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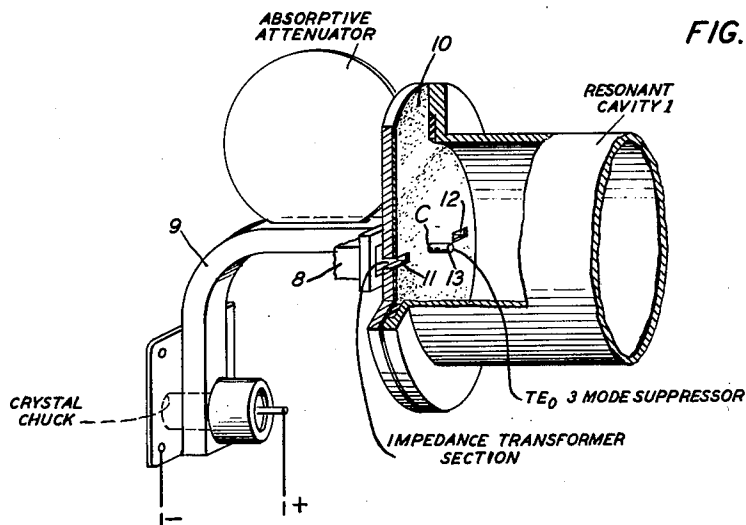
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2,701,343

HIGH Q RESONANT CAVITY

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2 Sheets-Sheet 1



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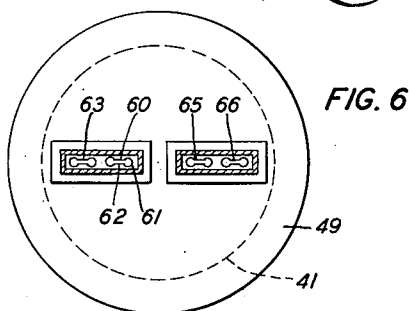
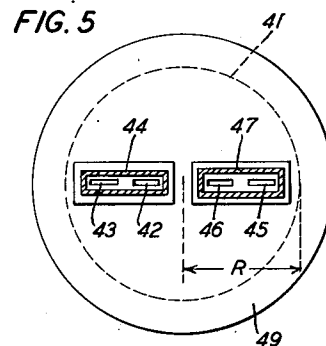
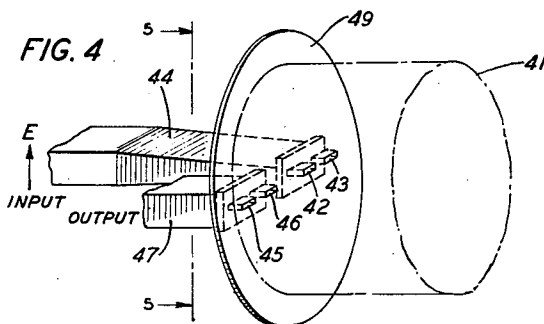
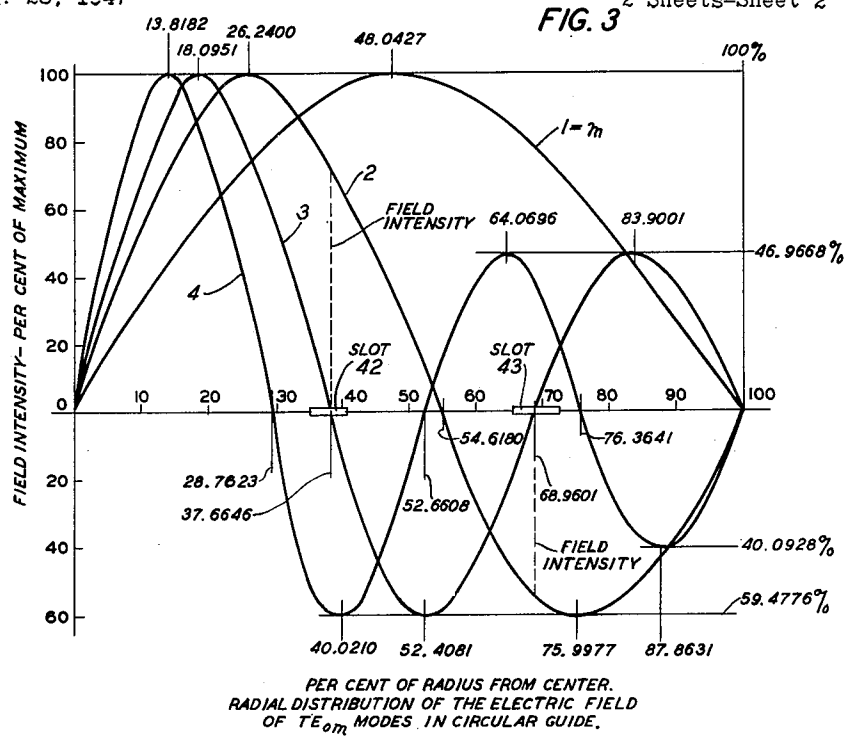
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2 Sheets-Sheet 2



