply and a high potential source are connected as described above, to provide cathode electron emission and accelerating potential along the electron path. A utilization device, such as a detector, is connected to output coaxial line 18, and a source of ultra high frequency excitation energy is coupled to the input resonator 6 through a coaxial line 15, 16. The frequency of the excitation source may be of the order of 300 megacycles per second, for example.

The input resonator 6 is then tuned by means of adjustment screws 21, 21' to the frequency of the excitation source coupled thereto, and the output resonator 17 is tuned to the desired harmonic of the input frequency, e. g., the tenth harmonic, which in the above example would be of the order of 3000 megacycles per second.

The device shown in Fig. 1 was found to be difficult to adjust for best performance; this was noted to be especially due to critical movements of the input tuning screws, 21, 21' required for obtaining maximum harmonic output energy from resonator 17. When a large change of resonant frequency of the resonator 6 was required to reach resonance with a coupled source of excitation signal, it was necessary to make small successive adjustments on all of the input resonator tuning screws in turn, repeating this procedure in a number of steps until resonance with the new frequency was achieved. Even then, the resonator 6 often was found to perform unsatisfactorily unless minute adjustments of the different input tuning screws were made to find the most effective combination of positions of all of the input resonator adjusting screws.

After several successive adjustments of the input resonator tuning screws, retracting one and advancing another, an adjustment of resonator 6 eventually could be found at which very good performance was obtained.

The critical adjustment characteristics of input resonator 6 were believed to be largely due to the great axial extension of inner cylinder 8 from an effective pivotal point in the vicinity of flexible diaphragm 11. Because of this, an advancement of a single input resonator tuning screw, e. g., 21, while effective as intended to produce axial movement of inner cylinder 8 with respect to outer shell 9, also resulted in a radial movement of the end 27 of inner cylinder 8 which was much greater than the resultant axial movement. Of course, only the axial movement was desired, since it was advantageous to retain grids 29 and 30 in substantially coaxial positional agreement, so that the respective parts of the grids would remain aligned.

Moreover, the lumped loading capacitance provided by closely spaced elements 7 and 28 varied sharply when a relative radial movement between these elements was produced by such differential adjustments of screws 21 and 21'.

Of course, in the design of the frequency multiplier electron discharge device of Fig. 1, it was intended that large axial movements of element 28 and grid 29 with respect to end wall 7

and grid 30 for tuning over a large frequency range would be accomplished with negligible radial motion of elements 28 and 29 with respect to elements 7 and 30, by successive small adjustments of each of the input resonator tuning screws in turn. Actually, however, it was found difficult to so regulate the rotary adjustments of the tuning screws as to restrict the above radial movements to negligibility. Furthermore, the alignment of the elements 8 and 28, and of elements 29 and 30 within the resonator 6 could only be estimated on the basis of the performance of the frequency multiplier tube, since these elements were hidden from view.

Then, too, while large changes of tuning of the input resonator were accomplished by small, successive movements of the different input resonator screws in turn, the relatively small final tuning adjustments of the input resonator usually required concentration on a single adjustment screw, as screw 21, adjustment of which would result in greater radial movement of elements 28 and 29 than axial movement of those elements, as explained above.

Thus, the structure shown in Fig. 1 of the drawing in this case, and shown and claimed in the above-mentioned application Serial No. 416,170, operated successfully after a tedious series of adjustments, but required great care in manipulation of the individual input resonator tuning screws to obtain best performance.

The present invention, in order to overcome the disadvantages above recited, provides in the frequency multiplier or harmonic generator of Fig. 2 an improved input cavity resonator characterized by substantially fixed alignment of the input resonator grids and the cathode, and further characterized by an inner cylinder 8 rigidly positioned within shell 9. A further feature of this improved cavity resonator is the incorporation therein of a rigidly fixed capacitance loading element 33 extending between the end 27 of the inner cylinder 8 and the corresponding end of outer shell 9. This fixed capacitor is supplemented by an adjustable lumped capacitor comprising a metal cylinder 37 and element 36 movable axially in closely spaced relation to the end 27 of inner cylinder 8. Metal cylinder 37 and element 36 are separated axially from the end of inner cylinder 8 by a small annular gap which is varied by movement of element 36.

