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CAVITY RESONATOR

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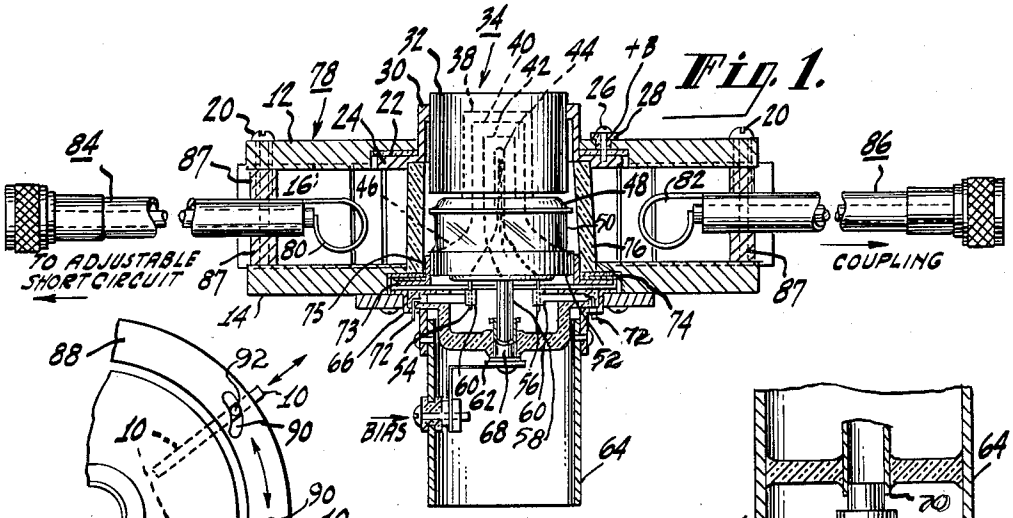


Fig. 1.

Fig. 3.

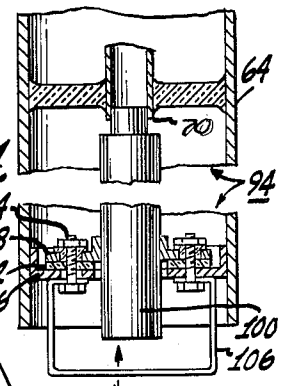


Fig. 4.

Fig. 2.

Fig. 1a.

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CAVITY RESONATOR

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The present invention is related to cavity resonators.

Various cavity resonators are known the resonant frequency of which may be adjusted by various means. One of these means is to vary the size of the resonator itself. However, prior resonators of adjustable size have not been well suited to large scale production with standardized parts. Even where the resonators need not be adjustable, where it is desired to manufacture resonators of different sizes, the manufacturing costs are high because each size resonator must be constructed with component parts especially designed for its own particular size of resonator.

It is an object of the present invention to provide a novel cavity resonator of adjustable size.

A further object of the invention is to provide a cavity resonator which may be made any desired size, within limits, using standard component parts.

Another object of the invention is to provide a cavity resonator symmetrical about a central axis which is readily adjustable in radial dimensions.

A still further object of the invention is to provide a cavity resonator symmetrical about a central axis which may be constructed from standard component parts and which, nevertheless, may be pre-adjusted to any frequency within a desired frequency range.

Another object of the invention is to provide such a cavity resonator especially for use in conjunction with a standard type vacuum tube.

In accordance with the invention, the cavity resonator has two opposed flat metallic walls between which are held a plurality of vanes positioned radially about a predetermined axis and having those edges adjacent the axis preferably straight, parallel to the axis and normal to the opposed flat walls. The vanes may be substantially planar, but other shapes may be employed. The spacing between any vane and that next to it is less than half the free-space wavelength, that is, less than cut-off. Consequently, at their inner edges, that is the edges adjacent the axis, the vanes act as a virtual solid wall. Preferably these internal edges are positioned each at the same radius from the axis, and thus the resonator operates like a resonator having circular symmetry. In one embodiment, the walls may be disassembled, the vanes moved to have their inner edges each at a new radius different from that in their former position, and the structure reassembled. The resonator then resonates at a different frequency, higher or lower according to whether the new radius and the cavity is smaller or larger. Fine tuning may also be provided. The flat metallic walls may have apertures to receive a centrally positioned discharge tube.

