Oct. 29, 1946. J. C. SCHELLENG 2,410,109

VARIABLE CAVITY RESONATOR

Filed Feb. 13, 1943

FIG. 1

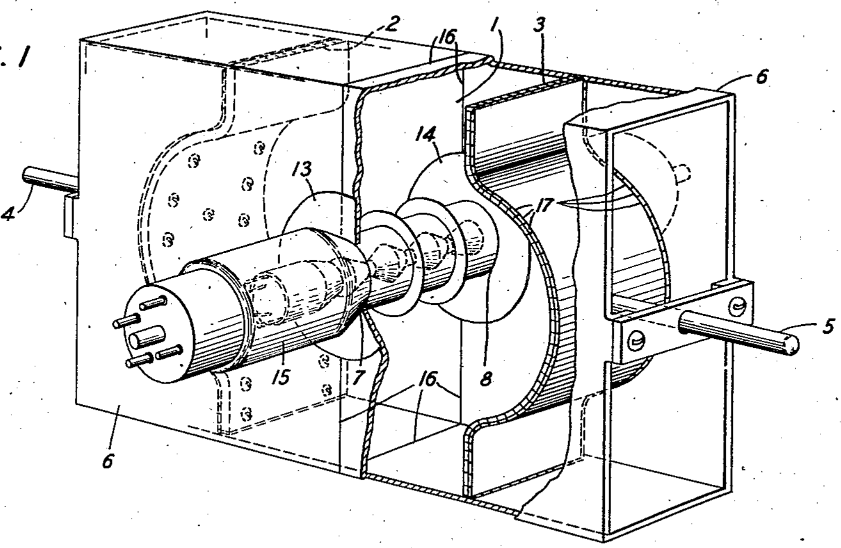


FIG. 2

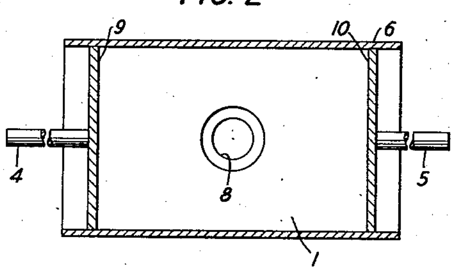


FIG. 4

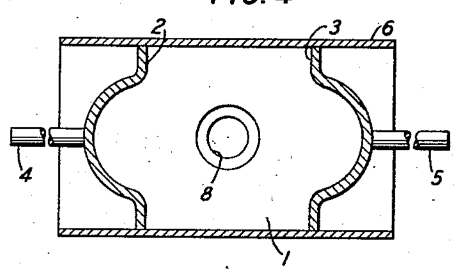


FIG. 3

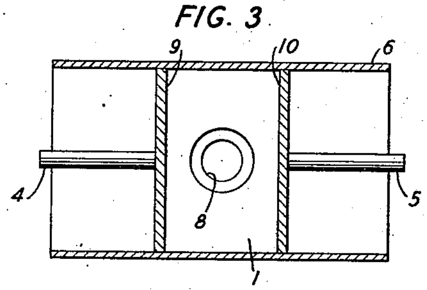


FIG. 5

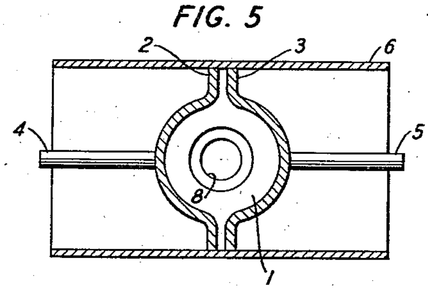
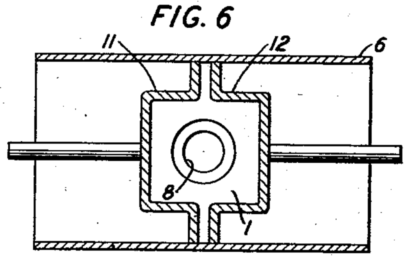


FIG. 6



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VARIABLE CAVITY RESONATOR

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13 Claims. (Cl. 178—44)

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This invention relates to cavity type electrical resonators sometimes termed space resonators and particularly to such resonators with dimensions variable for the purpose of changing the resonant frequency.

A principal object of the invention is to provide such a resonator adjustable over a relatively wide range of frequency.

Another object is to provide such a wide range cavity resonator that is simple of adjustment.

Another object is to retain in such a resonator optimum conditions for coupling between the high frequency field of the resonator and an electron stream passing therethrough.