With these features the resonator 6' overcomes the critical adjustment characteristics of the operation of the resonator 6 shown in Fig. 1.

In the form of resonator shown in Fig. 2, the rigid electrically conductive cylinder 8 is rigidly connected to outer shell 9 through rigid conductive end plate 32. Cylinder 8 and end plate 32, together, form a rigid conductive re-entrant member connected to outer shell 9 at one end thereof. Such a re-entrant member may be composed of a disc portion and a cylindrical portion bonded together, or may be made as a unit by spinning or drawing a single piece of metal to the desired form. A large lumped loading capacitance is provided between the ends of outer shell 9 and inner cylinder 8 by a conductive member 33 attached to cylinder 8 and extending between cylinder 8 and outer shell 9. Preferably, element 33 may include a disc portion 33' and a cylindrical portion 33'', the latter having an outer diameter slightly smaller than the inner diameter of shell 9. Such portions, if desired, may be formed as a single metallic member spun from suitable sheet metal. The cylindrical portion of element 33

provides a large capacitance concentrated between this element and the inner surface of the cylindrical shell 9.

Attached to the end of shell 9 adjacent capacitance element 33 is an end wall 34 provided with a flexible diaphragm 35 which permits movement of adjustable flanged tuning element 36 relative to the end 27 of inner cylinder 8 and also relative to the disc surface 33' of fixed capacitance loading element 33. Flange 36 is connected through cylinder 37 to rigid flange 38, which in turn is attached through metal cylinder 39 and a glass extension 41 to a conventional vacuum tube base 42. Within the metal cylinder 39 is positioned a cathode structure 13 similar to that shown in Fig. 1. Also there is positioned within flange 38 an accelerating grid 44 adapted to cooperate with cathode structure 13 in projecting electrons axially along resonator 6' through the drift tube space within conductive cylinder 8.

Adjustment screws 45 cooperating with suitably tapped holes through flange 38, and compressed springs 46, provide means for adjustment of the spacing or gap between adjustable capacitor element 36 and the end 27 of inner cylindrical conductor 8. Thus, while the large lumped capacitance provided by the closely spaced element 33 and shell 9 of the cavity resonator remains substantially constant by virtue of the rigid construction of these parts of the cavity resonator, tuning element 36 may be variably positioned within the cavity resonator to provide resonant frequency adjustment throughout a predetermined small frequency range.

The flanged tuning element 36 may be arranged to cooperate with the disc surface 33' of fixed loading capacitor element 33 as well as the end 27 of inner cylinder 8, if a moderately wide range of input resonator tuning adjustment is desired. The flanged tuning element 36 not only provides for a desired range of tuning adjustment, but also serves a very important additional purpose in the structure shown in Fig. 2, by electrostatically shielding the disc surface 33' of fixed capacitor loading element 33 from flexible diaphragm 35. Even though the position of the cylindrical member 37 is fixed with respect to shell 9 of the cavity resonator for a given adjustment of tuning screws 45 so that the outer and inner circular edges of diaphragm 35 are fixedly positioned, variations of atmospheric pressure due to barometric changes or to impinging sound waves may cause movements or vibrations of the portion of flexible diaphragm 35 intermediate the inner and outer circular extremities thereof. Without the tuning flange 36 interposed between flexible diaphragm 35 and the disc face of the capacitance loading element 33, an appreciable variation of capacitance, and accordingly, an appreciable variation of resonator tuning would be caused by such movements of the flexible diaphragm.

By virtue of the unusual arrangement of parts in resonator 6', the flanged tuning element 36 is at substantially the same ultra high frequency potential as diaphragm 35, so that small changes of capacitance between adjacent surfaces of these elements are of negligible effect on the resonant frequency of the resonator 6'.

