A Two-phase Full-wave GA Optimization for W-band Image Rejection Waveguide Filter Design

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1. Abstract

The feasibility of a new two-phase design approach for image rejection waveguide filter using a genetic algorithm is demonstrated in this paper. The design approach is capable of minimizing the number of simulations required in the full-wave analysis, without sacrificing the accuracy of final design. In addition, it has been employed for a high-pass waveguide filter design at W-band and yields a satisfactory performance.

2. Introduction

Conventional synthesis procedure for waveguide transformer [1] had been investigated, however, the performance isn't satisfactory [2]. Otherwise, mode matching technique [3] with quasi-Newton method [4], which is not computationally intensive and requires a good initial guess, had been employed for waveguide filter design. In order to avoid the dependence on starting point, stochastic methods, such as genetic algorithms(GAs) [5], are more suitable.

In this paper, a two-phase full-wave GA optimization for waveguide filter design approach is proposed. To begin with, the waveguide filter is modeled as cascaded transmission lines and then the waveguide H-plane dimensions are optimized by a GA. The E-plane dimensions of waveguide sections are assumed to be in a linear variation, for which the best linear coefficient is determined from full-wave analysis [6]. The approach had been applied to design an image rejection waveguide filter at W-band and both the simulated and measured results are demonstrated in this paper.

2. Statement of the problem

Fig. 1(a) shows the configuration of a symmetrically double-plane stepped rectangular waveguide filter. Several waveguide sections of width A_i, height B_i, and length C_i (i=1,...,2N-1) are inserted into standard waveguide with $A_0=A_{2N}=2.54$ mm. Figs. 1(b) and 1(c) show the dimensions in H-plane and E-plane, respectively. The design specifications are listed in Table I.

3. Numerical results

A. A Conventional Filter Design with N=8

For the specification in Table I, a waveguide filter with N=8 has been designed by conventional method [7]. The parameters A_i, B_i, and C_i are listed in Table II. Fig.2 shows the simulated results by both the full-wave solver HFSS and the transmission line analysis. Maximal return loss is −13.2 dB by HFSS simulation and −11.3 dB by the transmission line analysis. The $|S_{12}|$ value at 84 GHz is −4.05 dB by HFSS simulation and −5.34 dB by the transmission line analysis.

B. GA Design for H-plane Dimensions of Waveguide Filter with N=4

Table III shows the H-plane dimensions of a waveguide filter designed by simple genetic algorithm. Fig. 3 shows the simulated results by employing the transmission line analysis as well as by full-wave solver HFSS. The maximal return loss in pass band is −15 dB by transmission line analysis. The insertion loss is −4.46 dB at 84 GHz. Also shown in Fig. 3, the maximal return loss in pass band is −18.65 dB and the insertion loss at 84 GHz is −3.02 dB by HFSS simulation.

C. Design for E-plane Dimensions

The section heights in E-plane are assumed to be in a linear form as below

$$B_i = 1.27 - i\Delta, \quad i = 1,2,3,4 \tag{1}$$

where Δ is difference in height between two adjacent sections.

By adjusting Δ from 0 to 0.1mm with an increment of 0.02 mm, the full-wave solver HFSS has been employed to simulate the frequency response of the waveguide filter in Table III. Fig. 4 shows the maximal return loss in the pass-band and insertion loss at 84 GHz. It can be found that the suitable Δ ranges from 0.04 to 0.08 mm.

D. Performance of a practical 4-section filter

An image rejection waveguide filter with N=4 designed by the two-phase optimization approach has been accomplished. The parameters A_i, B_i, and C_i are listed in Table IV. Fig.5 shows the measured data as well as the simulated result by the full-wave solver HFSS. Fig. 6 shows the profile of 4-section filter. Maximal return loss is measured to be −10.9 dB as opposed to −9.78 dB by HFSS simulation.

4. Discuss and conclusions

A new two-phase design approach for wide-band rectangular waveguide filter design has been presented. The design approach is capable of minimizing the number of simulations required in the full-wave analysis.

The approach has been employed to design a high-pass waveguide filter at W-band and yields a satisfactory design with smaller number of sections. Numerical results demonstrate that the waveguide filter design with N=4 provides a comparable performance as that with N=8 by conventional approach. In addition, the measured result meets the simulated one by the full-wave solver HFSS.

References

[1] G. Matthaei, L. Young, and E.M.T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*. New York: McGraw-Hill, pp. 255-354, 1964.

[2] L. Young, "Practical design of a wide-band quarter-wave transformer in waveguide," *The Microwave Journal*, 6, No. 10, pp. 76-79, Oct. 1962.

