Mixed Modes Cylindrical Planar Dielectric Resonator Filters with Rectangular Enclosure

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ABSTRACT

A compact mixed modes cylindrical planar dielectric resonator filter in rectangular enclosure with excellent spurious free performance is presented. Space coupling between different mode's dielectric resonators and iris coupling between identical mode's dielectric resonators are realized in the filters. All couplings are computed by rigorous full wave mode matching technique. A 6-pole elliptic function filter is designed, constructed and tested. Excellent filter frequency response is obtained.

I. INTRODUCTION

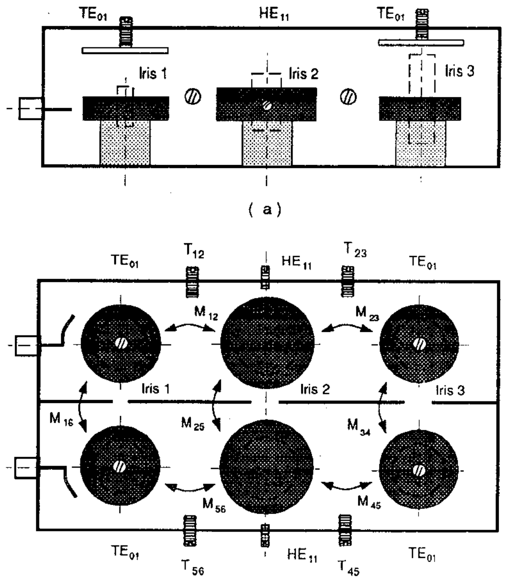
Dielectric resonator loaded filters play an important role in mobile communications. Significant development efforts have been spent and great progress has been achieved in D.R. Filters technology since the end of 1960's [1-5]. However, the couplings between resonators are usually realized by iris, and cavities are mostly cylindrical enclosures. Planar dielectric loaded resonators [6] have good mechanical stability, but irises are required at different sides of cavity, which makes the structure of the filter more complex and more difficult to tune. Furthermore, the contact between the cavities will tend to be poor.

Dielectric resonator filters without iris operating in dual HE_{11} mode were described in [4]. The draw back of this kind of filters is its inferior spurious characteristics. For TE_{01} (fundamental mode) single mode filters, suitable design of the coupling structure can suppress the transmission of the higher order modes [7]. To achieve the negative coupling between TE mode resonators, coupling probe is usually needed, and this will make the construction and adjustment of filter more difficult. A recent paper [9] reports on the application of mixing the TE_{01} and HE_{11} modes ring dielectric loaded cavity resonators in a quasi-elliptic function filter. The structure achieves good spurious performance.

In this paper, a new configuration of a dielectric resonator loaded cavity filter is proposed. Mixed TE_{01} and HE_{11} single mode planar dielectric resonators are used in the filter. Space coupling between different mode's dielectric resonators and iris coupling between identical mode's dielectric resonators are realized in the filters. Rigorous full wave mode matching technique is used to compute all the coupling coefficients. The computed results are compared with the experimental results, and it is shown that they are in good agreement. A 6-pole elliptic function filter is designed, constructed and tested. Excellent filter frequency response is obtained.

II. CONFIGURATION AND ANALYSIS

A typical structure of a 6-pole canonical elliptic function planar dielectric resonator filter in a rectangular enclosure is shown in Fig. 1. The high permittivity dielectric is supported by a low dielectric constant material, and the structure has good mechanical stability. Two dielectric res-



(a)

(b)

Fig. 1 The structure of the 6-pole elliptic function filter (a) side view (b) top view.

onators in the middle of the filter are operating in single HE_{11} mode. With the HE_{11} mode dielectric resonator, negative coupling can be obtained by iris easily, so that elliptic function response can be realized. The coupling between dielectric resonators operating in same mode are achieved by irises. Direct space couplings are used in the filter between TE_{01} and HE_{11} mode dielectric resonators. The spacing between TE_{01} and HE_{11} resonators to achieve a certain coupling is much less than that between two TE_{01} mode dielectric resonators to achieve the same coupling. This property makes the structure of the filter compact, very simple and easy to build.