An output resonator 17 comprising a cylindrical outer wall 51, a flexible diaphragm 52 and an inner conductive cylinder 53 may be fastened to rigid end wall 32, employing the outer surface 54 of this wall of the input resonator as a conductive surface portion of cavity resonator 17.

Coaxial line 18 is shown provided with a coupling loop 55 extending within cavity resonator 17 for extraction of ultra high frequency energy therefrom.

Tension springs 26 and adjustment screws 22 are provided in a disc or flange 25 rigidly connected to inner cylinder 53 of the output resonator. These adjustment screws and springs permit the spacing between disc wall surface 54 and the inner cylinder 53 of the resonator 17 to be adjusted as desired for tuning the resonator 17 to a desired harmonic of the input resonator excitation signal. Grids 59 and 61 may be provided within wall surface 54 and inner cylinder 53, respectively, if desired.

In the construction of an input resonator 6' as shown in Fig. 2, care must be exercised to insure that the large capacity loading element 33 is so dimensioned, relative to the dimensions of the inner cylinder 8 and the outer cylindrical shell 9, as to tune the resonator 6' to a frequency slightly higher than the desired operating frequency. The small variable capacitance added by the flanged capacitance element 36 then provides adjustment of the tuning of resonator 6' to the precise frequency desired.

In Fig. 2, a coupling loop 14 and a coaxial line having an inner conductor 15 and an output conductor 16 is shown inserted at a point of low potential and high current and magnetic field strength within the resonator 6'. Such a coupling element is suitable for introduction of low frequency power into the resonator 6' from a low impedance source. If desired, however, a high impedance input coupler may be provided in resonator 6' as shown in the partial view in Fig. 3, wherein is shown a modification of the structure of Fig. 2 to provide a conductive lead 62 fixedly positioned in an opening through outer shell 9 by a glass seal 63 and connected to a capacitance loading element 33 as by a soldered joint 64. An outer tubular conductor 65 connected to outer shell 9 as by a soldered joint may be provided along with lead 62, to form therewith a high impedance coaxial line for input connection to the resonator 6'. If an intermediate impedance coupler is desired the conductor 62 may be connected to any point along inner cylinder 8 instead of capacitance loading element 33.

Figure 4 shows a modification of the structure of Fig. 2, in which the rigid relation of the cylindrical conductor 8 and the outer shell 9 is retained, but the inner cylinder 8 encloses the cathode assembly 13' on an insulated supporting structure 68. With this arrangement, the direction of the electron stream projected from the cathode structure 13' through the grids 29' and 39' of resonator 6'' is substantially the opposite of that shown in Fig. 2, so that the electron drift tube 69 may be made external of the resonator 6'' and may be made of any length shorter than resonator 6'' if desired. This has the advantage of permitting greater design flexibility of resonator 6'', substantially independent of the drift tube length requirements of a velocity variation frequency multiplier tube structure.

In Fig. 4, conductive cylinder 69 supporting at one end the flanged tuning member 36' is rigidly fastened to adjustable flange 71, and is extended beyond this flange to provide the inner cylindrical conductor 72 of output resonator 17'. A rigid flange 58 is provided on output resonator 17' for adjustment through screws 57 of the spacing between output resonator grids 59' and 61' for changing the lumped capacitance therebetween

to tune the resonator. For this purpose, screws 57 pass through tapped holes through the flange 58, and the rounded lower ends of screws 57 bear against flange 71.

Flange 71 is also adjusted with respect to end wall 34' of input cavity resonator 6'' by screws 45' which are seated in threaded holes through flange 71 and bear against wall 34' to permit relative adjustment of the spacing between flanged tuning element 36' and the disc portion of the lumped capacitance loading element 33.

Otherwise than in the revision of the input resonator to permit the location of the cathode structure 13' within the boundaries of the resonator 6'', and thus to permit a choice of drift tube length substantially independent of the length of resonator 6'', the operation of the version of Fig. 4 is substantially similar to that of the arrangement shown in Fig. 2, as will now be described.

