TRIPLE–MODE DIELECTRIC RESONATOR LOADED CAVITY①

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Abstract––with dual HE_{11} and single $TM_{01\delta}$ in dielectric loaded cavities, six–pole elliptic function bandpass filter was realized, and the measured result was given.

I. INTRODUCTION

The single–cavity multiple–mode filters were first introduced by W.G.Lin in 1951 [1], Atia et al extended this idea to multicoupled cavities and realized microwave multiple–coupled cavity bandpass filter [2]. Based on the dual –made waveguide filter, the dual–mode (two orthognal HE_{11}) dielectric resonator (DR) loaded cavity filters have been developed [3]. Recently Tang et al presented a multiplex filter with dual HE_{112} and single TM_{011} mode dieletric resonator loaded cavity [4]. However, so far about the filter using triple–mode dielectric resonator loaded cavity has no detailed reports. No doubt, the use of triple resonant degeneracies of DR will yield further savings of volume and weight, and their application to microwave narrow–band, coupled–cavity filter has important value for space and terrene microwave communication equipment.

This paper describes a filter using triple–mode dielectric resonator loaded cavity with dual HE_{11} and single $TM_{01\delta}$ modes. The sample of C–band filter shows good agreement between theory and experiment.

II. THE EVALUATION OF THE RESONANT FREQUENCIES

The foundamental steps to realize the multiple–mode filter, are calculating the resonant frequencies of the dielectric resonator loaded cavity, drawing out mode–charts and finding out the available degenerate modes. We can use the magnetic wall method, finite element method, variation technique, mode–match method and open waveguide method to evaluate the frequencies of this DR loaded cavity. The more complete the considered boundary conditions, the higher the evaluation precision and the more complex the evaluating procedure. The open waveguide method has a certain precision that may satisfy the engineering requirement and has analysis charcteristic equations which is easy to solove. But it only applies to symmetrical TE modes and TM modes in published literatures. We noticed that the characteristic equations also are applicable for mixed modes, by treating the boundary conditions appropriately. A circular cylindrical dielectric resonator is laid in a cavity symmetrically, and the cavity is divided into four regions as shown in Fig.1. As an approximate method, the fields in the regions TV are neglected. Solving the electromegnetic equations in regions I, II, III, and using the boundary conditions on the surfaces $r=a$, $z=\pm 1/2$, we obtain the characteristic equations of the mixed modes

$$\left[\frac{J_n'(u)}{uJ_n(u)}+\frac{R_n'(v)}{vR_n(v)}\right]\left[\frac{\varepsilon_{r1}J_n'(u)}{uJ_n(u)}+\frac{\varepsilon_{r2}P_n'(v)}{vP_n(v)}\right]=\frac{\beta^2 n^2}{k_o^2}\left(\frac{1}{u^2}+\frac{1}{v^2}\right)^2 \quad (1)$$

where

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$$P_n(v)=I_n(\frac{v}{a}b)K_n(v)-K_n(\frac{v}{a}b)I_n(v)$$

$$P_n'(v)=I_n(\frac{v}{a}b)K'(v)-K_n(\frac{v}{a}b)I_n'(v)$$

$$R_n(v)=I_n'(\frac{v}{a}b)K_n(v)-K_n'(\frac{v}{a}b)I_n(v)$$

$$R_n'(v)=I_n'(\frac{v}{a}b)K_n'(v)-K_n'(\frac{v}{a}b)I_n'(v)$$

and

$$\beta l=p\pi+2tg^{-1}\left[\frac{\alpha}{\beta}cth(\alpha\frac{L-l}{2})\right] \tag{2}$$

or

$$\beta l=p\pi+2tg^{-1}\left[\frac{\varepsilon_{r1}\alpha}{\varepsilon_{r3}\beta}th(\alpha\frac{L-l}{2})\right] \tag{3}$$

where p = 0,1,2,3,.......

Between the characteristic parameters u, v, β, α, k there exist the following relationships:

$$\beta^2+u^2/a^2=k_o^2\varepsilon_{r1}=\omega^2\mu_o\varepsilon_o\varepsilon_{r1} \tag{4}$$
$$\beta^2-v^2/a^2=k_o^2\varepsilon_{r2}=\omega^2\mu_o\varepsilon_o\varepsilon_{r2} \tag{5}$$
$$-\alpha^2+u^2/a^2=k_o^2\varepsilon_{r3}=\omega^2\mu_o\varepsilon_o\varepsilon_{r3} \tag{6}$$

where ε_{r1} , ε_{r2} , ε_{r3} , is the dielctric constant of the resonator, the supports and air , respectively.

