Nov. 16, 1948.

J. C. SCHELLENG

2,453,760

CAVITY RESONATOR

Filed March 2, 1945

2 Sheets-Sheet 1

FIG. 1

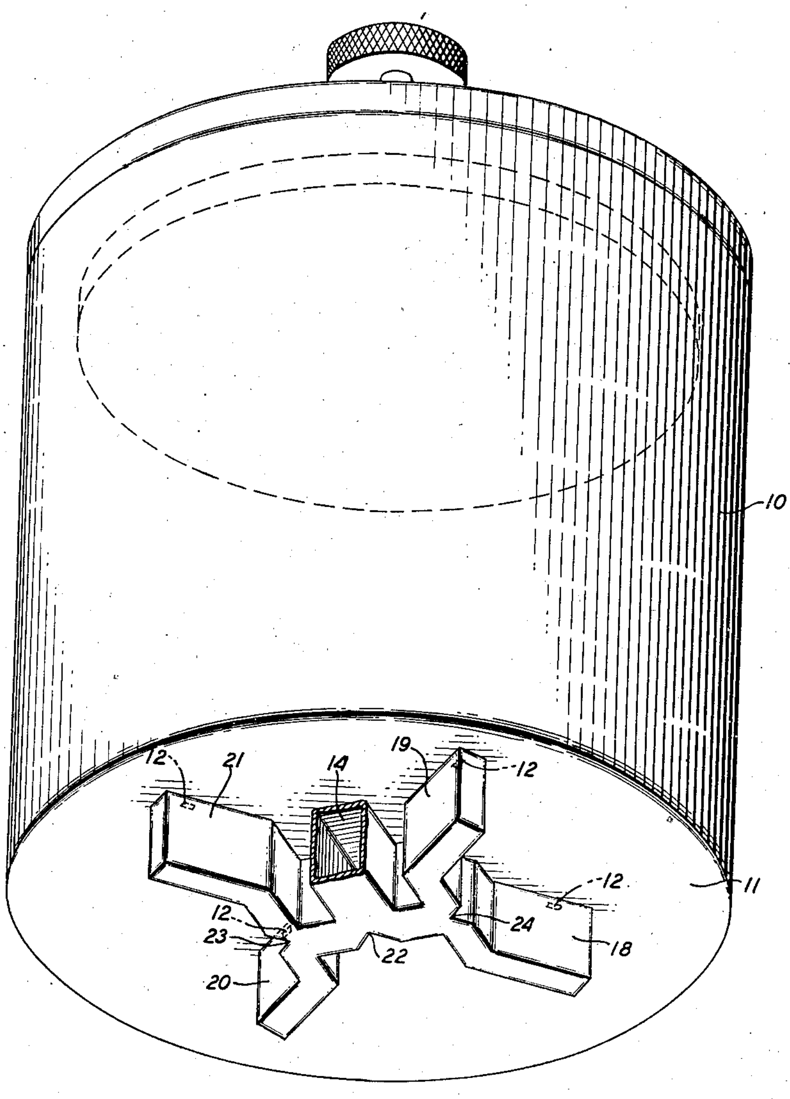

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FIG. 2

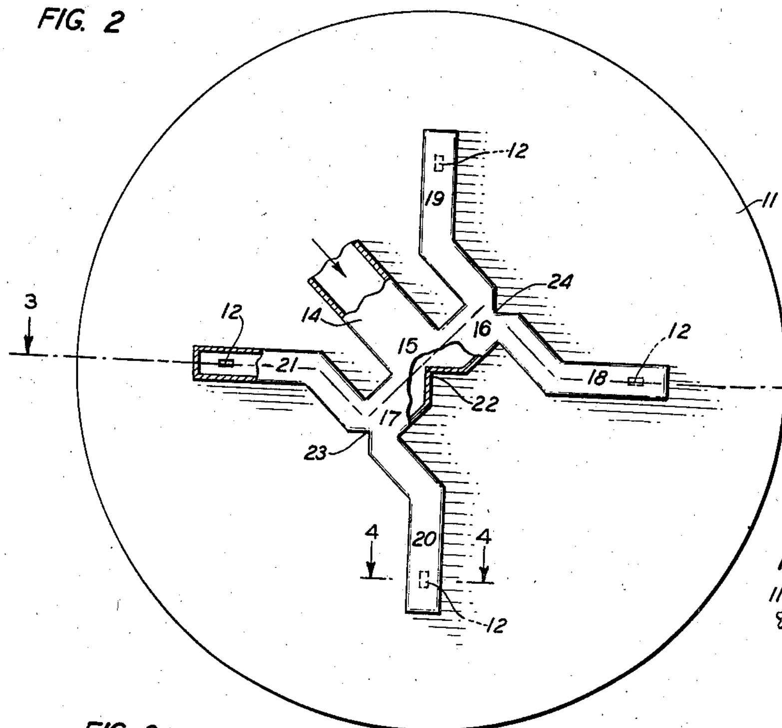


FIG. 4

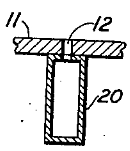
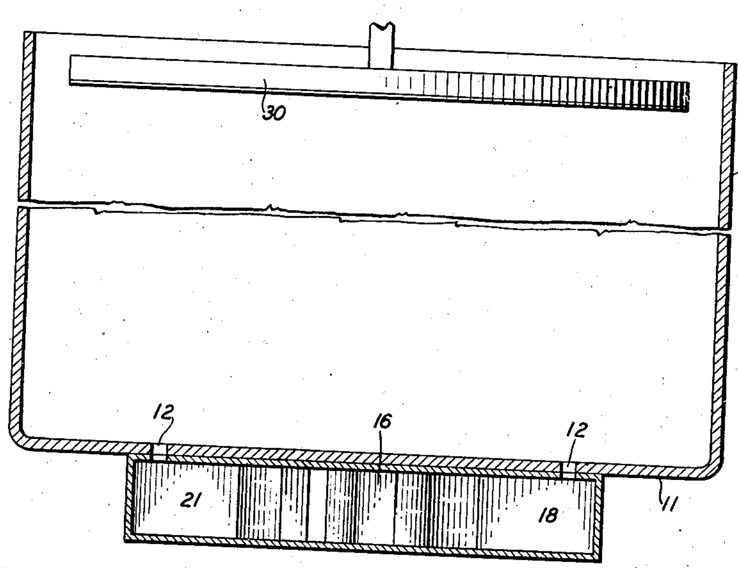


FIG. 3



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CAVITY RESONATOR

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5 Claims. (Cl. 178—44)

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This invention relates to cavity resonators and more particularly to improvements in the energy transmission connections to cavity resonators.

An object of the invention is to provide a cavity resonator with energy transmission connections which will accentuate oscillations of a desired mode while discriminating against and tending to suppress those of undesired modes.

Another object of the invention is to provide circuit connections for a cylindrical cavity resonator which will enhance oscillations of TE_{01} modes while discriminating against oscillations of TE_{11}, TE_{1m}, TE_{2m} and other transverse electric modes.

An additional object of the invention is to provide circuit connections between a wave guide and a cavity resonator which shall discriminate against oscillations of undesired TM modes.

Cavity resonators serve in electrical microwave technique as selective devices in a manner somewhat analogous to that of tuned circuits at lower frequencies. However, because of their distributed reactances, large cavities are in general susceptible of a large number of different modes of oscillation. Most of these modes are effective at frequencies which may be relatively remote from a desired predetermined mode of oscillation but some may prove troublesome because adjacent in frequency to the desired oscillations. Moreover, in the case of oscillations in perfect circular cylindrical resonators, TE_{0m} and TM_{1m} mode oscillations occur in pairs at identical frequencies, thus rendering their separation rather difficult. What is more, the different modes of oscillation of a cavity resonator which occur at the same resonance frequency appear to interact so that energy dissipation by a resistance effective upon one mode of oscillation may sap energy from the other.

