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CAVITY RESONATOR MODE SUPPRESSION MEANS

Filed June 29, 1946

2 SHEETS—SHEET 1

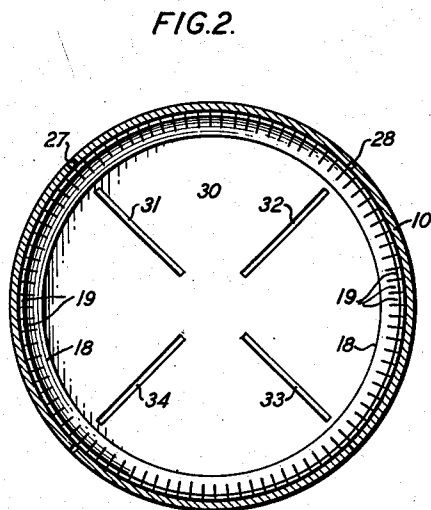
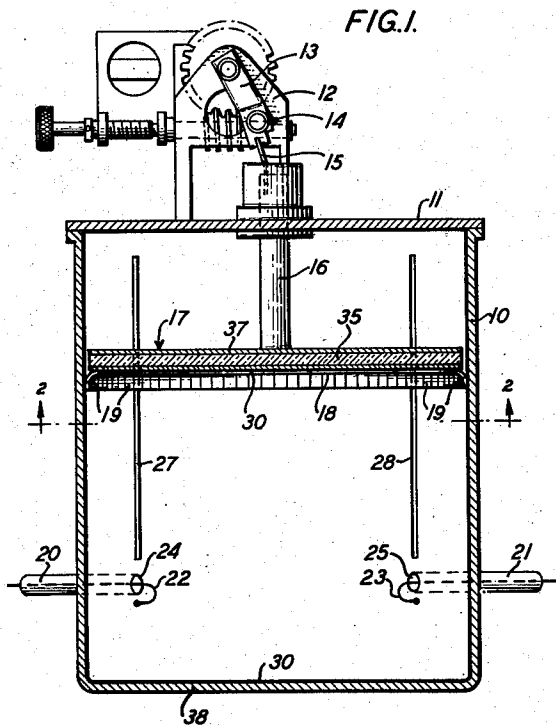


FIG. 3.

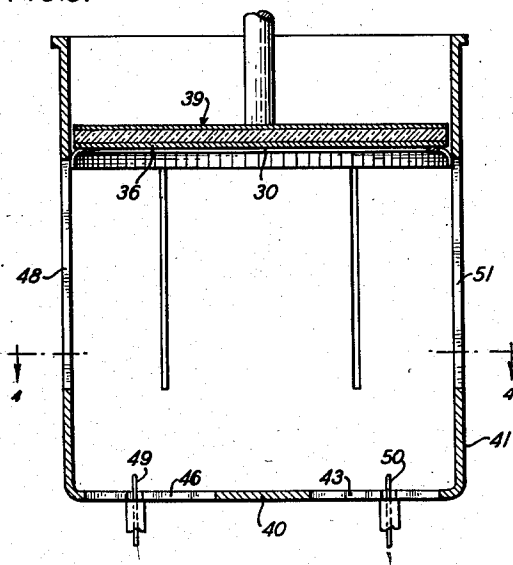
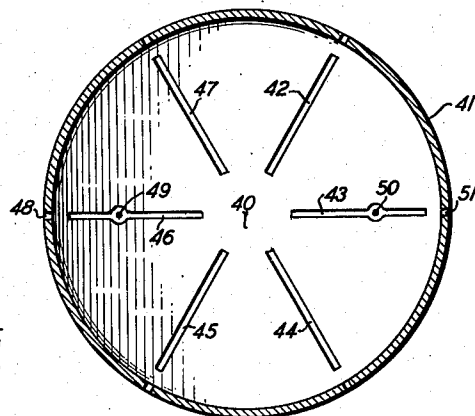


FIG. 4.



