FULL-WAVE DESIGN AND ANALYSIS OF BANDPASS FILTERS USING $\frac{1}{8}$-CUT HIGH-Q DIELECTRIC RING RESONATORS

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1 Introduction

Bandpass filters constructed using $TE_{01\delta}$ dielectric rod resonators in a TE_{01} cutoff circular waveguide have been the focus of many publications [1]-[4]. Approximate expressions for the coupling coefficients between resonators were given by Cohn [2]. The Mode-Matching Technique (MMT) was used by Kobayashi and Minegishi to accurately determine the resonant frequencies of the resonators and therefrom the coupling coefficients of ring resonators [3]. A similar approach was followed in the design of 1/4-cut image resonators [4].
Despite the fact that the resonant frequencies of the individual resonators were determined from a full wave analysis, the effect of higher order modes on the performance of the interacting resonators was not addressed. In this paper, we propose to take into account these interaction and forgo the need for computing the resonant frequencies. The synthesis of the filter is performed from the scattering parameters of the dominant mode using the Coupled-Integral-Equation Technique [5]. The scattering parameters of the multiple interacting resonators are determined in a single step thereby taking into account all relevant higher order modes.
To further eliminate the spurious responses in these type of filters, 1/8-cut image resonators are used to guarantee that the TE_{01} mode is the dominant mode. Despite the reduction in the Q-factors of the resonators resulting from the reduction in the volume of the resonators, high Q-values can be obtained using materials of high dielectric constant appropriately positioned inside the waveguide.
Two design examples are presented to document the validity of the approach.

2 Method

The synthesis of the filter is carried out using the scattering parameters of the dominant mode in the dielectric loaded regions of the filter depicted in Figure 1. The dimensions of the cross section of are chosen such that, at the center frequency of the filter, the dominant mode is a "slow mode" to guarantee maximum size reduction . The normal modes of the dielectrically loaded region with no angular dependence are determined straightforwardly from a transcendental equation, they are not discussed here. Once these are known, they are used as basis functions in the application of the Coupled-Integral-Equation Technique

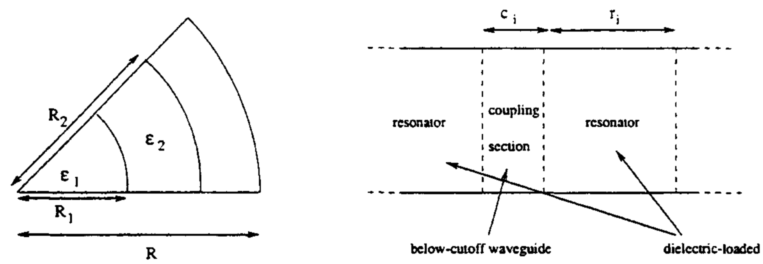

Figure 1: 1. Cross-section and side-view of a 1/8-cut dielectric loaded filter.

(CIET) [5] to determine the scattering parameters of the individual coupling sections whose lengths are adjusted to obtain the desired values of the inverters [6]. The lengths of the resonators are then determined from the propagation constant of the dominant mode at the center frequency following [6]. The analysis of the frequency response of the filter is then carried out in one step using the CIET [5]. Further details of the approach will be provided during the presentation.

3 Results

Two filters were synthesized and then analyzed using the approach described above. The first one is a 28-MHz with a 25 dB minimum return loss at the center frequency of 11.958GHz. The dimensions of the filter are summarized in Table I. The return and insertion losses as a function of frequency are shown in Figure 2 for 3 and 4 basis functions. More basis functions were used and led to only minor changes. In each case, 50 modes were used in the below-cutoff coupling sections. The convergence of the numerical solution is evident along with the fact that the original specifications of the filter are met. In comparison to a similar filter operating at the same frequency in an empty waveguide, the radius of the waveguide is reduced by a factor of approximately 2 since the TE_{01} mode starts propagating at 11.958 GHz when the radius is larger than 15.3 mm. The overall length is considerably reduced by designing the filter in the region where the "slow mode" is dominant. At the center frequency the guided wavelength is 11.59 mm while the free space wavelength is 25 mm. Assuming that the length of a 4-resonator filter is approximately twice the guided wavelength in a waveguide whose radius is 18 mm, at the center frequency of this filter (11.958GHz), the approximate length of the filter is 100 mm. Using the dimensions of the filter in Table 1, this corresponds ot a reduction in volume of the order of 8.