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2,701,343

HIGH Q RESONANT CAVITY

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10 Claims. (Cl. 333—83)

This invention relates to resonant chambers, echo boxes and the like, and more particularly to improvements in extraneous mode suppressors therefor.

An object of the invention is the non-excitation of extraneous TE_{02n} , TE_{03n} , TE_{04n} modes separately or simultaneously in a resonant chamber operating in the TE_{01n} mode.

A further object of the invention is to excite the operating TE_{01n} mode of a resonant chamber and concomitantly degraded the excitation of the TE_{03n} mode.

A further object of the invention is to continuously degrade extraneous modes in a tunable cavity over the tuning range without concomitantly affecting the operating mode.

Another object of the invention is to excite the operating TE_{01n} mode of a resonant chamber at a null of the TE_{03n} mode and concomitantly cancel excitations of the TE_{02n} mode.

Another object of the invention is to additively excite the operating TE_{01n} mode in phase and concomitantly couple into the TE_{02n} mode out of phase, whereby to produce cancellation of the latter.

A feature of the invention is an end feed for an echo box, with feed orifices spaced at proper radial positions to cancel TE_{02n} and non-excite TE_{03n} modes.

Another feature of the invention is an end plate for an echo box or resonant chamber with a pair of feed orifices therein, one located at 37.66 per cent radius from the center, the other located at 68.96 per cent radius to produce zero field intensity of the TE_{03n} mode. The orifice dimensions and signal phases applied thereto are arranged in a manner to concomitantly obtain cancellation of the TE_{02n} mode and reinforcement of the TE_{01n} operating mode.

Another feature of the invention is a lossy plate or absorption disc in a resonant chamber located axially at a null of the operating mode and extending transversely to provide suppression of the TE_{03n} mode. The lossy disc may be fixedly located on the end plate of the chamber or may be relatively movable with respect to the tuning piston. In the latter case, it will continuously degrade extraneous modes over a wide tuning range without concomitantly affecting the operating mode.

Referring to the figures of the drawing:

Fig. 1 shows a mode suppressor for resonant chambers in accordance with the invention;

Fig. 2 represents a modification of the suppressor of Fig. 1;

Fig. 3 shows an explanatory curve of relative field intensities associated with TE_{0m} modes;

Fig. 4 represents a modified echo box mode suppressor involving pairing of feed slits; and

Fig. 5 is an end view of the echo box.

Fig. 6 is an end view of the echo box showing a modified form of energy feed slits.

Extraneous mode suppression in resonant chambers has heretofore been disclosed, for example, in the United States applications of J. C. Schelleng, Serial No. 580,517, filed March 2, 1945 which issued as United States Patent Number 2,453,760, November 16, 1948, and H. B. Brehm-W. F. Kannenberg, Serial No. 687,549, filed August 1, 1946 which issued as United States Patent Number 2,527,619, October 31, 1950.

