

[54] TUNABLE MICROWAVE BANDSTOP
RESONANT CAVITY APPARATUS

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334/40

[51] Int. Cl. H01p 7/06, H01p 5/04

[58] Field of Search 333/73 W, 83 R, 9,
333/33; 334/40

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[57]

ABSTRACT

A rectangular microwave bandstop resonant cavity having a plurality of tuning screws in a configuration which permits the resonant frequency, the quality factor, and the effective electrical location of the cavity to be adjusted. These adjustments can be made either independently one of the other, or in any desired combination.

12 Claims, 6 Drawing Figures

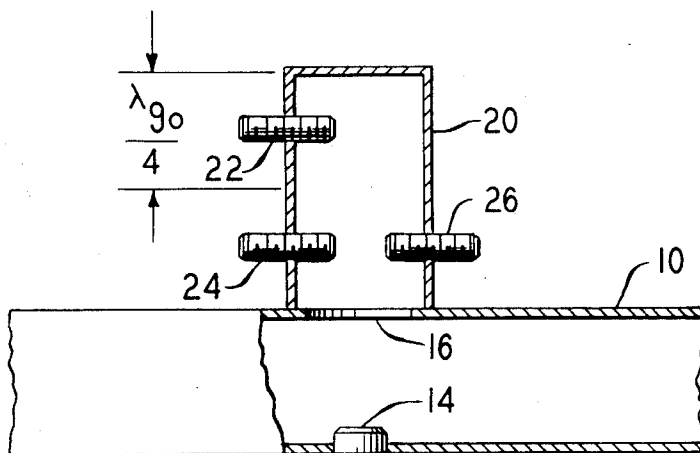


FIG. 1
(PRIOR ART)

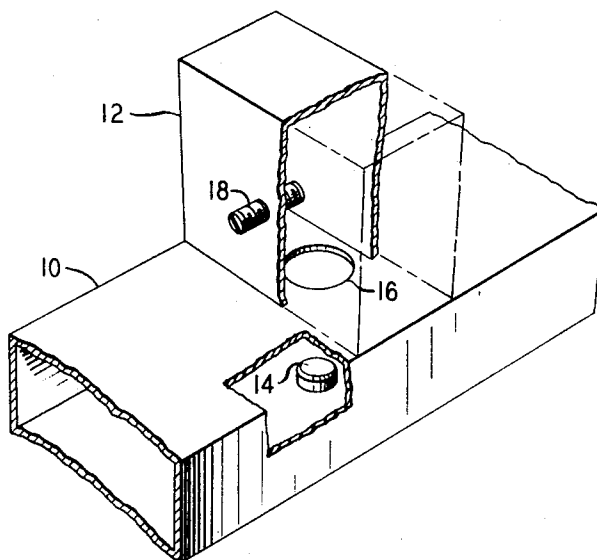
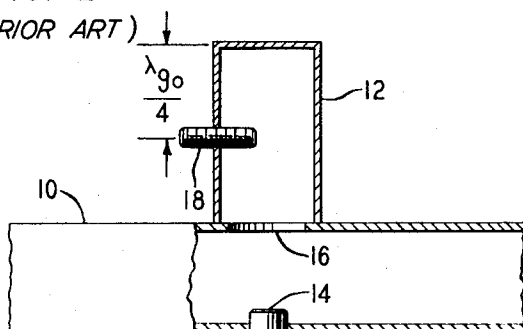


FIG. 2
(PRIOR ART)



