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CAVITY RESONATOR

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2,593,234

FIG. 1.

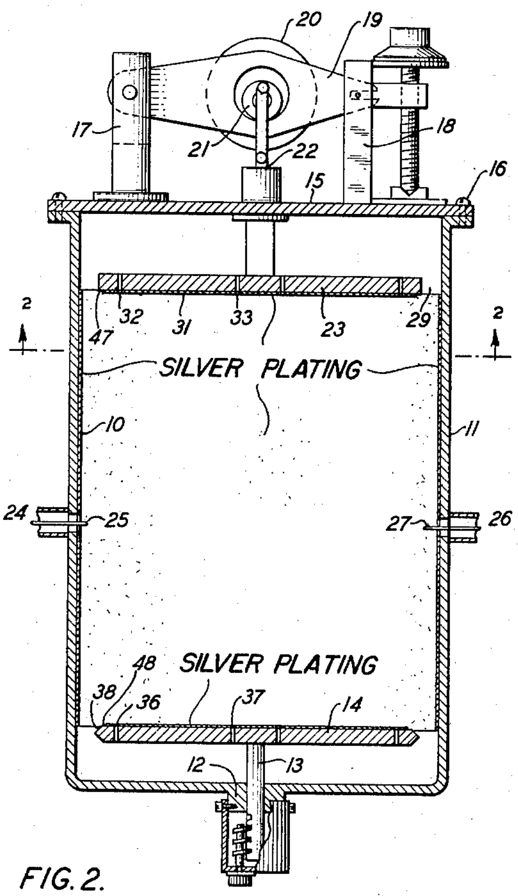


FIG. 4.

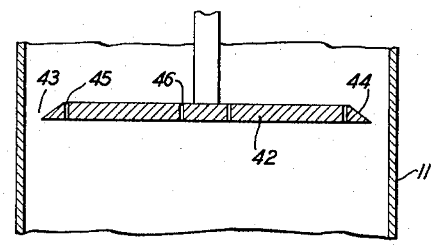


FIG. 5.

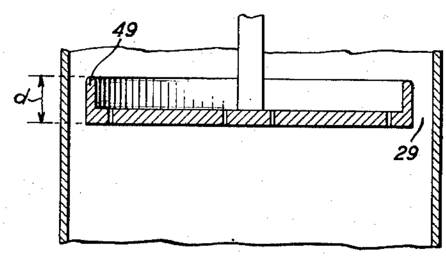


FIG. 2.

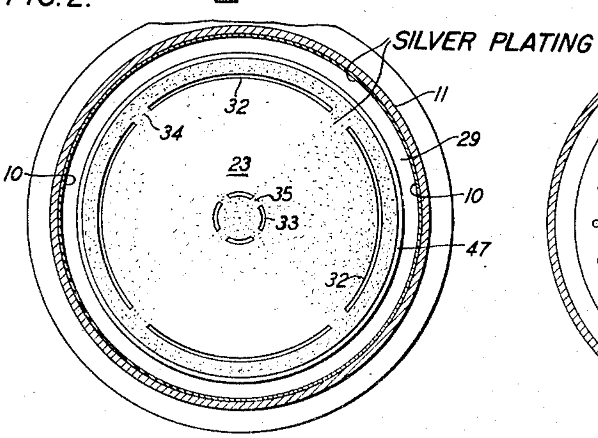
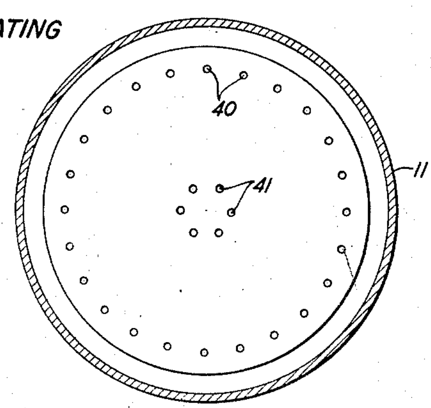


FIG. 3.



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CAVITY RESONATOR

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4 Claims. (Cl. 178—44)

This invention relates to selective electrical devices and more particularly to cavity resonators.