In certain microwave ranges, such as in the neighborhood of 1 centimeter waves, it becomes particularly desirable to eliminate in echo boxes and the like, extraneous modes such as TE_{02n} , TE_{03n} which have a field pattern

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similar to that of the operating TE_{01n} mode. These extraneous modes usually are outside the normal operating region in other frequency ranges, such as 10–100 centimeters.

In accordance with the invention, effective mode suppression in resonant cavities and the like is provided by utilizing a plane of lossy material, which may be maintained at a null of the TE_{01n} operating mode over the tuning range, and which extends into a position of high field strength for the TE_{03n} mode to appreciably degrade the latter. In accordance with another embodiment of the invention, a resonant cavity is fed at plural points therein, such that the TE_{01n} mode may be excited thereat in phase whereas the TE_{02n} modes are excited in such phase and amplitude as to cancel, and the resultant excitation of TE_{03n} are zero.

Referring to Fig. 1, a resonant chamber 1 provided with a supercharger type of feed, more fully disclosed in the United States application of W. A. Edson-R. W. Lange Serial No. 772,936, filed concurrently herewith, is shown with the tuning piston end omitted. The thin silver facing disc 10 of the resonant chamber or ring box 1 has a single rectangular input orifice 11 and a single rectangular output orifice 12 nominally at the 54.6180 per cent radius point from the center C to couple to the TE_{01n} mode, without exciting the TE_{02n} mode.

The slits 11, 12 in the facing plate 10 (cavity diameter 2.04 inches) are 10 mils high, 120 mils wide, when operating at 1.25 centimeter wavelength. Impedance matching transformer of the

$$\frac{\lambda_g}{4}$$

type, more fully disclosed in the aforementioned W. A. Edson-R. W. Lange application are connected to the resonant cavity or chamber 1 in such a manner as to match the impedance of each of the slits 11, 12 to the corresponding wave guides 8, 9.

The TE_{03n} mode is suppressed by an absorber disc 13 designated the TE_{03} mode suppressor. The absorber disc 13 is essentially a plane of lossy material, such as a coating of aquadag at the end of a polystyrene rod, which is centrally located, i. e., along the axis of the resonant cavity 1. Its longitudinal position is at a null of the TE_{01n} desired mode at approximately mid-band, but concomitantly it is not a null for the unwanted modes, for example, TE_{03n} . Therefore, energy is absorbed from such undesired modes with little or no effect on the desired mode. The amount of suppression of the undesired mode is determined in part by the diameter of the lossy plane 13, extending transverse to the chamber's longitudinal axis. Thus, if the plane extended to 5 per cent of the radius from the center C, the absorber would be at a relative field intensity of about 42 per cent of the undesired TE_{03n} mode and about 16 per cent of the TE_{01n} mode. Considerable energy could be absorbed from the TE_{03n} mode thereby degrading it appreciably with very little degradation of the TE_{01n} mode. Other extraneous modes are also degraded to a certain extent.

In an exemplary embodiment, the TE_{03} mode was reduced in ring and transmission by a TE_{03} mode suppressor located centrally in the feed plate and extending longitudinally into the cavity to the first null of the TE_{01} mode. The suppressor was supported on a polystyrene rod 0.094-inch in diameter and comprised a coating of aquadag on the square-cut cavity end of the rod. This aquadag presented a plane of lossy material located away from the null of the $TE_{03,3,23}$ and $TE_{03,3,24}$ modes. The aquadag extended radially from the center towards the sidewall 4.6 per cent of the radius where the field intensity of the TE_{03} mode was approximately 39 per cent of its undisturbed first maximum and that of the TE_{01} about 14 per cent. Thus the lossy material was located where it lowered the Q of the TE_{03} mode with very little degradation of the TE_{01} mode.

Incidental to this principal function the TE_{03} mode suppressor also lowered the Q of other modes which augmented the other Q lowering devices.

As the cavity is tuned over the operating range, the physical position of the first null of the desired mode tends to shift with respect to the plane 13 of the lossy

material. For a limited tuning range, this shift would be small. With a fixed physical position of the absorber, there may be a slight degradation of the desired mode over the tuning range.