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FIG. 3

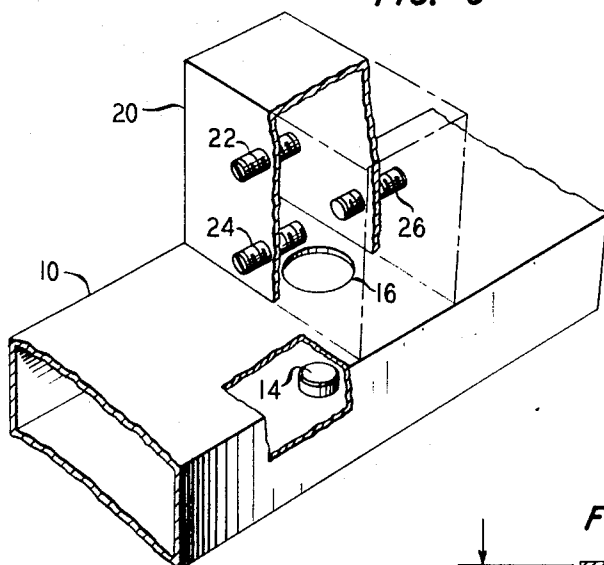


FIG. 4

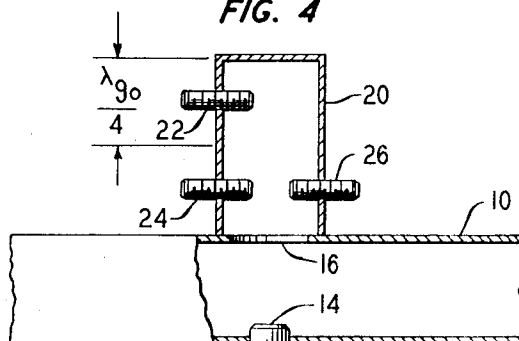


FIG. 5

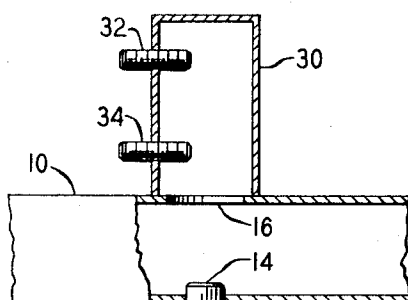
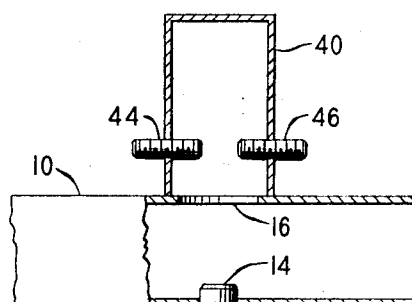


FIG. 6



TUNABLE MICROWAVE BANDSTOP RESONANT CAVITY APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to rectangular waveguide systems and more particularly to resonant cavities for use as filters in such systems.

2. Description of the Prior Art

At microwave frequencies, the components of ordinary resonant circuits become so small that they are physically impractical. Cavity resonators are therefore preferred because they are physically large and highly efficient. Complicated filtering functions and similar operations are conveniently performed in microwave waveguide systems by appropriate arrangements of such cavities. One such filter is described in an article by T. A. Abele entitled "A High-Quality Waveguide Directional Filter," *Bell System Technical Journal*, Vol. XLVI, No. 1 (January, 1967), pp. 81-104.

As with all microwave waveguide apparatus, the size, shape, and physical location of microwave resonant cavities must be precisely controlled to obtain the desired results. Because fabrication tolerances of sufficient stringency are difficult to achieve and because the properties of microwave systems change under the influence of such factors as time and temperature, it is desirable to have resonant cavity structures the electrical properties of which are to some degree adjustable. Commonly, a tuning screw in one wall of a resonant cavity is used to permit adjustment of the resonant frequency of the cavity. Properly positioned, a screw of this type can be used to tune resonant frequency without noticeable effect on the other properties of the cavity. In other positions such a screw may affect the quality factor, Q , of the filter function realized by the cavity as well as the resonant frequency of the cavity. Clearly, however, frequency and quality factor can not be independently adjusted in cavities of this type. In addition, such cavities provide no means for adjusting the effective electrical location of the cavity with respect to the waveguide to which they are coupled. A capability such as this is desirable to compensate for errors in the physical location or for changes in the effective electrical location of the cavity.

It is therefore an object of this invention to provide a microwave resonant cavity in which resonant frequency, quality factor, and effective electrical location can be adjusted independently or in any desired combination.

It is a more particular object of this invention to provide a microwave resonant cavity for use in rectangular waveguide systems in which resonant frequency, quality factor, and effective electrical location can be adjusted independently or in any desired combination.