With the negative terminal of a source of high potential connected to cathode structure 13 (or 13') and the positive terminal connected to the metallic resonator structure 6' (or 6'') and with a source of filament heater potential connected to heat the cathode element within cathode structure 13 (or 13'), a source of ultra high frequency energy may be connected to the input coaxial line 15, 16 or to the high impedance coaxial line 62, 65, and input resonator 6' (or 6'') easily may be tuned by adjustment of tuning screws 45 (or 45') to resonance with said ultra high frequency source. With an ultra high frequency utilization device, such as a detector, connected to output coaxial line 18, tuning screws 22 (or 57) may be adjusted to tune output resonator 17 (or 17') for maximum output at a desired harmonic of the energy supplied to the input resonator.

The improved non-critical performance of the input resonator embodying the present invention may then be observed by rotation of one of the input resonator tuning screws 45 through a small angle in a clockwise direction, and a similar rotation of another input tuning screw threaded in a similar sense through an equal angle in the opposite direction. With the first of these adjustments, it will be noted that the resonator 6' is detuned from resonance with the source connected to coaxial line 15, 16, resulting in a marked decrease of output from coaxial line 18. With the second of these adjustments, the axial alignment of cathode structure 13 and cylindrical structure 37 is shifted only very slightly with respect to the axis of shell 9 and inner cylinder 8, and the tuning of resonator 6' is readily restored to resonance with the source connected to coaxial line 15, 16 without any detectable relative radial displacement between grids 29 and 39, and thus without appreciable impairment of performance of the electron discharge device.

Thus, by the rigid positioning through end wall 32 of inner conductive cylinder 8 and capacitor loading element 33 with respect to outer shell 9, and by the very short axial length of the structure connecting flange 38 (or 71) and the adjustable flange 36 (or 36') the radial movement of flange element 36 resulting from rotation of a tuning screw 45 to obtain a desired axial movement of this element with respect to the end 27 of inner cylindrical conductor 8 is greatly reduced. This results in high mechanical and electrical stability of the input resonator 6' and permits greatly improved ease of tuning adjustment of the input resonator.

Along with this improved arrangement of ele-

ments in resonator 6', the radial extension of the flanged tuning element 36 is made sufficient to effectively shield the flexible diaphragm 35 from the relatively high potential surface of fixed capacitor element 33 and the end 27 of inner cylinder 8, thus safeguarding against vibration and pressure-responsive modulations of the energy supplied to input resonator 6'.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Cavity resonator apparatus comprising a conductive outer shell having a flexible wall at one end, a rigid conductive inner member fixed to said shell at the other end thereof and extending toward and adjacent to said flexible wall, conductive means supported at the central portion of said flexible wall and opposite the end of said inner member and defining a gap therebetween, for controlling the resonant frequency of said resonator, and shielding means adjacent said flexible wall for preventing vibration of said wall from modulating said resonant frequency, said shielding means comprising a disc positioned adjacent said gap.

2. Cavity resonator apparatus comprising a conductive outer shell having a flexible wall at one end, a rigid conductive inner member extending from the other end of said outer shell toward said flexible wall, conductive means supported at said flexible wall and opposite the end of said inner member and defining a gap between said inner member and said conductive means, and shielding means adjacent said flexible wall and extending radially a distance smaller than the inner diameter of said shell and intermediate said flexible wall and said end of said inner member for preventing distortion of said wall from affecting the resonant frequency of said resonator.

3. Apparatus as in claim 2 further including means connected between said conductive means and said shell for varying said gap whereby the resonant frequency of said resonator may be varied.

4. Cavity resonator apparatus comprising a conductive outer shell having a flexible wall at one end, a rigid conductive inner member fixed to said shell at the other end thereof and extending toward and adjacent to said flexible wall, conductive means supported at the central portion of said flexible wall and opposite the end of said inner member and defining a gap therebetween, means connected between said latter conductive means and said shell for varying said gap to vary the resonant frequency of said resonator, and shielding means adjacent said flexible wall for preventing distortion of said wall from affecting said resonant frequency, said shielding means comprising a conductive disc member located adjacent said gap and connected to said flexible wall and between said flexible wall and said inner member.