The foregoing and other objects, advantages, and novel features of the invention will be more fully apparent from the following description when read in connection with the accompanying drawing, in which like reference numerals refer to similar parts and in which:

Fig. 1 is a cross-sectional view of one embodiment of the invention in which the resonator with a tube inserted is used as a variable reactance;

Fig. 1*a* is a fragmentary top view of a portion of the tube of Fig. 1;

Fig. 2 is a bottom view of the embodiment of Fig. 1;

Fig. 3 is a fragmentary top view of a modification of the embodiment of Fig. 1, permitting easier adjustability of the resonator dimensions; and

Fig. 4 is a longitudinal cross-sectional view of a modification of the lower portion of the arrangement of Fig. 1.

Referring to Figs. 1 and 2, a plurality of planar rectangular vanes **10** are held between a top plate **12** and a bottom plate **14**. The vanes **10** may be received by grooves **16** in the plates into which they slidably fit. The straight inner edges **18** of the vanes **10** are parallel to a predetermined central axis coaxial with the outer circular edge of the plates **12** and **14**. The plates **12**, **14** are held together and in firm mechanical and electrical contact with the vanes by circumferentially spaced screws **20** of which only two appear in Fig. 1. The plates **12** and **14** are centrally apertured to be annular. At its internal edge, an annular dielectric spacer **22**, which may be of mica, is inserted in top plate **12** in an annular depression formed to receive it. An annular coupling plate **24** is held against the mica by screws such as **26** insulated from top plate **12** by dielectric grommets **28**. The coupling plate **24** has spring contact fingers **30** which hold and contact the external metallic cylinder **32** of a tube **34** inserted in the central aperture of top plate **12**. The tube is of a familiar type. A convoluted cooling sheet of metal **36** (see Fig. 1*a*) within the cylinder **34** is welded at many places to a cup shaped anode **38**. Thus the fingers **30** make good electrical contact with the anode **38** through the convoluted metal sheet **36** and the outer cylinder **32**. A screen grid **40** coaxial with and inside the cylindrical portion of anode cup **38** is made of a cage of wires each parallel to the axis, and indicated in dotted outline in Fig. 1. A control grid **42** surrounded by screen grid **40** and also coaxial with the anode **38** cup portion, but which may be wound, is also indicated only in dotted outline. A coaxially positioned oxide-coated cylindrical cathode **44** surrounded by the screen grid is shown in dotted outline. The screen grid **40** cage at its bottom is extended into a solid frustro-conical skirt **46**. A solid anode skirt **48** is extended from the bottom of anode **38** (the open end of the cup). A sealed glass cylinder **50** is sealed at a circumference of the anode skirt **48**. This cylinder is extended to a press (not shown) of the tube. A metallic contacting screen grid cylinder **52** surrounds the press and is connected to the screen skirt **46**, either throughout its circumference or by a suitable lead or leads sealed through the press. Heater leads are brought out to suitable contacts as at pin **54** sealed through the tube **34** press. A cathode lead is also brought out to a pin or pins as at **56**, sealed through the press. The control grid lead is brought out to a pin **58** centrally positioned. The pins such as **54** and **56** are received by connectors such as **60**. The central pin is received by a central connector **62**. A solid cylindrical metallic shield **64**, having its axis aligned with the axis of the tube, is connected through a metallic bushing **66** throughout the shield **64** periphery at one end of the shield to the bottom plate **14**. A lead from the control grid connector **68** which receives the control grid pin **58** is brought out through an aperture in the shield **64** and insulated by a suitable grommet, as shown, for a purpose peculiar to the use to which this arrangement was put.