In eqution (1), if n = 0, then we obtain

$$\frac{J_o'(u)}{uJ_o(u)}+\frac{R_o'(v)}{vR_o(v)}=0 \tag{7}$$

$$\frac{\varepsilon_{r1}J_o'(u)}{uJ_o(u)}+\frac{\varepsilon_{r2}P_o'(v)}{uP_o(v)}=0 \tag{8}$$

Solving equations (1), (4), (5), (6) and (2) or (3) simultaneously, we can get the resonator's resonant frequencies of HE modes. Solving equations (2), (4), (5), (6), (7) , we can get the results of TE modes. Solving equations (3), (4), (5), (6), (8) , we can obtain the results of TM modes

With the computer, we can calculate the frequencies of several lower modes for different sizes of the resonator, which is called the mode charts. To verify the validity of this method, we made a comparison between computer results of the technique presented above and reference [5] The evaluted mode chart for a dielectric–loaded cavity of same parameters is given in Fig.2 . It shows the differences in both do not exceed 3%.

Ⅲ . SELECTION OF MULTIPLEMODE OPERATION,AND DETERMINATION OF DR LOADED CAVITY SIZE

With the help of mode chart, it is observed that , the resonant frequencies of HEH_{01} and TME_{01} , or TME_{01} and HEE_{01} , or HEH_{12} and TEE_{01} , or TEE_{01} and HEE_{12} , ...etc. are degenerate at certain L / 1. Thus, they are available for the multiplemode filter. But we think that to obtain excellent electric and mechanical performance, the following several points should be considered:

(a) Should has the widest spurious–free stopband;

(b) The degenerated modes should have dissimilar field patterns at the intercavity iris for provision of independent mode coupling between the two different cavities;

(c) Size of dielectric resonator loaded cavity should be small. Taking into account of these points, it is evident that dual HEH_{11} and single TME_{01} is a good choice.

Usually the method to find the multiple–mode resonant frequency degeneracies is to seek a suitable L / 1 where the curve of f_o (HEH_{11}) vsL / 1 intersects the curve of f_o (TME_{01}) vs L / 1 at identical f_o . However, at some points of intersection, f_o is sensitive to L / 1. In addition, synthesis of DR loaded cavity is puzzled by calculation error. We find that f L / 1 exceedes a certain value for suitable 2a / 1 of DR, the curves of f_o (HEH_{11}) vs L / 1 and f_o (TME_{01}) vs L / 1 are flat and overlapping . It is convenient for construction of triple–mode resonator. As an example , Fig.3 shows the effects of varying 2a / 1, in Fig.3 (a), two curves have an intersecting point at L / 1 = 1.75; in Fig.3 (b) , two curves combine into one for L / 1 > 2.5; in Fig.3(c) , two curves are separate for all L / 1. It is thus obvious that in Fig.3(b) L / 1 has wider range of choice for same degenerated resonant frequency. For this reason, Fig.3(b) is desirable.

Theoretical analysis shows, the side wall effect can be neglected if a / b > 1.5, where b and a is radius of cylindrical wavegide and DR, respectively. In case 2a / 1 is given, vary radius a of DR, different resonant frequency is obtaind. In other words, appropriat 2a of DR can meet demands of bandpass filter center frequency.

Ⅳ. REALIZATION AND MEASURED RESULT OF THE FILTER

Experimental sample of a triple–mode, six–pole elliptic function bandpass filter with dual HEH_{11} and TME_{01} modes DR loaded cavity, is made. Fig.4(a) is the outside view of the filter . The cylindrical dielectric resonator is placed symmetrically within the metallic cavity. Equivalent circuit of the filter is shown in Fig.4(b) . Filter parameters obtained are as Table 1.

Table 1 Filter parameters

Center frequency (GHz)	5.11
Bandwidth (MHz)	45
Normalized input and output impedance (R_1 ,R_2)	1.25
Coupling matrix 〔M〕	

$$
\begin{bmatrix}
0 & 0.921 & 0 & 0 & 0 & -0.047 \\
0.921 & 0 & 0.593 & 0 & 0.247 & 0 \\
0 & 0.593 & 0 & 0.769 & 0 & 0 \\
0 & 0 & 0.769 & 0 & 0.593 & 0 \\
0 & 0.247 & 0 & 0.593 & 0 & 0.921 \\
-0.047 & 0 & 0 & 0 & 0.921 & 0
\end{bmatrix}
$$

In the DR loaded cavity, dual HEH_{11} modes are mathematically and geometrically orthogonal , so they can tuned and coupled independently by a set of screws located at the cavity's side wall (Fig.5(a)). For the TME_{01} mode, it can be tuned by perturbing the longitudinal electric field component Ez with screw located at the end of cavity (Fig.5(b)). The couplings in a cavity are provided by 45 degree screws, and between different cavities by an iris, as Fig.5(b) and (c), respectively.