[3] H. Patzelt, and F. Arndt, "Double-plane steps in rectangular waveguides and their application for transformers, irises, and filters," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, pp. 771-776, May 1982.

[4] R. Fletcher and M. J. D. Powell, "A rapidly convergent descent method for minimization," *Comput J.*, vol. 6, pp. 163-168, 1963.

[5] Y. Rahmat-Samii and E. Michielssen, *Electromagnetic Optimization by Genetic Algorithms*, New York: Wiley-Interscience, pp. 37-45, 2000..

[6] HFSS—High Frequency Structure Simulator (software package), Ansoft Co.

[7] CSIRO, private communications.

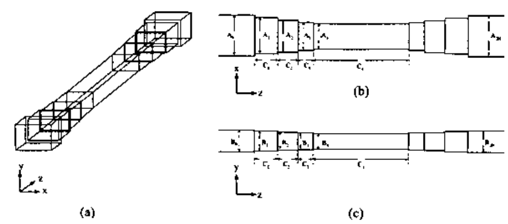

Fig. 1. Double-plane stepped rectangular waveguide filter (a) Geometry (b) Dimensions in H-plane. (c) Dimensions in E-plane.

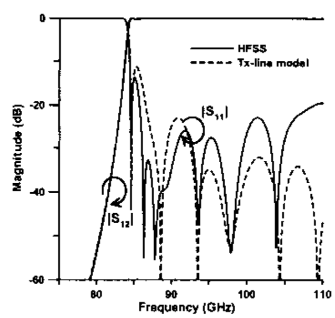

Fig. 2. Response of an 8-section filter.

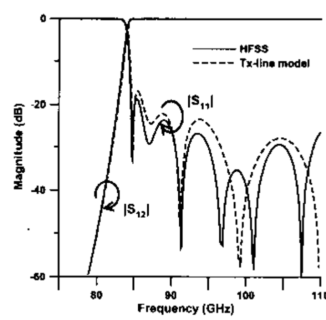

Fig. 3. Response of a 4-section filter.

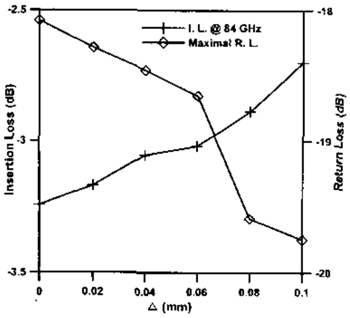

Fig. 4. Insertion loss and return loss versus Δ .

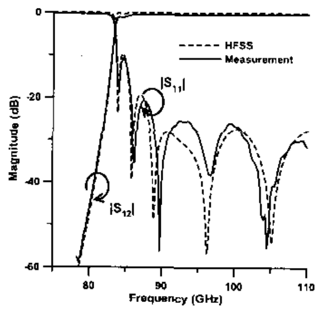

Fig. 5. Response of a practical 4-section filter.

Table I Filter Specifications

Frequency: 75 ~ 110 GHz

Pass-Band: S_{11} < -20 dB for f > 84.5 GHz

Stop-Band: S_{12} < -3 dB at 84 G Hz

S_{12} < -15 dB at 83 G Hz

S_{12} < -27 dB at 82 G Hz

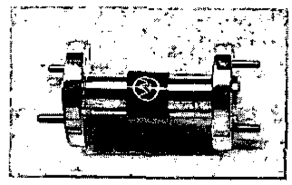

Fig. 6. Profile of a practical 4-section filter.

Table II

Dimensions of an 8-section waveguide filter

	A/mm	B/mm	C/mm
1	2.488	1.21	0.953
2	2.292	1.152	1.016
3	2.092	1.092	1.122
4	2.048	1.04	1.155
5	2.008	0.982	1.192
6	1.908	0.96	1.31
7	1.828	0.9	1.46
8	1.788	0.8	10

Note: A = width, B = height, C = length

Table III

H-palne Dimensions of a 4-section waveguide filter

Optimum double-plane 4-section filter				
	section 1	section 2	section 3	section 4
A/mm	2.26	1.96	1.84	1.79
C/mm	0.96	1.18	1.72	8.92

Note: A = width, C = length

Table IV

Dimensions of a practical waveguide filter

	section 1	section 2	section 3	section 4
A/mm	2.261	1.956	1.829	1.803
B/mm	1.219	1.143	1.092	1.041
C/mm	0.953	1.181	1.727	8.915

Note: A = width, B = Hight C = length