PSEUDO-ELLIPTIC WAVEGUIDE FILTERS WITHOUT CROSS COUPLING

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Abstract: Pseudo-elliptic waveguide filters which do not include additional couplings between non-adjacent cavities are presented. A 5th order TE_{111} circular waveguide filter with three finite transmission zeros, a 3rd order E-plane filter with three finite transmission zeros and 5th order H-plane filter with two transmission zeros are presented. The designs, which are carried out using the Coupled-Integral-Equations Technique (CIET), are validated by comparison with the Mode Matching Technique (MMT).

INTRODUCTION

Elliptic and pseudo-elliptic bandpass waveguide filters are commonly designed by introducing cross coupling between non-adjacent resonators to generate the required finite transmission zeros [1], [2]. Despite the considerable progress in Computer Aided Design (CAD) techniques, these filters are eventually tuned manually to compensate for manufacturing tolerances and, most importantly, to reproduce the proper cross coupling coefficients. Indeed, available design techniques are not accurate enough when it comes to determining the physical dimensions of the coupling elements which implement the cross coupling coefficients and taking into account the loading effect of these coupling elements on the different resonators, hence the necessity of manual tuning.

An alternative approach consists in designing elliptic and pseudo-elliptic filters which do not contain cross coupling thereby eliminating altogether the difficult task of designing these cross couplings. In such a mechanism, the finite transmission zeros are generated by properly designed circuit elements such as stubs. It is, however, not efficient to limit the function of these circuit elements to generating the finite transmission zeros; they are also used to determine the in-band return loss of the filter, i.e., the inverters of the filter. This approach has been described in [3] and [4].

A major advantage of filters designed according to this second approach is their simple geometry which makes their accurate analysis and design using field-theory-based techniques much simpler than cross-coupled filters in general. In this paper, we present three filters which contain no cross coupling to further demonstrate the range of results that can be achieved using this technique.

INITIAL DESIGN

We focus on structures which contain an arbitrary number of directly coupled resonators as shown in Figure 1 for the case of two resonators. The coupling between adjacent resonators is performed by coupling irises or stubs.

The initial design of the filters attempts to determine the dimensions of the coupling sections and resonators to reproduce the filter specifications. The frequency-dependent coupling sections, which are implemented using stubs, are required to produce one or more transmission zeros at prescribed frequencies and give the correct inverter value at the center frequency of the filter. The target values of the inverters are given in the classic paper of Cohn [5], as discussed in [4]. For circular filters using the TE_{111} mode, we found that this simple criterion does not give satisfactory initial designs. Instead, the coupling section is required to give an inverter value whose deviation from the target value over the entire passband is minimum in addition to producing the prescribed zeros. A separate optimization of the zero-generating coupling sections can lead to better filters and may be even necessary for broader band cases. The design is then finalized by optimization using the Coupled Integral Equation Technique (CIET) as an accurate, fast and reliable analysis tool [6].

An important difference between the approach used here and the pole extraction method [7], is that the zero-generating elements do not have to be located immediately at the input and output of the filter thereby offering more flexibility to the design engineer.

RESULTS

The first example (filter 1) is a 5-pole circular waveguide filter, designed at 29.5GHz with an equiripple bandwidth of 1GHz (return loss 23dB) exhibiting two transmission zeros in the lower and one the upper stopband. The zeros are located at 27.68GHz, 28.12GHz and 35.4GHz, respectively. The filter is basically realized with TE_{111} mode cavity resonators. To generate these transmission zeros, the first coupling section from the input and output are implemented using radial stubs whose width and length are adjusted during the design. The remaining coupling sections are standard 1 mm-thick circular irises. The design is then finalized by optimization.
Figure 2 shows the response of the optimized filter (solid line) and the response of the prototype. The agreement between the two responses is excellent in the passband and the lower stopband including the position of the zeros. Despite the agreement in the location of the zero in the upper stopband, the prototype outperforms the designed filter due to the strong effect of higher modes which is a known problem for iris filters. More zeros could be included in the upper stopband to improve the response of the filter to some extent; the effect of higher modes is too strong and end up prevailing especially away from the passband.