SUMMARY OF THE INVENTION

These and other objects are accomplished, in a rectangular resonant cavity having conventional proportions and conventional coupling to a rectangular waveguide, by means of a unique configuration of tuning screws. In particular, a closed section of rectangular waveguide is inductively coupled to a rectangular waveguide line to form a resonant cavity perpendicular to the longitudinal axis of the waveguide line. A first tuning screw is positioned in one of the cavity walls so that it is parallel to the longitudinal axis of the wave-

guide line and so that it penetrates the cavity in the region of its closed end. A second tuning screw is located in the same cavity wall but is located so that it penetrates the cavity in the region of the waveguide coupling. A third tuning screw is located opposite the second tuning screw.

Any or all of the tuning screws may be employed to adjust the resonant frequency of the cavity. By proper adjustment of the combination of all three screws, the quality factor, Q , of the filter function realized by the cavity can be adjusted without affecting the resonant frequency of the cavity. Similarly, the effective electrical location (i.e., the apparent physical location) of the cavity can be adjusted without affecting either the resonant frequency or Q by the proper adjustment of the second and third tuning screws. Thus the resonant frequency, Q , and effective electrical location of the resonant cavity of this invention can be adjusted in any desired manner.

Further features and objects of the invention, its nature, and various advantages will be more apparent upon consideration of the attached drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partially cut-away perspective view of a prior art microwave resonant cavity;

FIG. 2 is a sectional view of the resonant cavity of FIG. 1;

FIG. 3 is a partially cut-away perspective view of the microwave resonant cavity of this invention;

FIG. 4 is a sectional view of the resonant cavity of FIG. 3;

FIG. 5 is a sectional view of another embodiment of this invention; and

FIG. 6 is a sectional view of yet another embodiment of this invention.

DETAILED DESCRIPTION OF THE INVENTION

In the prior art apparatus of FIGS. 1 and 2, resonant cavity 12 is coupled inductively to rectangular waveguide 10 by means of circular coupling aperture 16 and stud 14. Rectangular waveguide 10 has major and minor cross-sectional dimensions determined by the frequencies of the signals to be supported therein and by the desired mode or modes of propagation of those signals. Waveguide systems are most frequently designed to transmit the desired signal frequencies only in the fundamental mode. In rectangular waveguides this is the H_{10} or TE_{10} mode. The dimensions of waveguide 10 may therefore be chosen to prevent the propagation of energy in modes other than this fundamental mode.

Cavity 12, arranged with its longitudinal axis perpendicular to the longitudinal axis of waveguide 10, has a rectangular cross section with major and minor dimensions equal, respectively, to the major and minor cross-sectional dimensions of waveguide 10. Other cross-sectional dimensions are, of course, possible for cavity 12. As is well known, the presence of cavity 12, inductively coupled to waveguide 10 as shown in FIG. 1, will substantially attenuate signals in a particular predetermined frequency band propagating in the waveguide. Such cavities are therefore frequently employed as bandstop filters. As a first approximation, to which well known corrections are generally applied, the center frequency, f_0 , of the stop band of such a filter will be the frequency whose guide wavelength, λ_g , is twice

the length of the resonant cavity. f_0 is known as the resonant frequency of the cavity.

It is well known that in a resonant cavity of the type shown in FIGS. 1 and 2, the inclusion of a tuning screw 18 in one of the cavity walls defining the major dimension of the cavity cross section at a distance $\lambda_{g0}/4$ from the closed end of the cavity enables the adjustment of the resonant frequency of the cavity. Such a new screw has a capacitive loading effect determined by its penetration of the medium (usually air) enclosed by the cavity. Thus increased penetration of screw 18 lowers the resonant frequency of the cavity. As has been mentioned, however, it is also desirable to be able to make adjustments to other characteristics of such a cavity.

The apparatus of FIG. 3 is similar in purpose and effect to the apparatus of FIGS. 1 and 2. However, in accordance with the principles of this invention, the apparatus of FIG. 3 includes a resonant cavity 20 with three tuning screws. Of these three screws, screw 22 is threaded through one of the walls defining the major dimension of the cross section of cavity 20 and protrudes transversely into the medium enclosed by the cavity in the region of its closed end. Screw 24 is threaded through that same cavity wall and protrudes transversely into the medium enclosed by the cavity in the region of waveguide coupling aperture 16. Screw 26 is similarly mounted directly opposite screw 24. Screws 22, 24, and 26 are in the same vertical plane, i.e., the plane defined by the longitudinal axes of waveguide 10 and cavity 20.