A dielectric web **70** including supports **69** and which may be pressed of a single piece of such dielectric as polyethylene tetrafluoride (sold under the trade name of Teflon) holds the various connectors such as the central connector **68** and connectors **60**. The non-centrally located pins have leads brought out through the

arms of the web 70 and apertures in the bushing 66 to be readily available as at 72 for the application of desired direct current (D. C.) voltages. An annular capacitive coupling plate 73 is spaced from a rim of the bottom plate 14 by an annular mica spacer 74. The coupling plate 73 contacts the screen grid connecting cylinder 52 with spring fingers 75. A cylindrical spacer 76 of low-loss ceramic dielectric holds the anode annular coupling plate 24 in proper position and prevents accidental contact of screen coupling plate fingers 75 with the bottom plate 14 edges. The use of the dielectric cylindrical spacer 76 is known.

A pair of coupling loops 80 and 82 provide couplings to coaxial line sections 84 and 86 respectively. One line section 84 may be connected to a further line section short-circuited in any suitable known manner at a position of adjustable length from the coupling loop 80. The other line section 86 may lead to a suitable load or be coupled to other circuit elements. The loops 80 and 84 may be adjusted by insertion to any desired extent and also by orientation in any plane as desired before the screws 20 are tightened to hold the line sections in fixed position by blocks 87 which hold the line sections midway between the plates 12, 14. Thus the screws when tightened cause both the vanes 10 and the line sections to be held in place.

Assume a virtual solid metallic wall to lie on a cylindrical surface defined by the inner edges 18 of the vanes 10. The remainder of the cavity resonator 78 of the invention is demarcated at the top from the inner vane edges 18 by top plate 14 and annular anode coupling plate 24, sufficiently closely coupled that little, if any, energy is lost therebetween; by the anode connecting cylinder 32, along its outside surface from the plane of the anode coupling plate 24, the fingers being so close that little energy escapes upward at that point, and in any event at the broad contacts made by the fingers; by the bottom of the convoluted sheet 36, the convolutions being so closely spaced that little energy is lost through them; then by the anode skirt 48, first along the upper and outer surface of anode skirt 48 and then along the inner surface of this skirt 48; and then by the inner surface of the anode 38. At the bottom, from the inner vane edges 18; by the annular screen coupling plate 73 and fingers 75; by the screen grid cylinder 52 and skirt 46; and by the screen grid 40 itself.

In this arrangement the coupling line 86 couples the cavity resonator to an oscillator tank circuit (indicated by legend only). The reactance of the resonator is varied by varying the voltage by a signal on the control grid 40. When the tube is operated with suitable voltages applied to its elements, the signal on control grid 42 causes a variation of the electron stream density in the resonator in the space between screen grid 40 and anode 38. This variation of the electron density varies the effective dielectric constant of the space or medium within the resonator and therefore the reactance of the resonator. The variation in reactance is reflected into the tank circuit to frequency modulate the oscillator.