5. An ultra-high frequency cavity resonator comprising a conductive cylindrical outer shell having a rigid conductive wall attached at one end and a flexible conductive diaphragm attached at the opposite end, a conductive inner cylinder positioned within said outer shell and rigidly connected at one end to said rigid wall and extending toward said flexible diaphragm and providing lumped capacitance therewith, a fixed capacity-loading element extending between said inner cylinder and said outer shell and fixedly positioned with respect to said cylinder and said outer shell and means for varying said lump capacitance, comprising means connected to said flexible diaphragm for axial adjustment thereof toward said inner cylinder.

6. An ultra high frequency cavity resonator comprising a conductive outer shell having a rigid conductive wall attached at one end and a flexible conductive diaphragm attached at the opposite end, a conductive inner cylinder positioned within said outer shell and rigidly connected to said rigid end wall and extending toward said flexible diaphragm, a fixed capacitance loading element extending between said inner cylinder and said outer shell and fixedly positioned with respect to said cylinder and said shell and providing a large capacitance therebetween and a movable shielding flange connected to said diaphragm and extending radially between said diaphragm and said conductive inner cylinder whereby the direct capacitance between said flexible diaphragm and said inner cylinder is rendered substantially ineffective.

7. Apparatus as in claim 6, wherein said fixed capacitance loading element comprises a conductive cylinder positioned adjacent the inner surface of said outer shell at said opposite end thereof and connected to the end of said inner cylinder adjacent said diaphragm.

8. Ultra-high frequency electron discharge apparatus comprising a conductive cylindrical shell, a flexible conductive diaphragm connected to said shell at one end and having an opening through the central portion thereof, a rigid conductive disc connected to said shell at the other end, a conductive tube coaxially positioned within said shell and fixedly connected to said disc and also extending therefrom substantially the length of said outer shell toward said flexible diaphragm, a fixed capacitance loading element fixedly positioned coaxially with said shell and said tube adjacent said flexible diaphragm through at least part of the radial spacing between said shell and tube, means including a cathode for projecting electrons through said conductive tube substantially parallel with the axis of said shell, and means coupled between said diaphragm and said conductive tube for varying the axial spacing between said flexible diaphragm and said conductive tube for varying the tuning of said apparatus.

9. Ultra-high frequency electron discharge apparatus comprising a conductive cylindrical shell, a flexible conductive diaphragm connected to said shell at one end and having an opening through the central portion thereof, a rigid conductive end wall connected to said shell at the other end, a first conductive tube coaxially positioned within said shell and fixedly connected to said end wall and also extending therefrom substantially the length of said shell toward said flexible diaphragm, a second conductive tube coaxially positioned within said shell and connected to said diaphragm and extending therefrom toward said first conductive tube, a first conductive disc located adjacent one end of said first conductive tube and extending radially to almost contact said shell, said first disc having an axially extending flange positioned at the periphery thereof parallel to and spaced from said shell, a second conductive disc located adjacent one end of said second conductive tube, said first and sec-

and conductive discs forming a variable lumped capacitance, said flange portion of said first disc and the adjacent portion of said shell forming a fixed lumped capacitance, means including a cathode for projecting electrons through said conductive tubes substantially parallel with the axis of said shell, and means for varying the axial spacing between said first and second conductive tubes for varying the tuning of said apparatus.

10. Ultra high frequency apparatus comprising a resonator comprising a conductive outer shell having a rigid end wall and an opposite end wall, a conductive cylinder fixedly positioned within said shell by a connection to said rigid end wall and extending axially within said shell toward said opposite wall to substantially the axial extent of said shell, a fixed capacitance loading element extending substantially between said shell and the end of said inner cylinder adjacent said opposite end wall, and an axial tuning element supported in said opposite end wall and movable for adjustment relative to the adjacent end of said inner cylinder whereby the tuning of said resonator may be varied through a narrow frequency range.