Just as increased penetration of screw 18 into the cavity of FIG. 1 lowers the resonant frequency of that cavity, increased penetration of any one or more of screws 22, 24, and 26 into cavity 20 of FIG. 3 has the effect of lowering the resonant frequency of cavity 20. Thus any of screws 22, 24, and/or 26 may be employed to adjust the resonant frequency of cavity 20. Screws 22, 24, and 26 may, however, also be employed to make adjustments to the quality factor and effective electrical location of cavity 20.

The quality factor, Q , of a resonant bandstop cavity is conveniently defined as

$$Q = f_0/f_2 - f_1$$

(1)

where f_0 is as defined above and is thus the frequency of greatest attenuation and f_2 and f_1 are respectively the frequencies above and below f_0 at which attenuation has dropped to some predetermined fraction of attenuation at f_0 (e.g., attenuation at f_1 and f_2 is 3db less than at f_0). Q is thus a measure of the sharpness of the frequency response of the cavity.

The quality factor of the cavity of FIG. 3 is increased by reducing coupling between the resonant electromagnetic field in cavity 20 and the signal energy propagating in waveguide 10. Coupling can be thus decreased by perturbing or displacing the electromagnetic field in cavity 20 away from coupling aperture 16. This is accomplished by either increasing the penetration of screws 24 or 26, or by decreasing the penetration of screw 22. Increasing the penetration of screw 24 and/or screw 26, without changing the penetration of screw 22, effects an increase in Q with an attendant decrease in f_0 . Decreasing the penetration of screw 22, without changing the penetration of screws 24 and 26, also effects an increase in Q but, with an attendant in-

crease in f_0 . Thus, by means of changes in the relative penetrations of screws 22, 24, and 26 as described above, Q can be changed with or without alteration of resonant frequency. Q can be reduced while maintaining the desired frequency control by retracting screws 24 and 26 and increasing the penetration of screw 22.

Yet another adjustment of the characteristics of the resonant cavity of FIG. 3 is possible. By increasing the penetration of screw 24 while decreasing the penetration of screw 26, the point of effective coupling between cavity 20 and waveguide 10 can be translated to the right along the longitudinal axis of waveguide 10. Conversely, retraction of screw 24 and further insertion of screw 26 produces a leftward translation of the point of effective coupling between cavity 20 and waveguide 10. These changes in the effective electrical location of cavity 20 are again caused by the influence of screws 24 and 26 on the field in the cavity in the proximity of aperture 16. In particular, an increase in the penetration of screw 24, for example, displaces the field in the cavity away from the wall in which screw 24 is mounted. To the field in the cavity, this effect is similar to a rightward translation of the portion of that wall in the vicinity of coupling aperture 16. Increased penetration of screw 24 is complemented by decreased penetration of screw 26 causing a slight rightward perturbation in the field near aperture 16 and thus a rightward translation of the effective center of coupling between the field in cavity 20 and that in waveguide 10. Such adjustments are ideally suited for making precise corrections for manufacturing tolerances and other perturbations in the location of the cavity along the waveguide line. It is to be noted that since one of screws 24 and 26 is further inserted to make adjustments of this type while the other is retracted, there is no net effect on the capacitive effect of the screws in the cavity. Thus no change in resonant frequency occurs. Similarly, there is no net change in the strength of coupling between cavity 20 and waveguide 10 and hence no change in Q . Accordingly, adjustment can be made to the effective electrical location of cavity 20 independently of resonant frequency and Q .

The positioning of screws 22, 24, and 26 in the vertical plane mentioned earlier is not critical. Screw 22 is generally located in the half of cavity 20 nearest the closed end of the cavity while screws 24 and 26 are generally located in the half of cavity 20 nearest coupling aperture 16. As shown in FIG. 4, these portions of cavity 20 are approximately delineated by a transverse plane parallel to the closed end of the cavity at a distance $\lambda_{g0}/4$ from that end.