Now consider the virtual cylindrical wall mentioned above. The virtual wall determines the radius of the resonator. The vanes 10 are arranged normal to the top and bottom plates 12 and 14. In the region of the vanes, the resonator operates in a mode in which the electric vectors are normal to these plates. The vanes 10, however, are spaced apart at less than a half wavelength as measured in the dielectric between the plates. If the dielectric between the vanes is air, as the velocity of waves in free space and air is substantially the same, they are spaced at less than a half free space wavelength, at the inner edges 18 and for some distance outwardly. This spacing between adjacent vanes therefore causes any adjacent pair to behave like a hollow pipe waveguide having dimensions less than the cut-off dimensions for the dominant mode. All the spaces between adjacent vanes 10 are non-resonant at the operating frequency. All of these spaces are open, except for the blocks 87 holding line sections 84 and 86. It may also be observed that preferably the mode of resonance of the cavity resonator is such that the plates 12, 14 are spaced apart less than a half wavelength. Accordingly, waves at the resonant frequency cannot enter and propagate between any adjacent pair of vanes 10. Instead, the waves are reflected at a virtual wall defined by the inner edges of vanes 10. The vanes 10 are not necessarily planar, but should be separated by less than a half wavelength. However, a planar rectangular form for each of vanes 10 is desirable because the vanes then fit into grooves 16 and may more easily than otherwise be positioned as desired. Suppose, for example, that it is desired to decrease the frequency of resonance of the cavity resonator. The tube 34 is withdrawn. The screws 20 are loosened. The vanes 10 are moved outwardly after removal or loosening of the top plate 12, so that the inner edges 18 lie on a new radius. The plates 12, 14 are then tightened to hold by the screws 20 the vanes in place and in contact at their upper and lower edges respectively with plates 12 and 14. If the frequency is to be increased, the radius of inner edges 18 may be made smaller. Preferably, the inner edges are all at the same radii, but each may be independently adjusted. The grooves 16 keep the plates spaced at equal angular distances around the axis, and assist in accurate positioning. If the plates were otherwise than straight and planar at their upper edges, then the grooves could not hold them in radial planes that include the axis and at the same time permit their radial movement.

In one embodiment, the vanes were adjustable between extreme positions to provide a range of resonant frequencies from 650 mc./s. (megacycles per second) to 850 mc./s. The unloaded Q of the resonator was in excess of 300 at selected frequencies throughout the range, including the extremes, and was over 390 at 850 mc./s. This Q could be increased by silver plating all parts. In the embodiment on which these measurements were made, most of the parts, including upper and lower plates, were of brass.

Although the vanes may be held in place as shown, once the desired position for a particular resonant frequency range is known, the parts may be otherwise held in place, as by soldering the vanes at their upper and lower edges to the plates 12 and 14. Therefore, the parts can be manufactured in quantity, and yet assembled for each particular resonator to be resonant at a different resonant frequency. Thus, resonators to be resonant at 850 mc./s may be made of the same parts as resonators to be resonant at 650 mc./s., or any frequency in between. The parts need only be positioned differently in assembly. Moreover, the tube 34 or one of the same size, fits any of these resonators of different resonant frequency.

For a fine tuning control, the short-circuited section of line 84 may be employed. Fine tuning is accomplished by rotating the coupling loop 80, by increasing or decreasing its insertion into the cavity having its virtual wall defined by the inner vane edges 18, or by adjusting the effective short-circuit distance or length of line 84. The effect is to increase or decrease the coupling and quantity of a suitable reactance into the resonator to change by a small amount its resonant frequency. The particular tuning means shown (the variable length line 84 and the coupling variable by orientation of the loop) is known. Other tuning means to provide fine tuning may be employed. Thus, the resonator according to the invention may be employed in conjunction with known tuning means.

Referring to Fig. 3, an alternative embodiment has an annular disk 88 lying in a plane normal to the predetermined axis in the radial planes of which lie the vanes 10. The disk 88 may be mounted in any suitable

manner to rotate about the axis, and has cam slots **90**. Cam followers **92** attached to the vanes **10** ride in the slots **90**. The vanes **10** may be held in contact, as in the embodiment of Figs. 1 and 2, in such a manner that they are readily released.

In the modification of Fig. 3, a change in the resonant frequency of the resonator is accomplished by releasing the plates so that the vanes **10** are loose enough to slip in the grooves **16**, turning the cam plate **88** to move all the vanes **10** in or out together, and again tightening the upper and lower plates **12** and **14** to hold the vanes **10** in their new position in contact with the upper and lower plates **12, 14**.

