Field Theory Based CAD of Inductive Iris Waveguide Filter

Vijay Kumar Chaudhary, Prakash Verma, Uma Balaji

Dept. of Electrical Engineering,
Indian Institute of Technology, New Delhi
ubalaji@ee.iitd.emet.in

Computer aided design of inductive iris filter in waveguide technology is described here using Mode Matching Method (MMM). Direct coupled cavity filters form compact structures. Such a bandpass filter is first designed using equivalent network theory approach. Mode matching method has been used to analyze discontinuities present in the filter and hence its performance is obtained. Using optimization techniques the analyzed filter dimension are altered to improve its performance.

1 Introduction

Direct coupled cavity filters have the advantage that the physical structure is more compact than the quarter wave coupled filters. Design procedure for such bandpass filters are available in [1,2]. Mode matching method is a very useful tool in the computer aided design of such waveguide filters. Further, optimization of the performance is necessary as the design based on equivalent network theory approach yields filters which may need some amount of tuning. This paper discusses the design of direct coupled cavity filter based on Mode matching method and optimization as a tool to improve the performance.

2 Theory

The analysis of any discontinuity using MMM involves the following steps. The fields on both sides of the discontinuity are expanded in terms of a series of modes of incident and reflected waves. The magnitude of power carried by each of the modes is set to unity. The continuity conditions for the tangential components of electric and magnetic fields are imposed. Using the principle of orthogonality of modes, the equations of continuity conditions are transformed into matrices relating the expansion coefficients of incident and reflected waves at the discontinuity. The matrices are rearranged and inverted suitably to obtain the generalized scattering matrix which describes the discontinuity in terms of the dominant and higher order modes. Theoretically the generalized scattering matrix is of infinite dimension corresponding to the infinite number of eigenmodes. The matrix is truncated to a finite size for numerical computations after testing the convergence of the s-parameters.

The inductive iris direct coupled cavity filter constitutes inductive iris followed by empty sections of waveguide as shown in Figure 1 and Figure 2. The inductive iris is formed by the discontinuity from an empty waveguide to that of a waveguide of narrower broad wall. It is a H-plane discontinuity. Such a discontinuity can be analyzed using Mode Matching Method by considering $TE_{m0}$ modes alone for fundamental $TEQ$ excitation as it does not excite any other higher order modes. It is therefore necessary to match only $E_y$ and $H_x$ in order to characterize the discontinuity. The electric field in the regions I and II of the discontinuity can be written as

$$E_y = \sum_{n=1}^{M} F^n H^n e^{ipW} e^{i\phi^*}$$  \(1\)
where $f_{c_I}$, are the propagation constants in the regions $I$ and $II$ of the fundamental and evanescent modes. The coefficients $P$ represent the power normalization constants and are obtained by setting the magnitude of the power carried in each of the modes to unity. The magnetic field $H_x$ in each regions can be obtained from admittance of the waveguide and $E_y$ for each of the modes. The matching condition at the interface of the discontinuity are

$$E_y^* = E_y' \quad 01 < x < a_2$$

$$H_i = H_i' \quad a_1 < x < a_2$$

Using the above matching conditions plus principle of orthogonality and algebraic manipulations the following sets of algebraic equations are obtained,

$$[A' + B'] = [L](A'' + B'')$$

$$[A''-B''] = [L]'[A' - B']$$

where $[L]$ and $[L]'$ are the coupling integral matrices that relate the unknown incident and reflected waves at the discontinuity and are given in the appendix. The size of these matrices are determined by the number of modes incorporated in the analysis of the discontinuity. Algebraic manipulations on the above equations result in the generalized scattering matrix of the discontinuity from empty rectangular waveguide to a narrower waveguide.

Inductive iris filter constitutes a finite length of inductive iris followed by empty waveguide sections (Figures 2 and Figure 3). The generalized scattering matrices of a finite length of H-plane discontinuity are obtained by considering the propagation of the fundamental and evanescent modes in the finite length section [1]. The generalized scattering matrix of the filter is obtained by cascading the generalized scattering matrices [1] of a the discontinuity in the filter.

The filter is first designed using the design formulae developed by Cohn and presented in [2]. The initial dimension of the inductive iris are obtained from the equivalent network theory approximation for a very thin inductive iris [4]. The performance of the filter can be improved by using optimization. In order to optimize the performance an error function is minimized at selected frequency points in the passband and stopbands of the filter. The error function is based on the insertion loss and return loss characteristics in the passband and stopband of the filter. A practical quasi Newton algorithm [3] has been utilized for this purpose.

### 3 Results

A program to analyze the H-plane discontinuity was developed. It was observed that inclusion of a maximum of 15 modes in the analysis was sufficient for the convergence of S-parameters. The ratio of number of modes in region I and II was chosen approximately equal to the ratio of the broad wall dimension of regions I and II in order to avoid relative convergence error [1]. A program to cascade the generalized scattering matrices of H-plan.
discontinuity was developed in order to analyze the performance of inductive iris filter. A filter was designed using Cohn's approach for a certain passband at a center frequency of 10.1 GHz. The initial dimensions of the filter were obtained from [4] based on the equivalent networks of inductive iris. The performance of the filter was tested taking 40 modes in the analysis and is as shown in Figure 3. The initial dimensions of the filter were optimized using a practical quasi Newton algorithm and its improved performance is shown in Figure 4. Figure 5 shows the measured performance of the filter.

4 Conclusions

This paper has shown that efficient computer aided design of inductive iris direct coupled cavity can be achieved using MMM and optimization. Such filter are compact and can be easily fabricated.

Appendix

The integrals involved in the determination of S-matrix of H-plane discontinuity are given by

\[
L_{mi} = 2 \int \frac{V^2}{\rho a} \sin \frac{mi \pi x}{a} \sin \frac{in(x - a \pm)}{(a_2 - a_1)} dx
\]

References


Figure 1: Inductive Iris Filter
Figure 2: Discontinuity regions in an inductive iris filter and expanded view of one showing incident and reflected wave amplitudes

Figure 3: Performance of inductive iris filter without optimization in a waveguide of dimensions, a=22.86mm, b=10.16mm, thickness of the iris=0.1mm, l1=12=16.99mm, d1=d3=8.6mm, d2=4.6mm

Figure 4: Performance of inductive iris filter with optimization in a waveguide of dimensions, a=22.86mm, b=10.16mm, thickness of the iris=0.1mm, l1=12=16.1mm, d1=d3=10.5mm, d2=7.4mm

Figure 5: Measured performance of inductive iris filter with above dimensions