The manner in which various modes of oscillation interact is attributable in part to coupling occurring at the entrance by which energy is supplied to the resonator. As an illustration, suppose that a pulse of radio frequency energy is applied for one microsecond through a small loop or turn of wire at the end of the inner conductor of a coaxial line, this turn being oriented in such a way as to excite simultaneously two modes of oscillation of the cavity, one mode desired and the other not. During the period of decay following the pulse, the desired mode (the undesired also) will cause a current to flow in the loop. But the same loop by assumption is coupled to the undesired mode, and hence power will in general be fed from the desired into the undesired

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mode. Hence the factors causing damping in the undesired mode will contribute to that in the desired mode.

In accordance with the invention, discrimination in favor of the desired mode of oscillation of a cavity resonator and against an undesired mode is attained by coupling the resonator to its feed line or to its output circuit or to both by a multiple point coupling, the coupling points being so chosen as to be in phase agreement for the desired mode of oscillation and to be in phase disagreement for oscillations of undesired modes.

In this specification, transverse electric and transverse magnetic modes will be designated respectively as TE and TM, and in the case of right circular cylindrical resonators the subscripts n, m and l will be used, referring respectively to the number of 360-degree phase changes in the circumferential direction and 180-degree phase changes in the radial and length directions. Hence, TE_{019} mode oscillations in a right circular cylinder describe an oscillation having a standing wave pattern such that its electric vectors are transverse to the cylinder axis; there is no change in phase circumferentially; there is a single half-wave change in phase in radial direction and there are nine half-wave changes in the longitudinal or axial direction.

In the drawing:

Fig. 1 shows in perspective a cavity resonator involving one embodiment of the invention;

Fig. 2 is a plan view of the lower end of the structure of Fig. 1;

Fig. 3 is a section along a vertical plane passing through the zigzag broken line **3—3** of Fig. 2; and

Fig. 4 is a section along the line **4—4** of Fig. 2.

Referring to the drawing, a cylindrical cavity resonator **10** designed to operate in TE_{019} mode is shown in Fig. 1. In order to excite TE_{01} mode oscillations through the end plate **11** a plurality of coupling apertures **12**, in this case four, are provided. As shown in Fig. 2, the apertures are located at equally spaced points along the perimeter of a circle of about four-tenths the radius of the end plate, at a distance from the center where the electric field of the TE_{01} wave is strong relative to that at the circumference and center. These apertures in the embodiment disclosed are in the form of radially directed slots of the order of one-eighth inch in length and one thirty-seconds inch wide. The main energy transmission system which may serve as a feed line for the resonator is a wave guide **14** designed to transmit oscillation energy of the desired frequency. The radial coupling slots of apertures 12 have their length direction transverse to the electric vectors of the desired TE_{01} mode in the resonator and in the wave guide coupling sections. They, accordingly, are relatively effective for transfer of oscillation energy of that mode but are relatively ineffective for transfer of energy of modes having radial electric vectors which are only slightly intercepted by the narrow slots. For oscillations of TE_{01} mode, the four apertures excite the resonator in phase thus building up a strong symmetrical internal field. If a considerable number of apertures be used, effective discrimination may be had against modes having greater values of n than zero.

In passing from one of the exciting apertures to another in the direction in which the electric vector of the desired electromagnetic field extends no change of phase will be experienced. In this specification and the annexed claims the expressions "in phase agreement" or "in phase" shall connote that condition as distinguished from the situation in more complex systems where physically separated points are electrically at potentials differing by an integral number of wavelengths. Moreover, the expression "gravest mode" of oscillation as related to a particular dimension or surface of an electrical boundary shall be understood to connote the mode or the series of modes of oscillation which is most basic or is of the lowest frequency in so far as that particular dimension or surface is concerned. In the example of Fig. 1, in which a TE_{019} mode of oscillation is disclosed as a selected mode from the TE_{01n} series, the gravest mode, referred to the end surface in which the coupling orifices occurs, is TE_{01} irrespective of the magnitude of n.