Table I

Dimensions of filter 1. $\epsilon_{r1} = 1.03$, $\epsilon_{r2} = 24$. $R_1 = 0.6$ R, $R_2 = 0.7$ R and R = 8.6 mm.

c_1/R	r_1/R	c_2/R	r_2/R	c_3/R	r_3/R	c_4/R	r_4/R	c_5/R
0.666	0.286	1.472	0.285	0.1.566	0.285	1.472	0.2856	0.666

Table II

Dimensions of filter 2. $\epsilon_{r1} = 1.03$, $\epsilon_{r2} = 24$. $R_1 = 0.5$ R, $R_2 = 0.7$ R and R = 41.5 mm.

c_1/R	r_1/R	c_2/R	r_2/R	c_3/R	r_3/R	c_4/R	r_4/R	c_5/R
0.3214	0.260	0.7747	0.254	0.8783	0.254	0.7747	0.260	0.3214

The second example is a 50-MHz filter with a 35dB minimum return loss in the passband with a center frequency of 2 GHz. The dimensions of this filter are shown in Table II. Figure 3 shows the return and insertion loss of this filter as a function of frequency again for 1 (dashed line), 5 (dashed dotted line) and 6 (solid line) basis functions and 50 modes in the coupling sections. It is evident that the original specifications are met by this design. The reduction in volume of this filter is of the order of 10 times. It is however, worth pointing out that the fabrication of the dielectric loaded filters is more demanding than that of the iris filters.

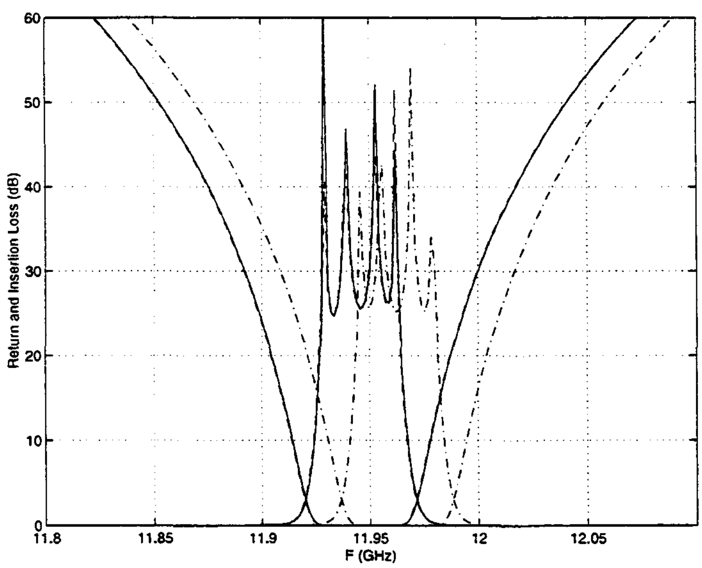

Figure 2: Return and insertion loss (dB) of filter 1 for 1 (dashed-dotted line), 5 (dashed line) and 6 (solid line) basis functions. Dimensions are given in table I.

4 Conclusions

TE_{01} filters using dielectric ring resonators were both synthesized and analyzed using a fullwave approach. Only 1/8 of a circular waveguide was used to suppress spurious responses. The response of the filters investigated are shown to satisfy the original specifications. The numerical solution reaches convergence with 6 basis functions.

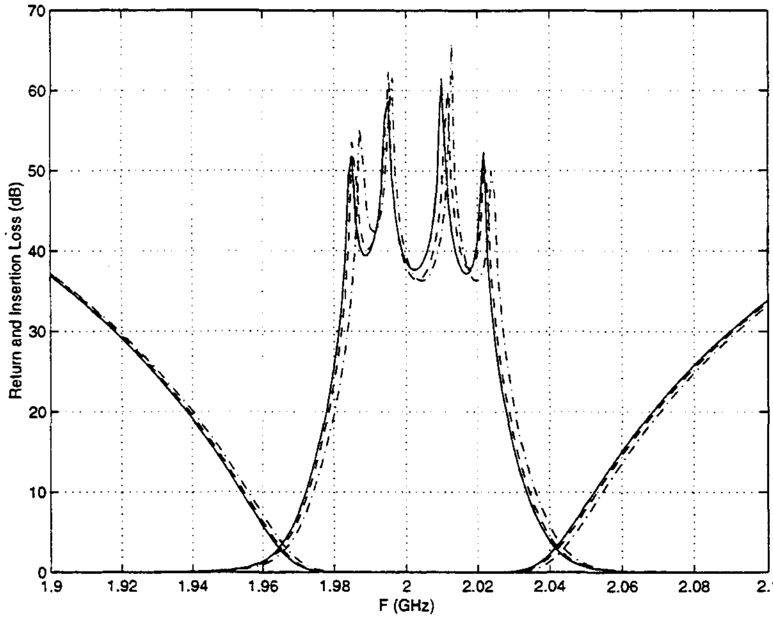

Figure 3: Return and insertion loss (dB) of filter 2 for 1 (dashed-dotted line), 5 (dashed line) and 6 (solid line) basis functions. Dimensions are given in table II.

5 References

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