In ultra-high frequency devices electrical circuits of the cavity or space resonator type present advantages on account of their low electrical losses and the fact that they completely enclose and thereby shield the high frequency field, thus preventing unwanted radiation. A disadvantage of some forms of cavity structure is that they are non-adjustable, and being usable only at a single frequency must be replaced when it is desired to operate at a different frequency. A small amount of adjustment is often provided such as by varying the amount a metallic tuning member projects into the interior space of the resonator or by changing the volume of the resonator by flexing a portion of its boundary or shell. Such adjustments are for tuning purposes and provide relatively little change in the resonant frequency. A greater change in resonant frequency is sometimes had by moving a side wall of the resonator like a piston in a cylinder. One or more walls may be moved so that the resonator dimension in the direction of wall movement is changed thereby changing the resonant frequency.

A considerable range of adjustment of the resonant frequency is possible with the usual movable wall type of resonator just described. However, it is sometimes desirable to make available a still greater range of adjustment such as may be required in apparatus designed to operate over a wide range of frequency and be adjustable continuously over that range.

Such a greater range of adjustment is obtained according to this invention by the use of movable walls so shaped that as they are moved in a single direction two dimensions of the resonator are changed. In this manner the ratio between the maximum and minimum volumes of the cavity is made large and a corresponding large ratio between the maximum and minimum frequencies is obtained.

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A more complete understanding of the invention may be had from the following description and the accompanying figures, of which:

Fig. 1 is a general view of a typical cavity resonator incorporating features of the invention and showing a method of mounting an electron tube for the purpose of passing an electron stream through the resonator.

Figs. 2 and 3 show, in section, a conventional movable plunger type of cavity resonator with the plungers in the positions for minimum and maximum frequencies respectively.

Figs. 4 and 5 show, in section, a cavity resonator typical of the invention with the plungers in the positions for minimum and maximum frequencies respectively.

Fig. 6 is similar to Fig. 5 but shows an alternative plunger shape.

In Fig. 1 the cavity resonator space 1 is bounded by the walls of the rectangular tubular member 6 and the plungers 2 and 3, all of conducting material. The plungers make sliding contact with the inner surface of the tubular member through the flexible fingers 17 and are movable toward and away from each other along the axis of the tubular member by any suitable means through the rods 4 and 5 connected to them. The openings 7 and 8 are to permit the insertion of means for passing an electron beam through the cavity space to interact with a high frequency electric field therein and thereby effect a transfer of high frequency energy between the electric field and the electron stream. In practice the openings may permit the insertion of an electron tube through the space of the resonator, such as in the manner shown in Fig. 1 where 15 represents a three gap electron gun generally similar to the two gap electron gun shown in Figs. 1 and 5 of the copending application No. 386,794, filed April 4, 1941, by A. E. Anderson and A. L. Samuel. In this copending application an arrangement of the electron gun with a cavity resonator is shown in Fig. 1 and the circuit is shown in Fig. 5. These showings are typical only as the present invention is applicable to different types of cavity resonators which may be associated with different types of electron tubes and circuits. Furthermore, resonators according to the invention may be used in circuits independently of electron tubes as variable circuit elements. The member 6 of Fig. 1 is split along the line 16, in the plane of the axis of the electron tube and the centers of the openings 7 and 8 to permit separating the two split parts of member 6 for insertion of the tube. When the tube is in place the two parts of member 6 are clamped together by a suitable means for maintaining good electrical contact along the line 16. The large discs 13 and 14 are of electrically conducting material and connect with electrodes in the tube. They effectively form part of the shell of the resonator, being clamped to member 6, and close the space around the tube in the openings 7 and 8.

The purpose of the clamping of the various shell members and of the flexible fingers 17 on the movable members 2 and 3 is to maintain low impedance high frequency paths throughout the boundary of the resonator and so enclose the space and the high frequency field within as completely as possible during operation and throughout adjustment of the movable members. Some openings in the shell are unavoidable such as those for injection of the electron stream, the introduction of leads for power supply or high frequency coupling and those due to mechanical imperfections. The term substantially closed will therefore be used in describing the cavity resonator to indicate that the shell is completely closed except for such necessary openings.