The measured result of this filter shown in Fig.6 exhibits good agreement with theoretical design.

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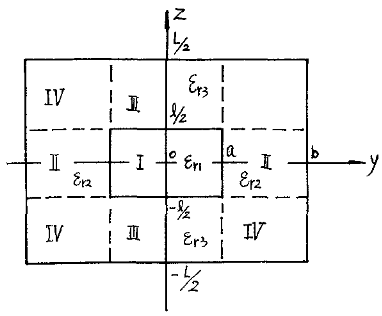
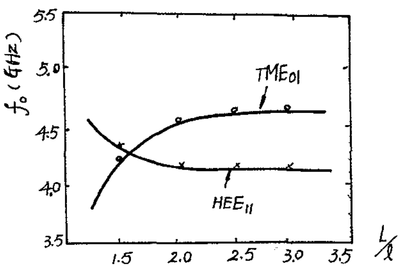


Fig. 1.



$\varepsilon_{r1}=35.74$, $l=7.62mm$, $a=8.636mm$

$b=14.478mm$.

—— After [5]

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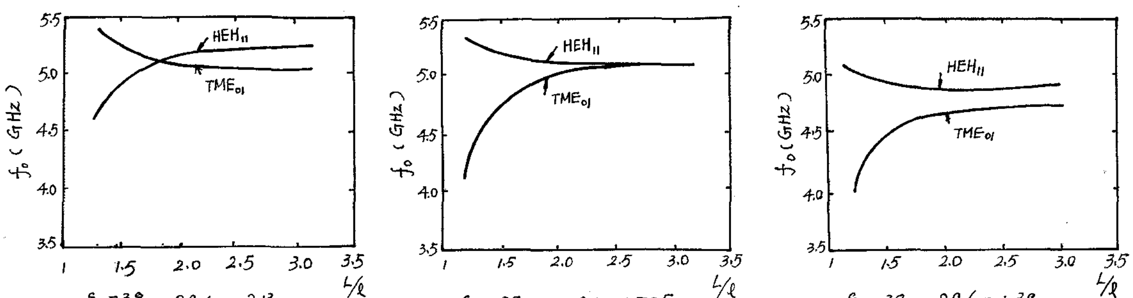
Fig. 2.



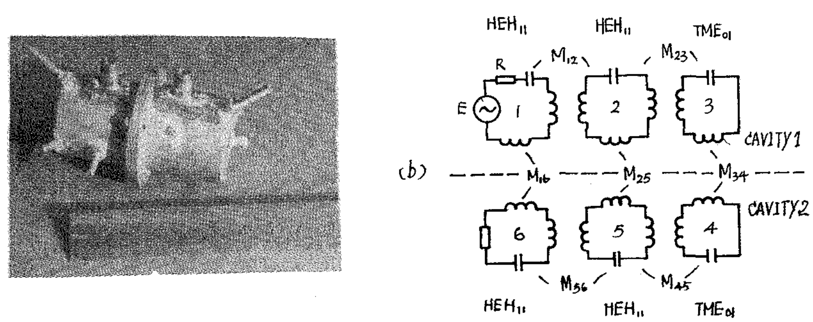
$\varepsilon_r=38$, $2a/l=2.13$, $a=6.9mm$, $b=12.5mm$ (a)

$\varepsilon_r=38$, $2a/l=1.725$, $a=6.9mm$, $b=12.5mm$ (b)

$\varepsilon_r=38$, $2a/l=1.38$, $a=6.9mm$, $b=12.5mm$ (c)

Fig. 3.

Fig.4. (a)



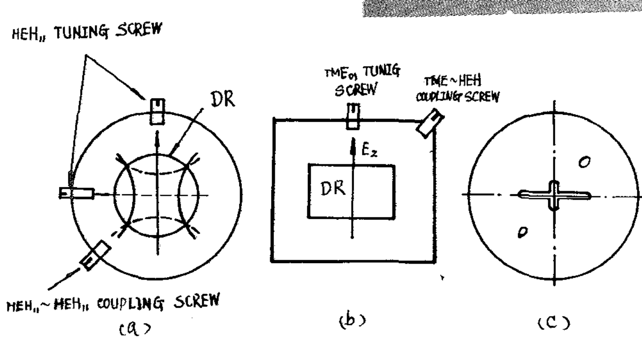


Fig. 5

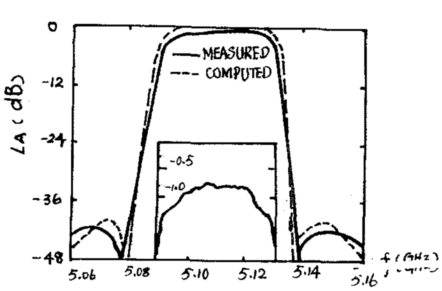


Fig. 6