An object of the invention is to provide a cavity resonator which will have a high Q.

Another object of the invention is to provide a cavity resonator which may respond to oscillations of a desired transverse electrical mode and may discriminate strongly against oscillations of the same frequency of a transverse magnetic mode.

Another object of the invention is to provide a tunable cavity resonator which may oscillate at a single mode only within its tuning band at each setting of the tuner mechanism.

A further object of the invention is to provide a high Q cavity resonator which shall have a reduced mass.

A still further object of the invention is to provide a cavity resonator having a motor-driven tuning mechanism in which the load upon the motor may be very small.

In accordance with the invention a hollow right circular cylinder of electrically conducting material capable of excitation to support an internal electromagnetic field of TE_{0mn} mode is provided with a disk piston which may be driven cyclically over the range of the tuning band by a connected motor. The area of the piston is made smaller than the interior of the cylinder by an amount of the order of ⅛ inch radius so as to present at its periphery a high impedance to the radially directed electric vector of the unwanted transverse magnetic mode (TM_1) oscillations having the same frequency as the desired transverse electric (TE_0) mode oscillations. To increase the impedance to undesired modes the piston may be provided with apertures located at regions of weak field for the oscillations of the desired TE_0 mode. In one species of the invention the piston may be provided with a flange to constitute a guide of high impedance for oscillations of the desired mode while, at the same time, permitting energy of undesired modes to be dissipated. In another modification the edge of the tuning piston may be bevelled to reduce the electrical capacitance in the path of the radial electric vector of undesired modes. To enable the midband frequency to be varied without adjustment of the tuning mechanism a separate movable disk may be used at the end of the resonator opposite the variable tuner.

In the drawing Fig. 1 illustrates partly in section a cavity resonator embodying the features of the invention;

Fig. 2 is a sectional view of the structure of Fig. 1 along the plane 2—2 viewed in the direction of the arrows;

Fig. 3 shows a modification of the structure shown in Fig. 2;

Fig. 4 is a sectional view of a modification of the tuning piston of Fig. 1; and

Fig. 5 is a sectional view of a further modification of the tuning piston of Fig. 1.

Referring to Fig. 1 a cylindrical chamber 11 which may be of spun or cast aluminum with an interior plating 10 of silver is apertured through a central boss 12 projecting from its lower end to provide a guideway for the stem 13 of an adjustably positioned disc 14 silver-plated on its upper face which serves as the lower boundary of the electromagnetic field within the chamber. The stem 13 may be moved longitudinally and held fixed in any position to which it is moved by any well-known position adjusting mechanism. At its upper end chamber 11 is provided with a cover 15 which may be attached to the chamber by screws 16 or other suitable fastenings. Standards 17 and 18 integral with the cover extend upwardly therefrom and support a cross-frame 19 which carries a motor 20 having a horizontally rotating shaft and a driving eccentric 21 connected thereto. Supported from the driving eccentric is a reciprocating mechanism 22 terminating in the tuning piston 23 which may also be silver-plated on its interior face as at 31 to constitute the upper boundary of the interior electromagnetic field.

The resonator may be excited to oscillate in a TE_{0mn} mode by energy supplied from an input circuit 24 to the coupling loop 25 which extends into the chamber in a horizontal plane at which oscillations of the desired TE_{0mn} mode are of relatively high intensity. An output circuit 26 may be similarly coupled to the electromagnetic field by a loop 27 lying in the same plane as the loop 25 at a position preferably but not necessarily angularly removed therefrom by 180 degrees. Such coupling loops are relatively ineffective to induce oscillations of undesired TM_1 mode and accordingly aid in discriminating against such undesired modes.