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FIG. 5.

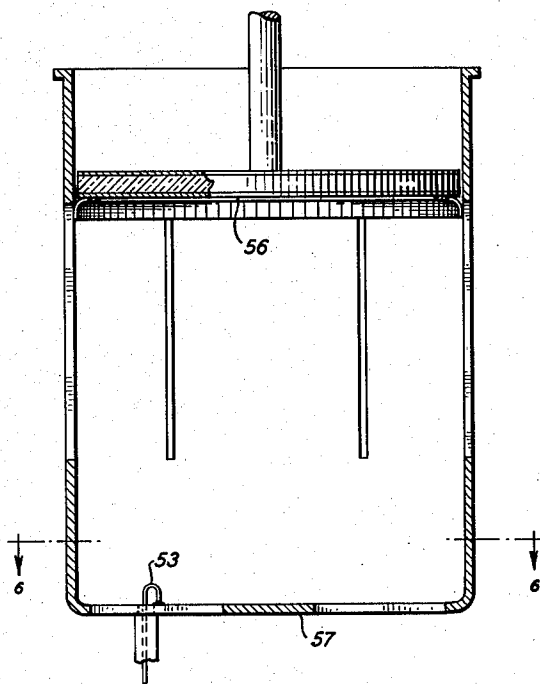
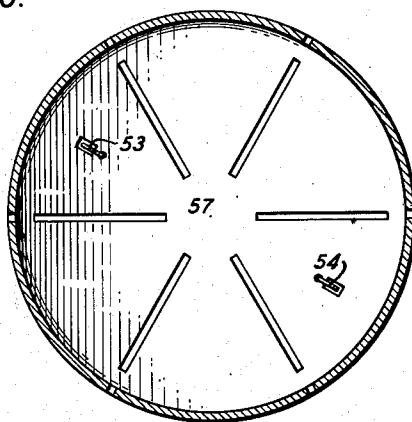


FIG. 6.



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CAVITY RESONATOR MODE SUPPRESSION
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6 Claims. (Cl. 178-44)

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This invention relates to cavity resonators and more particularly to suppression of unwanted modes of oscillation in such resonators.

Objects of the invention are to improve the Q or selectivity characteristic of the resonator, to enable discrimination between two sets of oscillations of substantially the same frequency but of different modes, and to render more stable the performance of a cavity resonator having a variable position end wall or variable tuner so designed as to provide the desired selectivity and discrimination.

Two generally distinct classes of oscillations which may occur in cavity resonators of cylindrical type are known respectively as transverse magnetic, TM, and transverse electric TE. The transverse magnetic class is characterized by magnetic fields which extend in planes perpendicular or transverse to the cylindrical axis, the transverse electric class by electric fields which exist only in planes perpendicular to the cylindrical axis.

In accordance with one embodiment of the invention a tunable cavity resonator which may be of cylindrical chamber conformation to be used for TM mode oscillations may be provided with a tuning piston serving as one end of the resonance chamber. The interior surfaces of the cylindrical chamber and of the movable end wall may all be of highly electrically conductive material. The tuning piston of the resonator may be constructed as a sandwich consisting of a plate of dielectric material between two metallic coatings or thin sheets. In order to discriminate between the longitudinal and radial electric vectors of the TM oscillations on the one hand and the transverse and circumferential electric vectors of TE modes of oscillation, on the other hand, longitudinal slots may be cut entirely through the cylindrical wall of the resonator for a portion of its length and similar radial slots may be provided through the end plates of the resonator. This brings about a relatively high discrimination in favor of the oscillations of TM mode and against the oscillations of the TE mode, the electric vector paths of which are intercepted by the slots in the cylindrical walls and end walls of the resonant chamber.