We might summarize as follows the behavior for the various modes of oscillation that require consideration in the case of a four aperture system used as a feed circuit for a cavity resonator. In general TE_{0m} oscillations are passed by radial slots. However, the mode corresponding to a particular value of m may be reduced by choice of the radius of the circle of slots. With respect to TM_{0m} oscillations reduction may be had by use of narrow radial slots or by using as a feed circuit an external oscillation path providing a circumferential electric field or both of these expedients as in the system illustrated in the drawing. For $TE_{2k+1,m}$ or $TM_{2k+1,m}$ where k equals 0, 1, 2, etc., so that the first subscript is odd, reduction may be had by using coupling slots arranged in symmetrical diametrical pairs. This is of particular importance in the case of the use of TE_{0m} oscillations where it is desired to suppress the equal frequency TM_{1m} mode. For TE_{2m} or TM_{2m} oscillations the two pair or four aperture arrangement affords effective reduction. For even values of the first subscript greater than 2 the four aperture feed does not effect a considerable reduction and it may be desirable to resort to a still greater number of apertures arranged in accordance with the principles of the invention.

The main wave guide 14 forks at 15 into two branches 16 and 17 of equal height in the direction of the longitudinal axis of the resonator each branch being of a width approximately half the narrower or transverse dimension of the guide 14. This device enables the main guide 14 to face a terminal impedance of the branches 16 and 17 which approximately matches its own. In turn, each of the branches 16 and 17 is forked so as to terminate in a pair of terminal branches 18, 19 or 20, 21 as the case may be.

It is desirable that excitations at the various apertures be in phase for oscillations of the desired mode. Consequently, for TE_{01} modes of oscillation with the apertures located as disclosed, the wave guide paths from the main transmission guide to the apertures 12 should be as nearly as possible electrically identical in wavelength. Notched configurations at the branching points 22, 23 and 24 assist in smoothing the transmission characteristics and in matching the parallel or joint impedance of the branches to that of the section from which they branch.

Tuning of the resonator 10 to a desired frequency may be effected by a well-known reciprocating piston structure indicated schematically at 30.

It will be apparent that the multiple coupling expedient of the invention enables a symmetrical excitation of a cavity resonator with consequent increase in correspondence of its actual performance with the theoretical or precalculated performance. It will also be obvious that the multiple coupling point expedient of the invention is an effective device for restricting the useful effect of a cavity resonator to a desired mode of oscillation and for preventing dissipation of the energy of the desired mode by a reaction of unwanted oscillations of other modes.

What is claimed is:

1. An electrical resonator comprising a hollow substantially closed cylindrical chamber adapted for sustaining within its interior space electromagnetic oscillations of a natural resonance frequency of the chamber and of a TE_{01n} mode, said chamber having plane circular end walls and having its interior space between said end walls substantially free of energy absorbing material or electrical conducting material, one of said end walls having a plurality of spaced apertures at points which are in phase agreement for oscillations of said resonance frequency and mode, and an oscillation path comprising a wave guide conduit respectively coupled to the field within said chamber at each of said apertures, said conduits each having equal rectangular cross-section with their greater transverse dimension arranged perpendicular to the plane of the apertured end wall, said conduits being all connected together at their ends remote from the respective aperture couplings to form a common rectangular transmission guide of the same major transverse dimension but of a greater dimension perpendicular to said transverse dimension.

2. An electrical resonator in accordance with claim 1 characterized in this that said apertures each consists of short narrow radial slits in the circular end wall of the resonator.

3. The structure of claim 2, wherein said apertures are located at equispaced points on a concentric circle where the TE_{01n} mode field is strong relative to that at the center and circumference of the end wall.

4. The structure of claim 2, wherein said apertures are located at four equispaced points on a concentric circle of radius approximately $=.4R$, where R is the reference radius of the circular end wall.

5. An electrical resonator in accordance with claim 1 characterized in this that the conduits which merge to form a larger conduit are provided at the junction point with means for

matching the impedances of the merging conduits to that of the larger conduit.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,129,714	Southworth	Sept. 13, 1938
2,206,923	Southworth	July 9, 1940
2,284,405	McArthur	May 26, 1942
2,408,409	Bowen	Oct. 1, 1946