To validate the design, Figure 3 shows the response of the filter computed using the Couple-Integral-Equations Technique (CIET) (solid line) and the Mode-Matching Technique (MMT) (dotted line). The agreement between the two methods is excellent. Also shown in the same figure is the response of the initial design (dashed line). Although the in-band response is not satisfactory, the location of the transmission zeros are well accounted for.

The second example (filter 2) is a 3 resonator E-plane filter with three transmission zeros, two of which are in the lower stopband. This filter is designed at 11 GHz having an equiripple bandwidth of 200 MHz (return loss 20 dB). The transmission zeros are located at 9.17 GHz, 10.44 GHz and 11.52 GHz, respectively. The first and last coupling sections are implemented using stubs while the remaining ones use E-plane septa.

The response of the optimized filter is shown in Figure 4 (solid line). The dashed line is the response of the prototype and is in close agreement with the designed filter except in parts of the lower stopband. This is due to dispersion effects.

The final example (filter 3) is a 5-pole H-plane filter at 9.15GHz with an equiripple bandwidth of 130 MHz (return loss 22 dB) that realizes two transmission zeros at 8.8 GHz and 9.55 GHz.

Figure 5 shows the response of the optimized filter (solid line). All the specifications are met, in particular the presence of the two transmission zeros. For comparison, the response of the prototype is also shown (dashed line). The agreement between the two is good except away from the passband where the effect of dispersion and higher order modes lower the selectivity. Filters 2 and 3 of Figures 4 and 5 were also verified by MMT calculations. Comparisons are not shown here as agreement within the plotting accuracy is achieved.

CONCLUSIONS

Pseudo-elliptic microwave waveguide filters which do not contain cross couplings are presented. Example filters in E-plane, H-plane and circular waveguide technologies are presented to demonstrate the performance of this kind of filters.

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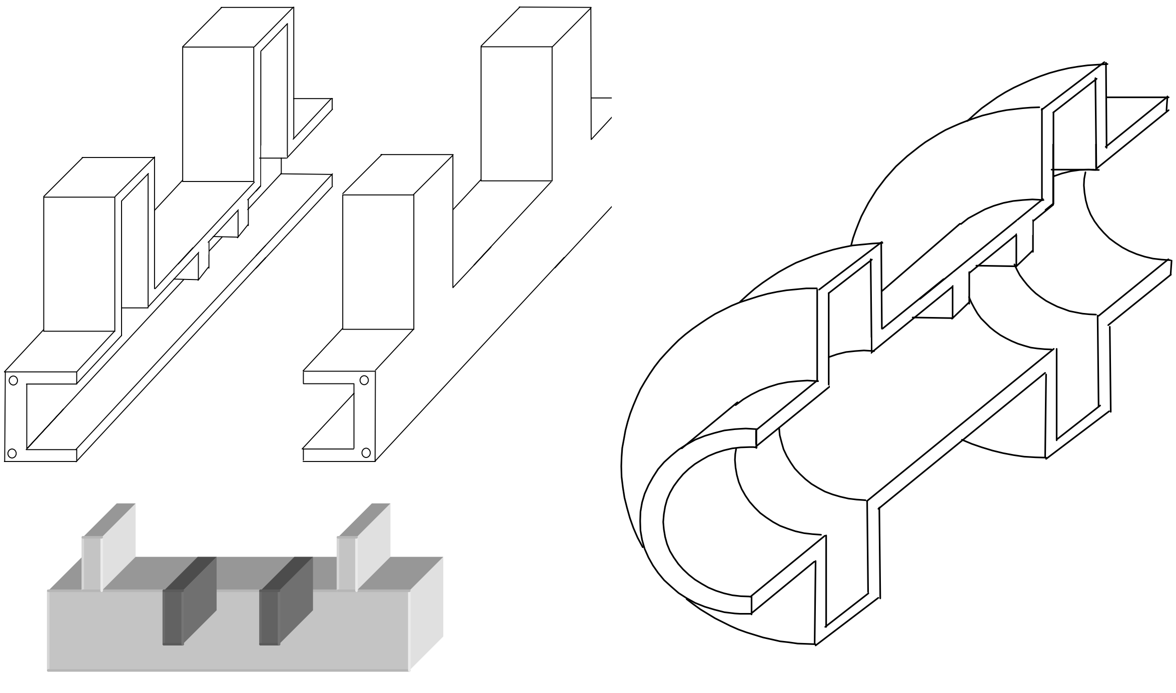