The most successful use of the absorber depends upon a small departure from the null of the desired mode and upon the greater initial increase of the TE_{03n} field intensity over that of the TE_{01n} intensity.

The modification of echo box illustrated in Fig. 2 utilizes a mode suppressor plane mounted on the piston in a manner to continually maintain the suppressor at the null of the operating mode, as the echo box is tuned over an extended frequency range.

The echo box or resonance chamber 21 is provided with a movable tuning piston 30, on which is mounted a mode suppressing plane or disc 33, extending transversely to the principal axis of the cylindrical chamber 21. The suppressor 33 may be formed of lossy material, for example, carbon black, neoprene or the like and is supported on a dielectric pedestal 35' formed of polystyrene or other low loss, and low dielectric constant material. The pedestal 35' represents the end portion of a movable rod 35, which moves the mode suppressor 33 relative to the piston. The rod 35 is exterior to the working cavity. Initially, the suppressor 33 is located at a null of the TE_{01n} operating mode, whereby it will have no appreciable effect on the main mode. However, all other unwanted modes characterized by a different number of half-wavelengths measured along the longitudinal axis of the chamber 21, will be degraded by absorption in the material of the suppressor.

As the piston 30 moves in the cavity to tune the same over an extended tuning range, the absorber 33 is projected therefrom to maintain its plane at the null of the desired TE_{01n} operating mode. This is accomplished by suitable gearing 36 connected to the piston drive mechanism 38—39, the latter being more fully disclosed in the United States application of W. A. Edson, Serial No. 575,515, filed January 31, 1945 which issued as United States Patent Number 2,465,639, March 29, 1949. Thereby, over a wide tuning range, the absorber 33 is always maintained at the null of the operating mode and in proper position to suppress extraneous modes without substantially affecting the operating mode.

It should be understood that the equalization of ring time over the tuning range by a lossy plunger as disclosed in the United States patent application Serial No. 771,002 of W. A. Edson-I. G. Wilson filed concurrently herewith which issued as United States Patent Number 2,688,122, August 31, 1954, and the mode suppression plane 33 here disclosed may be incorporated simultaneously in a high Q cavity to effect both equalization and mode suppression over the tuning range.

Fig. 3 illustrates graphically the radial distribution of the electric field of TE_{0m} modes in a circular wave guide or cavity. Specifically, the various curves 1, 2, 3, 4 in Fig. 3 present the relationship between relative field intensities of the TE_{01} , TE_{02} , TE_{03} , TE_{04} modes respectively plotted as ordinates against radial distances (per cent R) from the center C as abscissa.

Certain features may be noted as explanatory with respect to the location of feed slits in the chambers of Figs. 1, 4, 5 respectively. Thus, the null or zero intensity of the TE_{02} mode occurs at 54.6180 per cent R, and the two nulls for the TE_{03} mode occur at 37.6646 per cent R and 68.9601 per cent R respectively.

Referring to Fig. 4, the resonant cavity 41 is fed at a thin end plate 49 corresponding in thickness to the disc 10 (Fig. 1) through two slots 42, 43 spaced apart along the radius R. Each feed slot is so located along the radius R as to produce zero field intensity of the TE_{03n} mode. One slot 42 is at 37.6646 per cent radius from the center C while the other 43 is at 68.9601 per cent radius from the center as shown in Fig. 3. A tapered wave guide transformer 44 of the type disclosed in the United States application Serial No. 772,936 of W. A. Edson and R. W. Lange filed concurrently herewith, supplies input energy to both slots 42, 43. The height of the tapered transformer adjacent the slots 42, 43 is slightly greater than the heights of said slots or may range up to twice the slot height. Inasmuch as each exciting slot or feed orifice is not a point source, the tapered feed guide 44 at each of these radii must be so located that the resultant excitation of the TE_{03n} mode is zero. As is evident from Fig. 3, the TE_{01n} mode is excited by the two