In the drawing, Fig. 1 presents in a vertical section the structure of a cylindrical cavity resonator constituting one embodiment of the invention;

Fig. 2 is a horizontal section of the structure of Fig. 1 along the plane of broken line 2-2 viewed in the direction of the arrows;

Fig. 3 is a vertical section of a cylindrical cavity resonator similar to that of Fig. 1 but which is operated in a different transverse magnetic mode of oscillation;

Fig. 4 is a horizontal section of the structure of Fig. 3 taken at the plane indicated by the dash lines 4-4 looking in the direction of the arrows;

Fig. 5 presents a modification of the structure of Fig. 3; and

Fig. 6 is a section along the horizontal plane through line 6-6 of Fig. 5.

Referring to Fig. 1, the cylindrical structure 10 having at its open upper end a closure or cover 11 may consist of any suitable rigid structural material provided that the interior surfaces of the resonant chamber are highly electrically conductive. A manual tuning control mechanism 12 on the cover 11 serves through a connection from the crank arm 13 to the pivotally mounted crosshead 14, the flat spring 15 and a piston rod 16 to vary the position of a tuning piston 17 supported by the piston rod 16 and fitting closely within the cylindrical portion 10 of the resonator. The lower surface of the piston face is provided with a peripheral annular plate 18 of spring metal slotted transversely along one margin and attached in any desired manner to the piston. The slotted margin is flared outwardly and presents a closely spaced array of flat curved contact fingers 19 which engage the cylindrical wall in sliding contact relation to maintain good electrical contact between the piston and the cylindrical walls. The spring fingers 19 substantially close the peripheral gap about the piston 17 from an electromagnetic standpoint so far as the desired TM mode oscillations are concerned. However, the slits between the fingers present a certain dissipative leak for the fields of transverse electric modes of oscillation.

Input and output coaxial circuits 20 and 21 respectively terminate in coupling loops 22 and 23 which pass through apertures 24 and 25 in the cylindrical wall of the resonator 10 and are electrically connected to the inner wall.

When oscillation energy of a natural frequency of a TM resonance of the cavity resonator is supplied to the internal field space of the resonance chamber by coupling loop 22 the resulting TM mode field presents electric vectors which extend longitudinally of the resonator between the nodal planes parallel to the end plates and which extend radially in the region of the nodal planes. The field of any oscillations of transverse electric mode oscillations which there is a tendency to excite within the resonator presents electric vectors which lie wholly within planes

transverse to the longitudinal axis of the resonator and have a configuration such as to be intercepted by radii in these respective planes. Advantage is taken of these facts to impose high attenuation for oscillations of the unwanted transverse electric mode by cutting entirely through the wall of the resonator equidistant slots parallel to the longitudinal axis of the resonator and extending for a considerable portion of the length of the resonator. Two of these slots 27 and 28 appear in Fig. 1 and it will be noted that their planes are substantially aligned respectively with the planes of coupling loops 22 and 23. Since the slots 27 and 28 are parallel to the direction of the longitudinal electric vectors of the transverse magnetic mode oscillations they will impose little attenuation for these transverse magnetic oscillations. However, transverse electric vectors directed in general in loops in planes perpendicular to the slots will tend to set up differences of potential across the slots thus giving rise to a leakage of the field with consequent attenuation of these transverse electric oscillations. The two opposing electrically conductive surfaces constituting the end boundaries of the resonator determine nodal planes between which the transverse electric vectors lie.

The apparatus of Fig. 1 may serve as a variable frequency electric selector to receive microwaves from circuit 20 and to select those of its own natural resonance frequencies and to discriminate strongly against those of undesired modes and frequencies. It may be used to analyze the spectrum of a complex wave by selecting in turn, as its tuning piston moves, the components of the band of frequencies through which the tuning mechanism enables it to respond. It may be especially useful as a phantom target or "echo box" for a radar system in which outgoing pulses from the radar transmitter may be impressed upon the resonator through input circuit 20 and the resulting electromagnetic field built up within the resonator may upon cessation of each transmitter pulse return a protracted train of microwaves to enable tuning and testing the radar receiver as well as checking up on the performance of the radar system as a whole.