In Fig. 4, there is illustrated one modification of the arrangement of Fig. 1 so that the arrangement may act as an oscillator. The shield member **64** in Fig. 1 may serve as a conduit for cooling air through the web **70** and the convolutions of sheet **36**. In Fig. 4, the member **64** also serves as the outer conductor of a coaxial line section **94**. This line section **94** may be short-circuited for the radio frequency energy by first and second annular plates **96** and **98**, the plate **96** having spring fingers to contact the outer conductor **64** and the plate **98** having spring fingers to contact an inner conductor **100** coaxial with outer conductor **64**. The plates are separated by an annular mica washer **102**, and the assembly held together by bolts or screws **104** inserted through insulating grommets. Thus, the radio frequency short-circuit arrangement provides D. C. insulation. Suitable D. C. grid bias can then be applied by a connection (not shown) to the inner conductor **100** of line **94**. The short-circuit may be adjusted by a handle **106** to slide to any desired position.

When the line section **94** of Fig. 4 is adjusted to the proper electrical length to be resonant at or near the same frequency as the cavity resonator **78**, and proper D. C. voltages applied to the tube **34**, the arrangement oscillates. Feedback is obtained by the capacity coupling between screen grid **40** and control grid **42**. If this coupling is ineffective or inoperable, other known means of securing the desired feedback in proper phase may be employed. The output may be taken from the line section **86** to a load. The fine tuning line section **84** may be retained, if desired, for fine tuning purposes.

The arrangement of Fig. 4 may be used as an amplifier by coupling into the shorted coaxial line section **94** from the source of the energy to be amplified with a coupling loop or probe (not illustrated) inserted at a suitable point.

It is apparent that the invention discloses a novel cavity resonator, the resonant frequency of which may be readily adjustable over a desired frequency range, or which may be manufactured from parts standardized for its type to resonate at a selected frequency within a given range.

What is claimed is:

1. A cavity resonator comprising two relatively flat disc-like members spaced from and parallel to each other, and a plurality of planar and rectangular plate-like metallic vanes positioned edgewise, spaced from each other, and arranged at substantially equal angular intervals about a predetermined axis normal to said members, one of the two major dimensions of each of said vanes extending radially from said axis, said vanes being held between and in contact with said members, the distance between each pair of adjoining vanes, measured adjacent their inner edges, being less than a half-wavelength at the resonator resonant frequency, whereby the said inner edges define one virtual wall of said resonator completely surrounding said axis, the spaces between the outer edges of adjacent vanes, and also between the inner edges of adjacent vanes, being open.

2. A cavity resonator comprising two relatively flat disc-like members spaced from and parallel to each other, a plurality of planar and rectangular plate-like metallic vanes positioned edgewise, spaced from each other, and arranged at substantially equal angular intervals about a predetermined axis normal to said members, one of the two major dimensions of each of said vanes extending radially from said axis, said vanes being held between and in contact with said members, the distance between each pair of adjoining vanes, measured adjacent their inner edges, being less than a half-wavelength at the resonator resonant frequency, whereby the said inner edges define one virtual wall of said resonator completely surrounding said axis, the spaces between the outer edges of adjacent vanes, and also between the inner edges of adjacent vanes, being open; and means for adjusting radially the position of at least one of said vanes, thereby to adjust the position of its inner edge.

3. A cavity resonator comprising two relatively flat disc-like members spaced from and parallel to each other, a plurality of planar and rectangular plate-like metallic vanes positioned edgewise, spaced from each other, and arranged at substantially equal angular intervals about a predetermined axis normal to said members, one of the two major dimensions of each of said vanes extending radially from said axis, said vanes being held between and in contact with said members, the distance between each pair of adjoining vanes, measured adjacent their inner edges, being less than a half-wavelength at the resonator resonant frequency, whereby the said inner edges define one virtual wall of said resonator completely surrounding said axis, the spaces between the outer edges of adjacent vanes, and also between the inner edges of adjacent vanes, being open; and means for simultaneously adjusting radially the positions of all of said vanes, thereby to adjust the positions of the inner edges of said vanes.

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