It will be noted that the surfaces of the plungers 2 and 3 facing each other are not flat or simply curved but are shaped so that substantially flat portions along the edges parallel to the line of the openings 7 and 8 may come close together, practically in contact, over a substantial area when the plungers are moved to the positions nearest each other while the curved portions extending along the center parallel to the line of the openings 7 and 8 clear the space required by the electron tube and with the portions of the tubular member near the openings 7 and 8 enclose a relatively small space around the position of the electron stream. This is the minimum size of the cavity resonator determining the maximum resonant frequency. It will be seen that the volume of space in this minimum size resonator can be made relatively small so that the ratio between that and the maximum size resonator (that obtained when the plungers are the maximum distance apart) can be made large thereby providing a relatively large range of frequency adjustment. A comparison between the use of conventional flat surface plungers and the shaped surface plungers in accordance with the invention is illustrated by Figs. 2 and 3 and Figs. 4 and 5. These figures show sections along the axis of the tubular member and perpendicular to the line of the openings 7 and 8. Figs. 2 and 3 show respectively the minimum and maximum frequency positions of the flat surface plungers 9 and 10 and Figs. 4 and 5 show respectively the corresponding minimum and maximum frequency positions of the shaped surface plungers. It is readily apparent that the ratio of volumes and therefore the range of frequency variation is greater in the case of the shaped surface plungers of Figs. 4 and 5 which are like those illustrated in Fig. 1.

The shaped plungers need not be of the exact curved shape shown in Figs. 1, 4 and 5. For example an alternative shape is shown in Fig. 6. The important feature is that substantially flat portions along the edges parallel to the electron stream come close together in the minimum volume position in a manner to close off part of the cavity space and effectively reduce a cavity dimension other than the dimension in the direction of movement of the plungers while the central portions are apart to clear the electron stream path.

While not essential it is desirable that two movable plungers be employed so that the cavity space is always symmetrical with respect to the position of the electron stream.

The volume variation and corresponding resonant frequency variation between the plunger positions of Figs. 2 and 3 may of course be increased by simply moving the flat surface plungers farther apart in Fig. 2. This expedient, however, is not the equivalent of increasing the range by shaping the plungers according to the invention as illustrated in Figs. 4 and 5 (also in Figs. 1 and 6). In the case of simply moving the plungers farther apart there is a practical limit to the minimum frequency attainable because after a certain amount of separation of the plungers the frequency changes relatively slowly as the separation is increased. In the use of the shaped plungers advantages accrue because the maximum frequency (minimum cavity volume) is determined to a great extent by the size of the recess in each plunger which permits the use of a relatively large total plunger area and correspondingly large transverse dimensions of the tubular member of the cavity shell which then in turn requires relatively small separation of the plungers for the minimum frequency (maximum cavity volume). Thus the shaped plunger type of resonator has characteristics at both ends of the frequency range which make it advantageous where a large range of adjustment is required.

What is claimed is:

1. A substantially closed electrically resonant cavity of which the resonant frequency is dependent upon its dimensions and which has a rigid portion of the cavity shell movable, plunger-like, back and forth in opposite directions to vary the dimensions and thereby the resonant frequency of the cavity, the resonant frequency being determined by the position of the movable shell portion and the contour of the inner surface of the shell portion being such that when that portion is moved from one extreme position to the other extreme position at least two of the three orthogonal principal dimensions of the cavity are effectively changed to cooperate in changing the resonant frequency thereof.

2. A space resonator, the resonant frequency of which is dependent upon two of its principal dimensions which are at right angles, electrically conducting walls substantially enclosing the space within the resonator, rigid portions of the walls being movable over a range of adjustment in the direction of one of the said two dimensions to alter the resonant frequency and the volume of the enclosed space, and the internal faces of the movable wall portions being so shaped that within the range of adjustment the resonant frequency and the volume of the enclosed space are altered by changes in both of the two said dimensions which are effective in determining the resonant frequency.

3. A substantially closed electrically resonant cavity of which the resonant frequency is dependent upon two of its three orthogonal principal dimensions and having a portion of the enclosing wall movable along the direction of one of the said two dimensions between a position of maximum cavity volume and a position of minimum cavity volume, the movable portion of the wall being so shaped that when it is moved from the maximum volume position to the minimum volume position both of the said

dimensions effective in determining the resonant frequency are reduced.

4. A substantially closed electrically resonant cavity of which the resonant frequency is dependent upon its dimensions having a rigid portion of the cavity wall movable back and forth to vary the volume of the cavity in which the contour of the inner surface of the movable wall portion is such that when it is moved from the position of maximum cavity volume to the position of minimum cavity volume at least one dimension in a direction other than the direction of motion of the movable wall portion is effectively reduced to alter the resonant frequency.

5. A substantially closed electrically resonant cavity of which the resonant frequency is dependent upon it dimensions having a rigid portion of the cavity wall movable back and forth along a line of direction to vary the volume of the cavity and its resonant frequency in which the inner surface of the movable wall portion is such that when it is moved from the maximum volume position to the minimum volume position the cavity dimension along the said line of direction is reduced and also another cavity dimension in a direction perpendicular to the first said line of direction and upon which the resonant frequency of the cavity is dependent is effectively reduced as a frequency determining factor.