The space coupling between TE_{01} and HE_{11} mode dielectric resonators can be changed by tuning the screws T_{12}, T_{23}, T_{45} and T_{56} at the side wall as shown in Fig. 1. The metal plungers over the TE_{01} mode resonators are used to tune their resonant frequencies. The tuning screws at the side of the HE_{11} mode dielectric resonators are used to change their resonant frequencies. Because there is no conducting wall between the TE_{01} mode dielectric resonator and the HE_{11} mode dielectric resonator, the resonant frequency of the undesired orthogonal HE_{11} mode is much

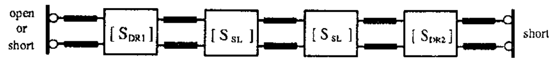


Fig. 2 Equivalent scattering matrix network of two different mode dielectric resonators through a slot.

higher than that of the operating HE_{11} mode, thus enabling single mode operation of the HE_{11} mode.

Rigorous analysis method (the mode matching technique) is used to compute the resonant frequencies of the dielectric resonators and the coupling coefficients [8]. By placing a perfect electric conductor (PEC) wall and a perfect magnetic conductor (PMC) wall, the corresponding resonant frequencies f_e and f_m are obtained. The coupling coefficient for single mode is given by:

$$k = \frac{f_e^2 - f_m^2}{f_e^2 + f_m^2} \tag{1}$$

To obtain the coupling coefficient between two dielectric resonators operating in two different modes, the resonators and the discontinuity between them are modeled by their equivalent generalized scattering matrices as shown in Fig. 2. One terminal port of the circuit is terminated with a short circuit, while the other port is terminated once with an open circuit and once with a short circuit. For each of the cases, the overall generalized scattering matrix of the structure is computed and the corresponding resonant frequencies are obtained. Those resonances are the natural frequencies of the structure f_{01}, f_{02} and f_p. Then the coupling coefficient can be computed by:

$$k^2 = 1 - \frac{\hat{f}^2 + f_p^2}{f_{01}^2 + f_{02}^2} \tag{2}$$

where

$$\hat{f}^2 = \frac{f_p^2 f_{01}^2 f_{02}^2}{f_p^2(f_{01}^2 + f_{02}^2) - f_{01}^2 f_{02}^2} \tag{3}$$

III. RESULTS

Fig. 3 shows the coupling coefficient between two TE_{01} mode dielectric resonators by a vertical iris versus the length of the iris. This coupling is achieved through the magnetic fields H_z of the respective modes. Thus only positive coupling can be realized. Fig. 4 shows the negative coupling coefficient between two HE_{11} mode resonators by a vertical iris as a function of the width of the iris. Negative coupling can only be achieved between the HE_{11} mode resonators through their radial electric fileds (E_r). The iris is rectangular shape and located at the center of the cross section plane. Fig. 5 shows the space coupling coefficient between TE_{01} and HE_{11} mode dielectric resonators versus the distance between two resonators. It is shown that the numerical solutions are in good agreement with the experimental results. The computed results obtained by the modified large aperture theory using the approximate equation $k^2 = k_{TE}k_{HE}$ – [9] are also shown in Fig. 5. The results of the approximation provide very good accuracy for small coupling values.

A 6-pole elliptic function filter with center frequency 4.035 GHz and bandwidth of 40.0 MHz is designed, built and tested. The normalized input/output resistances and coupling matrix elements of the filter as obtained from synthesis are: $R_1 = R_2 = 1.2475$, $M_{12} = M_{56} = 0.9415$, $M_{23} = M_{45} = 0.5909$, $M_{34} = 0.7953$. $M_{16} = 0.0566$ and $M_{25} = -0.2690$. Computed response of this filter is given in Fig. 6. The measured frequency response of the filter is shown in Fig. 7.