There are, however, several factors which influence the choice of locations for screws 22, 24, and 26. The farther screws 22, 24, and 26 are displaced in the vertical plane from the transverse plane mentioned in the preceding paragraph, the less effective each screw is in tuning resonant frequency. On the other hand, as screw 22 is located closer to the closed end of cavity 20 and screws 24 and 26 are located closer to coupling aperture 16, the ability to tune Q is enhanced. Similarly, the effect of screws 24 and 26 on the effective electrical location of cavity 20 is increased by closer proximity of those screws to aperture 16. The particular vertical positioning of the screws shown in FIGS. 3 and 4 (i.e., screw 22 at approximately one eighth of the characteristic wavelength from the closed end of cavity 20 and screws 24 and 26 at a similar distance from coupling

aperture 16) will therefore be understood to represent only one of many possible compromises between these several considerations.

In some applications it may be unnecessary to have the ability to make adjustments in the apparent electrical location of a resonant cavity. FIG. 5 therefore illustrates a resonant cavity constructed according to the principles of this invention in which the resonant frequency and quality factor of the cavity can be adjusted separately or in combination by means of just two tuning screws. As in the apparatus of FIG. 3, either or both of screws 32 and 34 may be inserted into or retracted from the medium enclosed by cavity 30 to respectively lower or raise the resonant frequency of the cavity. In addition, the Q of cavity 30 can be increased or decreased by decreasing or increasing, respectively, coupling between the fields in cavity 30 and waveguide 10. A decrease in this coupling is produced by increasing the penetration of screw 34 and decreasing the penetration of screw 32. An increase in coupling is produced by opposite adjustments of screws 32 and 34. Again, the locations of screws 32 and 34 in the vertical plane will be determined by the various considerations discussed above, the particular locations shown in FIG. 5 being only one of many possible choices.

Just as in some applications it may only be necessary to have the ability to tune resonant frequency and quality factor, in other applications it may only be necessary to be able to adjust the effective location of a resonant cavity. In that event, the cavity can be arranged according to the principles of this invention as illustrated in FIG. 6, i.e., with two oppositely disposed tuning screws (44 and 46) in the half of the cavity (40) nearest the coupling aperture. Adjustment of the effective electrical location of cavity 40 can then be made by complementary changes in the relative penetrations of screws 44 and 46 in the same manner discussed in connection with adjustment of screws 24 and 26 in the apparatus of FIGS. 3 and 4.

It is to be understood that the embodiments shown and described herein are illustrative of the principles of this invention only and that modifications may be implemented by those skilled in the art without departing from the spirit and scope of the invention. For example, whereas tuning screws have been shown and described herein, any other, preferably adjustable, capacitive tuning means may be substituted therefor. Similarly, any of many locations may be chosen for these tuning devices as discussed in detail above.

What is claimed is:

1. Rectangular microwave resonant cavity apparatus having one closed end and being adapted at the other end for electromagnetic coupling to a rectangular waveguide wherein the improvement comprises first and second conductive members adapted for adjustable penetration of said cavity, each of said conductive members being positioned to substantially affect both the resonant frequency and quality factor of said cavity.

2. The apparatus defined in claim 1 wherein said first member is positioned to penetrate said cavity in the region of said closed end, and said second member is positioned to penetrate said cavity in the region of said end adapted for coupling, such that increased penetration of said first member effects a decrease in resonant frequency with an attendant decrease in quality factor, and increased penetration of said second member effects

a decrease in resonant frequency with an attendant increase in quality factor.

3. The apparatus defined in claim 2 further comprising a third conductive member adapted for adjustable penetration of said cavity from a direction opposite the direction of penetration of said second member, said third member positioned in the region of said end adapted for coupling to substantially affect both the resonant frequency and the quality factor of said cavity.

4. The apparatus defined in claim 1 wherein said members are positioned to penetrate said cavity from opposite directions, said members located in the region of said end adapted for coupling.