Concomitant with excitation of oscillations of TE_{0mn} mode is a tendency for oscillations of the same frequency of TM_{1mn} mode to be initiated. The presence of such extraneous TM_{1mn} mode oscillations is indicated by theory and found in practice to reduce the time during which the desired TE_{0mn} oscillations continue subsequent to withdrawal of the exciting force. This effectively amounts to a reduction of Q of the resonance chamber 11 for oscillations of the desired mode. Consequently, it is highly desirable to inhibit or to suppress oscillations of the undesired TM_{1mn} mode as well as other extraneous oscillations which may tend to occur with frequencies within the range over which it is desired to tune the resonance chamber 11. One very effective expedient for inhibiting the undesired oscillations of TM mode takes advantage of the fact that oscillations of the desired TE_0 mode have no radial electric vector while oscillations of the undesired TM_1 mode and of other undesired modes do involve radial electric vectors. If, therefore, the tuning disc 23 be constructed with a diameter such that it fits very loosely within the resonance chamber 11, the peripheral gap 29 between the margin of the disc and the interior surface of the cylindrical wall will interpose an attenuating discontinuity in the path of the radial vector of the oscillations of the undesired mode. Moreover, the capacitance between the boundaries to the gap 29 is a factor in determining the frequency of oscillations of the TM_1 mode and hence tends to shift that frequency away from the frequency of the TE_{0mn} mode by an amount which, in some cases, may take the frequency of the undesired oscillations outside the frequency band through which the resonance chamber is to be tuned for oscillations of the desired TE_{0mn} mode. It will be appreciated that the gap 29 lies in a region of a relatively weak field for oscillations of TE_0 modes.

The discontinuity interposed by the gap 29 tends to cause the radial electric vectors of the oscillations of unwanted modes to give rise to currents traversing the walls of the chamber or space back of or above the tuning piston 23 over paths in shunt to the gap 29. These walls, that is, the portion of the cylindrical surface above the piston 23 and the inner surface of the cap 15, in fact, all surfaces back of the piston 23, may be left unplated thus subjecting the unwanted oscillations to additional attenuation. A similar expedient may be employed in the lower end space or chamber beneath the adjustably positioned disc 14.

The attenuation of unwanted modes of oscillation having radial electric vectors may be increased by leaving off the silver-plating at the outer periphery of the tuner discs, both on the surfaces directly exposed to the cylindrical walls and for a very small distance on the inner face of the discs adjacent their outer peripheries as indicated at 47 and 48.

The width of the gap 29, that is, the radial dimension between the contiguous faces of the cylindrical wall and the periphery of disc 23 is found to have an optimum magnitude such that smaller or larger gaps afford relatively less discrimination between oscillations of the desired mode and oscillations of extraneous modes. The optimum dimension of this gap is a function of the wavelength of the oscillations of the desired mode. For example, in a cylindrical cavity resonator designed for oscillations of TE_{01} mode and having a wavelength in free space of approximately 9 centimeters it was found that the apparent Q of the resonant chamber increased with increase of the width of the gap up to a dimension of approximately 0.3 centimeter after which the apparent Q was reduced with further increase of the gap.

The feature of the peripheral gap has a number of other advantages in the structure shown in Fig. 1. For one thing it eliminates entirely the problem of variable contact of the tuner disc with the side walls thus removing a source of considerable electrical instability and of mechanical wear. At the same time it enables the dimensions and precise shape of the tuner disc to be less critical. As has already been explained, it increases the apparent Q and the ring time for oscillations of a desired TE_{0mn} mode. It also reduces the weight of the reciprocating parts and the consequent load imposed upon the driving motor. The selectivity of the resonator for oscillations of the desired mode as against unwanted or extraneous oscillations is also increased.

Another feature of the tuning disc 23 of Fig. 1 is the provision of apertures extending therethrough in regions of relatively weak field as indicated at 32 and 33. Apertures 32 and 33 are extremely narrow slits extending in an annular direction to reduce and attenuate the radial vector of oscillations of unwanted modes and, at the same time, to additionally decrease the mass of the reciprocating parts. Apertures 32 and 33, as illustrated in Fig. 2, are interrupted at points in their length to leave uncut supporting ribs 34 and 35. In addition to their function of discrimination against oscillations of unwanted modes in favor of those of desired modes and of reducing the mass of the reciprocating structure these apertures together with the gap 29 reduce still further the load imposed upon the motor 20 in displacement of the air above the tuning disc 23.