11. Apparatus as in claim 10, wherein said tuning element includes a radially extending conductive flange between said opposite wall and said inner cylinder for electrostatically shielding said opposite wall from said inner cylinder.

12. Ultra high frequency electron discharge apparatus comprising a conductive outer shell having a rigid end wall and an opposite end wall, a conductive cylinder fixedly positioned with respect to said shell by a connection to said end wall and extending axially within said shell toward said opposite wall to substantially the axial extent of said shell, a fixed capacitance loading element extending between said shell and said inner cylinder adjacent said opposite end wall, an axial tuning element movably supported in said opposite end wall for adjustment relative to the adjacent end of said inner cylinder whereby the tuning of said resonator may be varied through a narrow frequency range, a first grid positioned within said tuning element, a second grid positioned in the end of said inner cylinder adjacent said tuning element, and means including a source of electrons positioned coaxially with said inner cylinder and for projecting said electrons through said grids and said inner cylinder for oscillatory coupling therewith.

13. In a velocity variation harmonic generator comprising an ultra high frequency input resonator, an output resonator or positioned coaxially with said input resonator and adapted to be tuned to harmonic relation with said input resonator means including, a cathode positioned adjacent said input resonator for projecting electrons along an axial path through said input resonator and said output resonator in turn, the input resonator comprising a conductive outer shell having a rigid end wall, a conductive cylinder fixedly positioned within said shell by a connection to said end wall and extending axially within said shell to substantially the axial extent of said shell, a fixed capacitance loading element extending between said shell and the end of said inner cylinder opposite said end wall, a second end wall attached to said outer shell adjacent said capacitance loading element, and an axial tuning element supported in said second end wall and movable for adjustment relative to the adjacent end of said inner cylinder whereby the tuning of said

resonator may be varied through a narrow frequency range.

14. A velocity variation harmonic generator as in claim 13 wherein said cathode is positioned adjacent said tuning element for projecting electrons through said tuning element and said inner cylinder in turn whereby said inner cylinder provides an electron drift space.

15. A velocity variation harmonic generator as in claim 14 wherein said cathode is positioned within said inner cylinder for projecting electrons therefrom through said tuning element.

16. An ultra high frequency cavity resonator comprising a conductive outer shell having a rigid conductive wall attached at one end and a flexible conductive diaphragm attached at the opposite end, a conductive inner cylinder positioned within said outer shell and rigidly connected at one end to said rigid wall and extending substantially the length of said shell toward said flexible diaphragm to form an inner conductive surface of said resonator, and means attached to said flexible diaphragm and extending toward said inner cylinder for providing effectively lumped capacitance therewith, said capacitance means including a flange mounted adjacent said diaphragm and adapted to electrostatically shield said flexible diaphragm from said inner cylinder whereby variations of tuning of said resonator due to pressure changes on said diaphragm are suppressed.

17. Ultra high frequency electron discharge apparatus comprising a cavity resonator and means including a cathode positioned coaxially with and adjacent to said cavity resonator for projecting a stream of electrons therethrough; said cavity resonator comprising a conductive outer shell having a flexible wall at one end, a rigid hollow conductive inner member fixed to said shell at the other end thereof and extending toward and adjacent to said flexible wall, conductive means supported at the central portion of said flexible wall and opposite the end of said inner member and defining a resonant-frequency-controlling gap therebetween for traversal by said electron stream, and shielding means adjacent said flexible wall for preventing distortion of said wall from affecting said resonant frequency.

18. Cavity resonator apparatus comprising a conductive outer shell having a flexible wall at one end, a rigid conductive inner member fixed to said shell at the other end thereof and extending toward and adjacent to said flexible wall, conductive means supported at the central portion of said flexible wall and opposite the end of said inner member and defining a gap therebetween, for controlling the resonant frequency of said resonator and shielding means adjacent said flexible wall for preventing distortion of said wall from affecting said resonant frequency, said shielding means comprising a flanged member connected to said flexible wall and between said flexible wall and said inner member.