5. Microwave bandstop filter apparatus for attenuating microwave energy in a rectangular waveguide comprising:

a rectangular waveguide section having a longitudinal axis perpendicular to the longitudinal axis of said rectangular waveguide, said waveguide section having one closed end and an inductive coupling to said rectangular waveguide at the other end;

a first tuning screw positioned to affect both resonant frequency and quality factor, protruding into said waveguide section transverse to said longitudinal axis of said section in the half of said section nearest said closed end; and

second and third tuning screws, oppositely disposed, positioned to affect both resonant frequency and quality factor, protruding into said waveguide section transverse to said longitudinal axis of said section in the half of said section nearest said inductive coupling, said tuning screws located such that increased penetration of said first tuning screws effects a decrease in the resonant frequency of said cavity with an attendant decrease in quality factor, and increased penetration of said second and third tuning screws effects a decrease in said resonant frequency with an attendant increase in said quality factor.

6. The apparatus defined in claim 5 wherein said first, second, and third tuning screws are in the plane defined by the longitudinal axes of said waveguide and said waveguide section.

7. Microwave bandstop filter apparatus for attenuating microwave energy propagating along the longitudinal axis of a rectangular waveguide, the attenuated energy having a characteristic guide wavelength, comprising:

a rectangular waveguide cavity having substantially the same cross-sectional dimensions as said rectangular waveguide, said cavity having a longitudinal axis perpendicular to said longitudinal axis of said rectangular waveguide, said cavity being closed at one end and having an inductive coupling to said rectangular waveguide at the other end, the length of said cavity being substantially equal to one half of said characteristic wavelength;

a first tuning screw positioned to affect both resonant frequency and quality factor, protruding into said cavity transverse to said longitudinal axis of said cavity at a distance from said closed end substantially equal to one eighth of said characteristic wavelength; and

second and third tuning screws oppositely disposed, positioned to affect both resonant frequency and quality factor, protruding into said cavity trans-

verse to said longitudinal axis of said cavity at a distance from said inductive coupling substantially equal to one eighth of said characteristic guide wavelength.

8. The apparatus defined in claim 7 wherein said first, second, and third tuning screws are in the plane defined by the longitudinal axes of said waveguide and said waveguide section.

9. Microwave bandstop filter apparatus for attenuating microwave energy propagating along the longitudinal axis of a rectangular waveguide, said attenuated energy having a characteristic wavelength, comprising:

a rectangular waveguide section having a longitudinal axis perpendicular to said longitudinal axis of said rectangular waveguide and approximately one half of said characteristic wavelength in length, said waveguide section having one closed end and an inductive coupling to said rectangular waveguide at the other end;

tuning means positioned to affect both resonant frequency and quality factor, protruding into said waveguide section transverse to said longitudinal axis of said section at a distance from said closed end substantially equal to one eighth of said characteristic wavelength; and

a pair of tuning means, oppositely disposed, positioned to affect both resonant frequency and quality factor, protruding into said waveguide section transverse to said longitudinal axis of said section at a distance from said inductive coupling substantially equal to one eighth of said characteristic wavelength.

10. The apparatus defined in claim 9 wherein said first, second, and third tuning means are respectively first, second, and third tuning screws threadably mounted through the walls of said cavity.

11. Microwave bandstop filter apparatus for attenuating microwave energy propagating along the longitudinal axis of a rectangular waveguide, said attenuated energy having a characteristic wavelength, comprising:

a rectangular waveguide section, having a longitudinal axis perpendicular to said longitudinal axis of said rectangular waveguide, approximately one-half of said characteristic wavelength in length, said waveguide section having one closed end and an inductive coupling to said rectangular waveguide at the other end;

first tuning means, positioned to affect both resonant frequency and quality factor, protruding into said waveguide section transverse to said longitudinal axis of said waveguide section at a distance from said closed end substantially equal to one-eighth of said characteristic wavelength; and

second tuning means positioned to affect both resonant frequency and quality factor, protruding into said waveguide section transverse to said longitudinal axis of said waveguide section at a distance from said inductive coupling substantially equal to one-eighth of said characteristic guide wavelength.

12. The apparatus defined in claim 11 wherein said first and second tuning means penetrate the same wall of said rectangular waveguide section.

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