feed orifices in phase to give the desired excitation of the TE_{01n} mode. Finally, it should be noted that the two orifices 42, 43 excited in phase for coupling to the TE_{01n} mode, oppose each other in the excitation of the TE_{02n} mode. To provide complete cancellation of the TE_{02n} mode, the excitation at the 37.6646 per cent radius point must be less in magnitude than that at the 68.9601 per cent radius point. This is evident from dotted line ordinates on the curve (Fig. 3), showing the inner slot 42, exciting the TE_{02n} mode at a region of relatively greater field intensity than slot 43. Differently stated, the inner slot 42 (37.6646 per cent radius point) is more closely coupled to the TE_{02n} mode than is the outer slot 43. Thus the ratio of the inner to outer feed point excitation should be the reciprocal of the field intensities existing at these points. Since the exciting orifice is not a point source, it is necessary that the resultant excitation of the feed orifices 42, 43 cancel in their excitation of the TE_{02n} mode. The output orifices 45, 46 in the end plate 49 connect to the output wave guide 47 of rectangular cross-section, provided with an attenuator and crystal chuck in the manner disclosed in Fig. 1.

This type of end plate feed mechanism shown in Fig. 4 was experimentally tested at 3-centimeter wavelength with a scaled echo box model originally designed for 1.25 centimeter. A very satisfactory degree of cancellation of the TE_{02n} and TE_{03n} modes was obtained together with the desired performance of the TE_{01n} mode. In this case, the end plate was symmetrical about the center line with the pair of output orifices 45, 46 balancing the pair of input orifices 42, 43. The purpose of this symmetry was the reduction in intermode couplings. The location and relative couplings of the feed orifices were necessarily adjusted by observation of the individual TE_{01n} , TE_{02n} and TE_{03n} mode performance until the desired suppression and performance was obtained. The usual critical tolerance associated with microwave components is further complicated by the simultaneous balance of two unwanted modes and the desired coupling to the wanted mode. With proper attention to such tolerances, the device operated effectively. It should be understood that the general technique heretofore described may be applied where the TE_{04n} mode is also undesired and is required to be suppressed.

In conjunction with the end feed plates for the resonant chambers shown in the various figures of the drawing, feed orifices 60 having the shape of dumbbells (Fig. 6) may be utilized to offer less intermode coupling impedance for a fixed coupling to the TE_{01n} mode. This facilitates securing the desired performance of the wanted mode at a region of simultaneous resonance of the wanted and undesired mode. The circular ends 61 of the dumbbell orifice 60 offer inductive reactance to partially neutralize the capacitive reactance of the rectangular portion 62 of the orifice. Thus, the net reactance of the entire orifice is lowered. A further advantage is that greater coupling to the TE_{01n} mode is available through a rectangular orifice when the ends are enlarged to provide dumbbell ends without change in the "a" or long dimension. In this manner, the orifice size may be reduced still further, thereby reducing the intermode coupling impedance.

Referring to Fig. 6, the end feed plate of the echo box 41 may be provided with two dumbbell input slits 60, 63 and two dumbbell output slits 65, 66 for simultaneous non-excitation of TE_{03} modes and cancellation of TE_{02} modes. A quarter-wavelength "supercharger" as disclosed in the United States application of W. A. Edson-R. W. Lange Serial No. 772,936, filed concurrently herewith, may be used to excite the input slits 60, 63. The input quarter wave step transformer and the output coupling may be adjusted with respect to the slits 60, 63 and 65, 66, and the slits with respect to the TE_{02} and TE_{03} fields within the cavity to suppress undesired modes and to provide the desired symmetry.

In an operative embodiment of an echo box, the dumbbell orifice feed excited the TE_{01} mode at two points of zero field strength of the TE_{03} mode, and excited the TE_{02n} mode in such proportion and phase as to cancel the latter. There was no observable transmission to the TE_{02} and TE_{03} modes when the transmission of the TE_{01} mode gave as much as 10 times the normal rectified current in the crystal circuit. This represents a very substantial cancellation of these unwanted modes. The ring of each of these unwanted modes was considerably re-

duced with respect to the main mode which represents a good balance.