Fig. 2 illustrates an expedient for increasing the attenuation suffered by the transverse electric oscillations. As shown in that figure, the metallic end surface 30 of the piston 17 which may consist of a thin copper aluminum or silver plate is cut through along radial lines as indicated at 31, 32, 33 and 34. Consequently, electric vectors of transverse electric oscillations in the region of the nodal plane tend to set up potential differences between the opposite margins of the slots 31, 32, etc. with a resulting tendency for leakage of the transverse electric field into the dielectric disc 35 which constitutes the main central portion of the movable piston 17. The dielectric substance serves to substantially attenuate the transverse electric field. It also serves as the structural support for the electrically conductive surface 30. Under conditions of heat and moisture there may be a tendency for the piston 17 to be warped. Any such effect which disarranges the nice parallelism which should obtain between the conductive end surfaces 30, 30' may seriously distort and reduce the desired oscillation field within the intervening space. In order to prevent such warping or distorting the piston 17 is provided with a back metallic plate 37 which tends both to stiffen the piston 17 as

a whole and prevent warping and also serves to preclude entrance of moisture into the piston structure with its consequent inimical effects. It will therefore be apparent that the sandwich construction of the piston 17 permits advantage to be taken of the lower mass which a dielectric structure may possess, of the energy-dissipating characteristic of the dielectric for the transverse electric field to which it is subjected through the slots 31 to 34, and the increased rigidity which the composite structure possesses. If desired, the lower end 38 of the resonance chamber 10 may be slotted radially in a manner entirely analogous to the lower conducting surface 39 of the piston 17.

The radial cuts in the conducting surface of the end plates have maximum effectiveness in suppression of such transverse electric oscillation modes as $TE_{11\pi}$, $TE_{12\pi}$, $TE_{13\pi}$ when the radial cut is directly over a coupling loop. For other positions of the slots the effectiveness for each mode family will diminish to a minimum when the coupling loops are positioned halfway between the adjacent slots.

The particular dielectric material to be used in the piston may depend upon such considerations as mass, freedom from moisture, and cost of manufacture. Among materials which may be used for this purpose are discs of wood and phenol fibre. Conducting faces 30 utilize any highly electrically conductive material in the form of a thin plate or of an electrodeposition or coating. The inner surface of the cylindrical wall of the resonator 10 may be made highly electrically conductive in the same manner. It is preferable, however, that the metallic back plate 37 have sufficient thickness to impart the necessary rigidity to the piston structure as a whole in order to preclude buckling or warping.

Figs. 3 and 4 disclose a modification of the structure of Figs. 1 and 2 in which the tuning piston except for the radial slots in the end surfaces and the specific form of coupler used may be identical with that of Fig. 1. In this embodiment the integral lower end 40 of the cylinder 41 which serves as the lower electrical boundary of the resonant chamber has an upper surface made highly conductive by a plating or deposition of silver, copper or other good conducting material. As is indicated in Figs. 3 and 4 the end 40 is slotted entirely through in radial directions as at 42, 43, 44, 45, 46 and 47. The lower conducting surface 36 of the piston 39 may be slotted in an analogous manner.

This structure presents little dissipation to modes of oscillation in which the electric vectors are entirely radial but acts to selectively suppress all modes of the TE_0 type and other TE modes which have electric vectors which must pass transversely to a radial slot of the end plate 40 or an aligned longitudinal slot 48 of the cylindrical wall of cylinder 41. The structure of Figs. 3 and 4 could support oscillations of TE_3 mode as, for example, TE_{312} and of TM_3 mode as, for example, TM_{312} . Which of the two is selected largely may be determined by the nature and positioning of the coupling element. For example, with probe couplers such as 49 and 50 positionally aligned with radial slots 46 and 43 and longitudinal slots 48 and 51 and extending longitudinally into the field the system may be excited in TM_3 mode of oscillations one of the couplers 49, 50 serving as input and the other as output transducer. The structure of Figs. 3 and 4 may be modified as in Figs. 5 and 6 to