The adjustable position end member 14 may be provided with apertures 36 and 37 similar to the apertures 32 and 33 of the disc 23. Its periphery may be bevelled as at 38 to reduce the capacitance between the periphery and the adjacent cylindrical wall while, at the same time, leaving a peripheral gap corresponding to the gap 29.

Fig. 3 shows an alternative construction in which the arcuate apertures 32 and 33 are replaced by a series of circular holes 40 and 41. In a cavity resonator designed for oscillations having a free space wavelength of approximately 9 centimeters and of TE_{011} mode it was found that such circular apertures could preferably have a dimension of the order of 0.6 centimeter.

Fig. 4 illustrates in section a tuner disc 42 which differs from the tuner disc 23 in that its peripheral edges while designed to provide a gap 43 equal to the gap 29 are bevelled as at 44 to reduce the peripheral capacitance to a minimum. This tuner disc may be provided with apertures 45 and 46 which may be similar either to the arcuate apertures of the structure of Fig. 2 or the circular apertures of the structure of Fig. 3. It has been found possible to so reduce the peripheral capacitance of the tuner disc that the resulting high reactance displaces the frequency of the oscillations of the undesired TM_1 mode entirely outside the band through which the apparatus is designed to tune.

Fig. 5 shows a modification of the piston structure in which a rearwardly extending annular flange 49 is provided, the outer marginal surface of which constitutes with the interior surface of the cylindrical wall an annular wave guide having a depth d measured from the front surface of the disc to the rear margin of the flange 49. This depth is preferably made such as to discriminate against leakage of the desired TE_0 mode oscillations through the gap 29.

It will be understood that in operation the motor 20 will actuate the tuning disc 23 to cause the natural frequency of oscillations of the desired mode to vary through a band of frequencies extending from a lower limit to an upper limit, the width of the band being determined by the extent of the motion of the disc **23**. The mid-frequency of the band and its limiting frequencies as well may all be increased or all decreased by an appropriate adjustment of the position of lower end disc **14**. The resonator **11** will undergo variation of its natural frequency at a cyclic rate corresponding to the speed of the horizontal rotating shaft of the motor **20**. Incoming energy impressed upon the resonator **11** by the input circuit **24** will excite the resonator at its natural resonance frequency when the position of the moving piston **23** is such that the natural resonance frequency is in agreement with the frequency of the incoming energy. At such instants the resonator **11** will serve to supply energy of its natural resonance frequency to the output circuit **26** to energize an indicator or other load element which may be connected thereto. The resonator **11** therefore serves as an electrical oscillation selector of high Q coupling the input circuit **24** to the output circuit **26**. If it be desired to utilize the resonator **11** as a so-called echo-box, that is, a resonator in which the microwave energy of brief pulses may be stored up for retransmission upon cessation of the pulse, the output circuit **26** may be omitted. Under such circumstances microwave energy of brief pulses incoming over the circuit **24** will excite a strong field within the resonator **11** when the resonator is tuned to the frequency of the incoming microwaves and upon cessation of the incoming pulse will feed back to the circuit **24** oscillations of the same frequency having a decrement depending upon the Q of the resonance chamber **11**.

What is claimed is:

1. A cavity resonator comprising a cylindrical chamber having an interior surface of electrically highly conductive material, a movable end wall positioned in said chamber with a uniform spacing between its periphery and the adjacent side walls of the chamber, said periphery being so tapered as it approaches its margin as to greatly reduce the electrical capacitance between the periphery of the piston and the adjacent side walls said gap providing a capacitance sufficient to shift the frequency of undesired TM modes outside of the operating range.

2. A cavity resonator having a movable tuning piston serving as one wall and separated at its periphery from the remaining walls by a uniform clearance, the peripheral margin of said piston being bevelled to so reduce the capacitance to the adjacent walls as to introduce a relatively high impedance for oscillations tending to pass from the surface of said piston to the contiguous surfaces of the other walls said gap providing a capacitance sufficient to shift the frequency of undesired TM modes outside of the operating range.

3. The structure of claim 1, said end wall being provided with arcuate slits for suppressing extraneous modes having a radial electric field vector.

4. The structure of claim 2, and extraneous mode suppression devices on said piston located at positions of relative weak field intensity for TE_{0mn} modes.

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