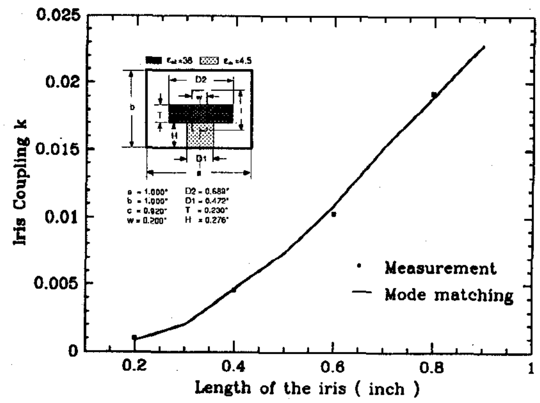


Fig. 3 TE mode coupling versus vertical iris length

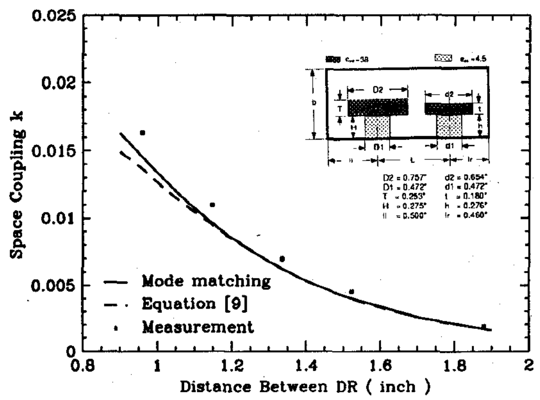


Fig. 5 Space coupling between HE and TE mode dielectric resonators.

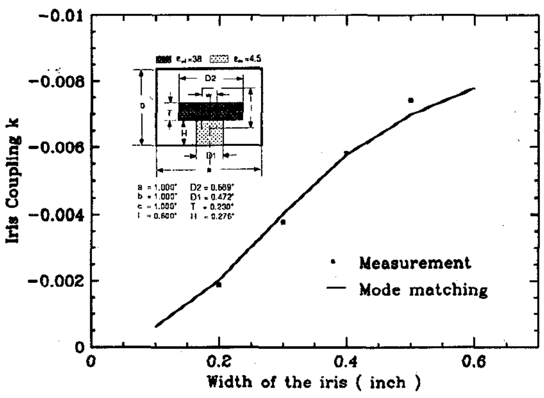


Fig. 4 HE mode negative coupling versus vertical iris width.

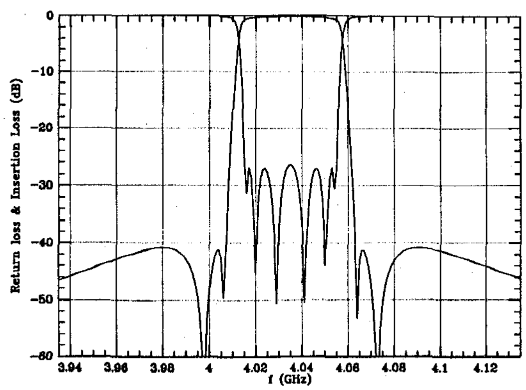


Fig. 6 Theoretical frequency response of the 6-pole elliptic function filter.

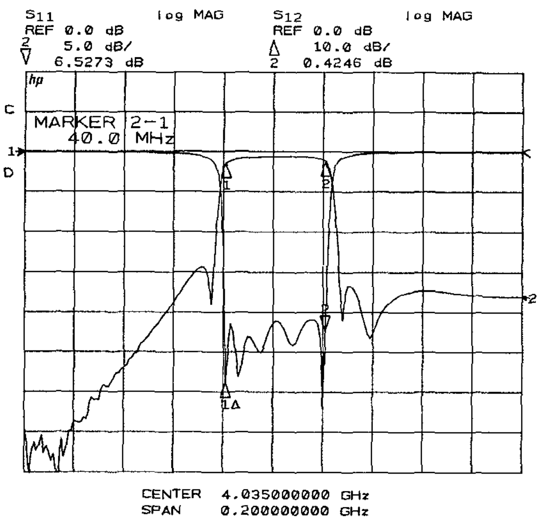


Fig. 7 Measured frequency response of the designed 6-pole elliptic function filter.

IV. CONCLUSION

A new type of mixed modes planar dielectric resonator filter in rectangular enclosure with good spurious performance and simple structure is presented. Rigorous analysis method is used to compute the coupling coefficient of the resonators. The numerical solutions are in good agreement with the measured results. A 6-pole elliptic function filter is designed, constructed and tested. Excellent filter frequency response is obtained

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