6. An electrically resonant cavity arranged to be excited by an electron stream projected therethrough along a certain path, at least one wall of the cavity extending in directions generally parallel to the path of the electron stream being movable toward and away from the path in directions generally perpendicular to the path to vary the volume of the cavity space and having a contour in a section perpendicular to the path such that when it is moved from the position of minimum cavity volume all of the cavity dimensions perpendicular to the path are effectively increased.

7. In combination with an electron tube a substantially closed electrically resonant cavity having a portion of the enclosing wall movable between a position of maximum cavity volume and a position of minimum cavity volume, the movable portion of the wall being so shaped that when it is moved from the maximum volume position to the minimum volume position two of the three orthogonal principal dimensions of the cavity are effectively reduced, one of the said two dimensions being in the direction of motion of the movable wall portion and the other being in a direction at right angles thereto.

8. An electrically resonant cavity comprising two piston like side walls in contact with and slidably movable within a tubular shaped member which together with the tubular shaped member enclose the cavity space and are movable to vary the volume and resonant frequency of the cavity, the inner surfaces of the movable walls facing each other and having contours tours such that if moved to the position of minimum cavity volume and maximum resonant frequency central portions of the surfaces are spaced apart substantially and enclose a space determining the resonant frequency of the cavity while other substantial portions of the surfaces are sufficiently close together that the space between is negligible, having substantially no effect in determining the volume and resonant frequency of the cavity.

9. A variable frequency substantially closed space resonator of a type in which the resonant frequency varies inversely as the volume of the enclosed space and is dependent upon two of its orthogonal principal dimensions, comprising electrically conducting walls substantially enclosing the resonator space, at least one wall portion being movable over a range of adjustment to vary the resonant frequency and the volume of said enclosed space, the volume increasing as the frequency decreases and decreasing as the frequency increases, and the internal face of at least one wall portion being so shaped that within the range of adjustment the resonant frequency and the volume of the enclosed space are varied by effective changes in both of the two said orthogonal dimensions upon which the resonant frequency is dependent.

10. A substantially closed electrically resonant cavity which has a rigid portion of the cavity shell movable, plunger like, to vary directly a first dimension of the cavity along the first of three orthogonal axes, the contour of the cavity shell being such that the distance between the interior surface of the said movable shell portion and the interior surface of an opposite shell portion in the direction of the said first dimension is less at points removed from the center of the cavity along a second orthogonal axis than at points in the central portion of the cavity, whereby, at the extreme where the said first dimension has its smallest value there are portions of the cavity space removed from the center along the said second orthogonal axis, and between the said movable shell portion and the said opposite shell portion, which are made narrow in the direction of the said first dimension and are thereby effectively shielded electrically from the wider space between the same said shell portions in the said central portion of the cavity and eliminated as a factor determining the effective dimensions of the resonant cavity, while at the extreme where the said first dimension has its greatest value the said portions of the cavity space removed from the center, and narrow in the first said extreme, are widened in the direction of said first dimension and are thereby effectively coupled electrically to the also widened said wider space in the center of the cavity and made an effective part of the resonant cavity whereby at the second said extreme as compared with the first said extreme the cavity size is effectively greater in the direction of the said second axis as well as in the direction of the said first axis.

11. A resonant cavity according to claim 10 in combination with means for producing electrical oscillations therein with a mode of oscillation such that the main components of the electric vector inside the cavity are parallel to the third of the said three orthogonal axes.

12. A resonant cavity according to claim 10 in which the frequency of resonance varies inversely as the dimension along the said second orthogonal axis whereby the shielding of the said space removed from the center along that axis has the effect of increasing the frequency of resonance.

13. A substantially closed electrically resonant cavity the resonant frequency of which is variable inversely with the volume of the enclosed space and having its volume adjustable between positions of maximum and minimum by the movement of at least one of two opposite portions of the enclosing wall to vary the separation

of the two interior surfaces of the said wall portions, the interior surface of at least one of the said wall portions being other than planar and so shaped that over the entire range of volume adjustment a part of its area is more distant from an opposite area of the interior surface of the other said wall portion than are other parts of its area and such that in the minimum volume adjustment the said other parts of its area are close to the interior surface of the said other wall portion whereby the intervening space is electrically shielded from and thereby is effectively cut off from the cavity space remaining between the said more distantly apart surface areas and is ineffective in determining the volume and resonant frequency of the cavity and such also that in the maximum volume adjustment the same said other parts of area are separated from the interior surface of the said other wall portion whereby the intervening space is intimately joined with the space between the said more distantly apart surface areas to make up the total volume of enclosed space, is an appreciably large proportion of the total enclosed space and is thereby effective in determining the resonant frequency of the cavity.

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