Figure 1. Structures used (3 resonators) for E, H-plane and circular waveguide filters.

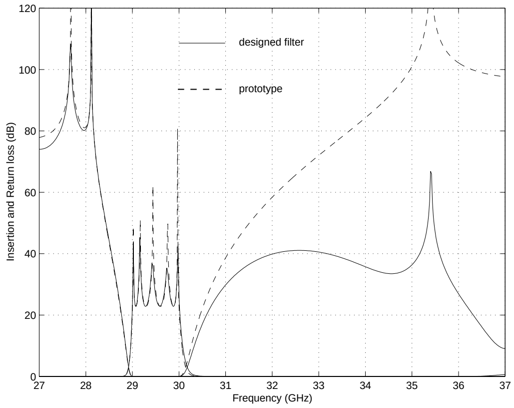

Figure 2. Insertion and return loss of filter 1. Solid line: optimized design, dashed line: prototype.

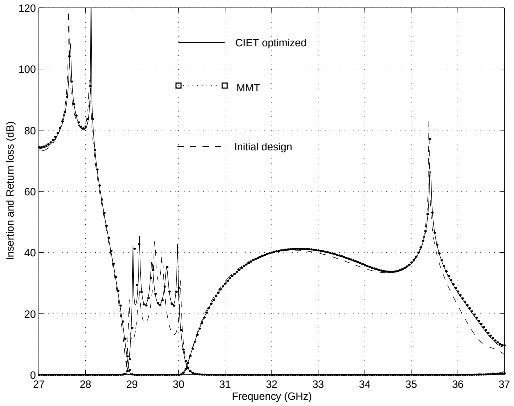

Figure 3. Insertion and return loss of filter 1. Solid line: CIET, dotted line: MMT, dashed line: initial design.

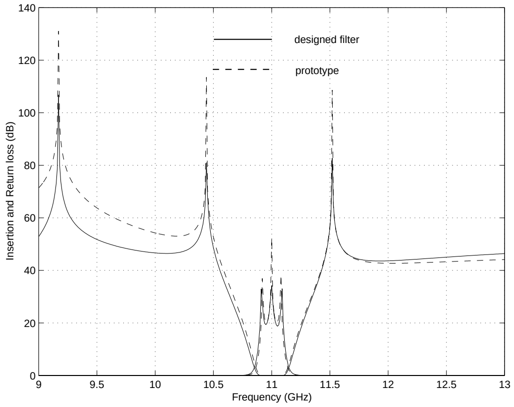

Figure 4. Insertion and return loss of filter 2. Solid line: optimized, dashed line: prototype.

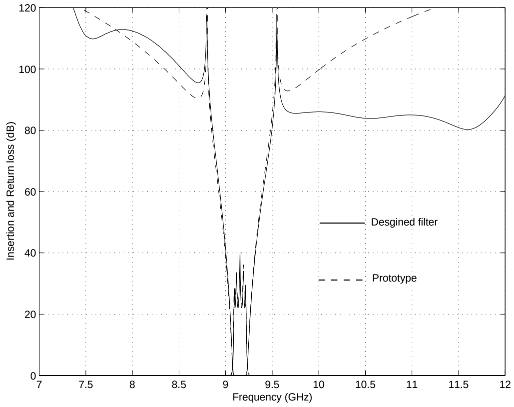

Figure 5. Insertion and return loss of filter 3. Solid line: optimized, dashed line: prototype.