What is claimed is:

1. A hollow cavity resonator of high Q, means for exciting a desired mode therein, a movable tuner comprising a reflecting piston, an absorber plate of lossy material connected to said tuner at a null of said desired mode and extending parallel to said tuner into a region of high field intensity of extraneous modes, a dielectric pedestal for supporting said plate to insulate it from the piston, and means for differentially moving said absorber with respect to said tuner along the longitudinal axis of said resonator to maintain the absorber at the null of the desired mode over an extended tuning range.

2. A high Q cavity resonator having a circular end plate, means for exciting an oscillating electromagnetic field of a TE_{01n} operating mode therein comprising an energy feed slit in said end plate, the spacing thereof from the center being 54 per cent R, where R is the radius of the end plate, whereby coupling to the TE_{01n} mode without excitation of the TE_{02n} mode is provided, and means for concentrating the input field intensity at said slit.

3. The structure of claim 2, and a TE_{0mn} mode suppressor comprising an absorber plane centrally located at the first longitudinal null of the operating mode parallel to said end plate and insulated therefrom, said plane extending into a region of high field intensity of TE_{0mn} modes and relatively low field intensity for the desired mode.

4. The structure of claim 2, and a TE_{03n} mode suppressor comprising a resistive plate located at a null of the TE_{01n} mode.

5. A cavity resonator of high Q having a circular end plate, means for exciting a desired TE_{01n} mode without concomitantly exciting TE_{03n} mode comprising a pair of spaced input slits, located along a radius R at a distance approximately equal to 37 per cent R and 68 per cent R respectively on the same side with respect to the center and a common tapering wave guide feed for concentrating the input field intensity at said slits.

6. A cavity resonator of high Q having a circular end plate, means for exciting a desired mode, said means comprising a pair of energy input slits spaced apart along a radius at positions where extraneous modes are excited in opposing phase on the same side with respect to the center and a common tapering wave guide feed for concentrating the input field intensity at said slits.

7. The structure of claim 6, wherein said slits are located at a null of a predetermined extraneous mode.

8. In combination, a hollow wave guide, a reflector therein, energy concentrating means for exciting an oscillating electromagnetic field within said guide having a desired mode of oscillation, a slotted circular plate extending across said wave guide, said slots extending radially on opposite sides of the center and spaced a dis-

tance equal .54 R where the TE_{02n} field intensity is nil, R being the radius of the plate and resistive means in said guide located at a null of the desired mode and extending into a region of high field intensity for TE_{0mn} modes, said resistive means being in a plane parallel to said reflector and adapted to differentially degrade TE_{0mn} modes.

9. A tunable high Q cavity resonator in the form of a right circular cylinder having a fixed end plate and a longitudinally movable piston, means for exciting electromagnetic waves in said resonator in a TE_{01n} mode, driving means connected to said piston for adjusting the longitudinal position thereof and thereby adjusting the frequency to which said resonator is tuned, said resonator having a diameter great enough to support higher order TE_{0mn} modes at frequencies within the tuning range of the resonator, a higher order mode suppressor comprising an insulating support member extending through said piston into the interior of said resonator and movable longitudinally thereof, a planar member of energy absorbing material mounted on said support member parallel to the face of said piston at a longitudinal position corresponding to that of a null of the said TE_{01n} waves, and means including a mechanical linkage between said piston driving means and said support member for maintaining said planar member at a null position as the tuning of said resonator is adjusted.

10. A high Q cavity resonator in the form of a substantially closed right circular cylinder having a pair of coupling apertures in one end thereof at different radial distances from the axis each substantially corresponding to the radial position of a null in the field intensity of electromagnetic waves of TE_{03n} mode in said resonator, a common transceiver of electromagnetic waves and means coupling said transceiver to the interior of said resonator through each said aperture in reciprocal relation to the field intensity of waves of TE_{02n} mode in said resonator at said different radial distances, and in aiding phase relation with respect to waves of TE_{01n} mode in said resonator, whereby said transceiver is coupled in energy transfer relation to said resonator with respect to waves of TE_{01} mode and decoupled with respect to waves of TE_{02} and TE_{03} mode.

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