19. An ultra high frequency cavity resonator comprising a conductive outer shell having a wall at one end, a conductive inner member rigidly connected to said shell at the other end thereof and extending toward said wall, a capacity-loading element extending between said inner member near an end thereof and said shell and rigidly fixed with respect to said member and said shell, and a movable member connected to the central portion of said end wall and defining a variable gap with the inner end of said inner member.

20. An ultra high frequency cavity resonator

comprising a conductive outer shell having a first conductive wall attached at one end and a second conductive wall attached at the other end, an inner conductor coupled to said first wall and extending toward said second wall and providing a lumped capacitance therewith, and a capacity loading member connected to said inner conductor and forming lumped capacitance with said second wall and said outer shell.

21. Apparatus as in claim 20 in which one of said lumped capacitances is variable.

22. Apparatus as in claim 20 in which one of said lumped capacitances is fixed.

23. Electron discharge apparatus comprising an ultra high frequency cavity resonator means including a cathode positioned adjacent to said resonator for projecting a stream of electrons therethrough, and means for coupling a source of high frequency oscillations to said cavity resonator for velocity modulating said stream of electrons; said cavity resonator comprising a conductive outer shell having a wall at one end, a hollow conductive inner member rigidly connected to said shell at the other end thereof and extending toward said end wall, a capacity-loading element extending between said inner member near the end thereof and said shell and rigidly fixed with respect to said inner member and shell, and a movable member connected at the central portion of said end wall and defining a variable gap with the inner end of said inner member.

24. A high frequency cavity resonator comprising a rigid outer shell, an inner member connected to said rigid outer shell and extending axially therewithin, means extending between said inner member and said outer shell for providing fixed effective lumped capacitance therebetween, and further means extending between said inner member and said outer shell for providing variable effective lumped capacitance therebetween.

25. A resonator comprising a conductive outer shell, an inner conductor coaxial with said outer shell and connected therewith, conductive means connected to said inner conductor for providing a fixed lumped capacitance between said outer shell and said inner conductor, and further means extending between said outer shell and said inner conductor for providing variable lumped capacitance therebetween.

26. An electron discharge device comprising a cathode, an output resonator, and an input resonator having a pair of electron-permeable wall portions positioned intermediate said output resonator and cathode, and comprising a pair of rigidly connected coaxial members having rigidly fixed lumped capacitance and variable lumped capacitance therebetween.

27. A resonator device comprising a pair of rigidly connected coaxial members having distributed capacitance, fixed lumped capacitance and variable lumped capacitance therebetween.

28. An ultra-high frequency cavity resonator comprising a conductive outer shell having a first conductive wall attached at one end and a second conductive wall connected to the other end, an inner conductor coupled to said first wall and extending toward said second wall, and a capacity loading means connected to the inner conductor and extending radially to almost contact the outer shell, a part of said capacity loading means forming lumped capacitance with the said outer shell, and a further part of said capacity loading means forming a variable lumped capacitance with said second wall.

29. Apparatus as in claim 28 in which means are provided for varying with a minimum of radial displacement the axial spacing between the end of said inner conductor extending toward said second wall and said capacity loading means.

30. An ultra-high frequency cavity resonator comprising a conductive outer shell having a rigid conductive wall attached at one end and a flexible conductive diaphragm attached at the opposite end, a conductive inner cylinder positioned within said outer shell and rigidly connected at one end to said rigid wall and extending substantially the length of said shell toward said flexible diaphragm to form an inner conductive surface of said resonator, a movable conductive disc spaced from said flexible diaphragm and adjacent the end of said inner cylinder adjacent said diaphragm, and a capacity loading means connected to said one end of said inner conductor and extending almost to the inner surface of said outer shell, a part of said capacity loading means forming fixed lumped capacitance with said outer shell, and a part of said loading means forming variable lumped capacitance with said disc.

31. Apparatus as in claim 30 wherein positioning means having a substantial pivotal point are provided for regulating with a minimum of radial movement the axial spatial separation of said disc and said capacity loading means, the axial distance from the end of said disc to said pivotal point being small, whereby said radial movement is minimized.

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