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utilize magnetic loop couplers 53 and 54 positioned midway between radial slots and with their principal planes generally perpendicular to the slots and hence parallel to the electric vector of the TM_z mode oscillations. In the instance of the loop the couplers should be located at positions of substantial field intensity and hence should be separated electrically from the outer conducting walls and from the internal nodal surfaces. In the instance of the probe couplers for TM_z mode oscillations the preferable position is at a point one-third of the radius or two-thirds of the radius from the center.

In Fig. 5 the lower metallic surface or coating 56 may be slotted in the same manner as the lower end 57 of the resonator chamber.

The vertical slots in the cylindrical walls extend over the central portion of the length of these walls. This leaves the lower portions of the resonators free for introduction of couplers where desired.

What is claimed is:

1. A high Q cavity resonator comprising a cylindrical chamber having electrically conductive surfaces bounding the space therewithin, means for initiating natural resonance frequency oscillations of TM modes within the chamber, an end wall of said chamber having radial slits therethrough to attenuate and inhibit unwanted extraneous oscillations of TE modes, said slits having potential differences for TE_{01n} modes set up between opposite margins thereof.

2. A high Q cavity resonator comprising a cylindrical chamber having electrically conductive surfaces bounding the space therewithin, means for initiating natural resonance frequency oscillations of a TM mode within the chamber, an end wall of said chamber having slits extending along the central portions of radii of said wall and having an oscillation energy transfer element extending through the opposite end wall at a position aligned with one of said slits.

3. A high Q cavity resonator comprising a cylindrical chamber having electrically conductive surfaces bounding the space therewithin, an end wall of said chamber being movably mounted with respect to the remainder of the chamber and one of the end walls of said chamber having slits therethrough extending in radial directions.

4. A cylindrical cavity resonator of electrically conducting material, means for initiating there-within oscillations of a desired mode, one end of the resonator comprising a disc of extraneous

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mode absorbing dielectric material having a conducting surface facing the resonator and a stiffening plate physically connected to the disc of dielectric material on its surface remote from the resonator to prevent warping, slits in said surface converging toward a common center for suppressing TE modes.

5. A high Q cavity resonator comprising a chamber having conductive surfaces bounding the space therewithin, means for exciting natural resonance frequency oscillations within said chamber, an end wall of said chamber being adjustable to tune said resonator, said end wall comprising a disc of attenuating dielectric material and two opposed conductive plates in flush contact with said dielectric material, and radial mode suppressing slits in one of said plates for producing leakage of extraneous modes into said dielectric.

6. A high Q cavity resonator comprising a cylindrical chamber having electrically conductive surfaces bounding the space therewithin, means for initiating natural resonance frequency oscillations of TM modes within the chamber, a wall of said chamber having longitudinal slits therethrough parallel to the electric vector of the TM mode oscillations to attenuate and inhibit unwanted extraneous oscillations of TE modes, and a tuning piston movable in said resonator, said piston having TE mode suppression slits radially disposed thereon, said radial slits being aligned with a plane containing said wall slits, said radial slits leaving the TM modes substantially unattenuated.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,151,118	King	Mar. 21, 1939
2,197,122	Bowen	Apr. 16, 1940
2,233,263	Linder	Feb. 25, 1941
2,267,289	Roosenstein	Dec. 23, 1941
2,283,568	Ohl	May 19, 1942
2,417,542	Carter	Mar. 18, 1947
2,428,287	Linder	Sept. 30, 1947
2,439,388	Hansen	Apr. 13, 1948
2,449,855	Marholz	Sept. 21, 1948
2,471,419	Edson et al.	May 31, 1949
2,500,417	Kinzer	Mar. 14, 1950