Design of Millimeter Wave Waveguide Bandpass Filter for Prototyping with 3D Printer

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Abstract

In order to prototype a waveguide bandpass filter (BPF) using a 3D printer and plating, we proposed a new window structure and used μGA (micro Genetic Algorithm) for its design. From the design results, it was confirmed that the proposed structure can also obtain filter characteristics.

1 Introduction

The use of 3D printers and plating to fabricate high-frequency components such as waveguides is attracting attention [1][2]. The advantage of this method is low cost, light weight and highly customizable. On the other hand, this method has the problem to find a structure suitable for prototyping. In this study, we propose a novel structure and design method for manufacturing a millimeter-wave waveguide bandpass filter (BPF) with 3D printer. The purpose of this study is to clarify the effectiveness of the waveguide BPF with the proposed structure.

2 Analysis Model and Design method

2.1 Analysis model

Figure 1 shows the analysis region of the waveguide bandpass filter. The FDTD method is used for the analysis. The numbers in Fig.1 is the cell numbers. The cell size is 0.1 mm. The waveguide standard is WR-19, and three windows are placed in the center. The window consists of an inductive iris and a capacitive post adjusted by width w and height h respectively. The window generally has the structure shown in Fig. 2(a), but the structure with steep rise and fall is difficult to reproduce with a 3D printer. In this study, we propose to use a novel structure shown in Fig. 2(b) for the waveguide BPF considering the printable angle of the 3D printer. Because conventional design methods cannot be applied to the proposed window structure [3], we use μGA (micro Genetic Algorithm), one of the evolutionary computation methods, to design w and h [4].

2.2 Optimization method and results

In this study, we design BPF with a passband of 50GHz in the waveguide usage range of 40 - 60 GHz. The range of the iris width w is set to 0.9 - 2.2 mm, and the range of the post height h is set to 0-1.0mm. the optimization is performed by changing the window position d. The objective function OF is shown in Eq. (1), and the objective is to maximize the transmission coefficient s_{21}.

$$OF = s_{21} - W_1 \times bw - W_2 \times \Delta f \quad (1)$$

Where *bw* is the frequency bandwidth of the bandpass spectrum and Δf is the different between the actual bandpass frequency and the design frequency. W_1 and W_2 are the weight coefficient.

The filter characteristics shown in Fig. 3 are obtained when d = 5.6 mm. The design value of h for all windows is 0 mm, and the widths of window #1, #2, and #3 are 1.0, 1.4 and 1.0 mm, respectively. It is found from Fig. 3 that the pass frequency band shift when w is changed.

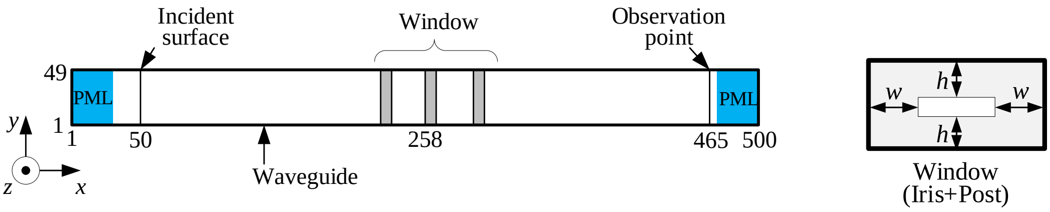
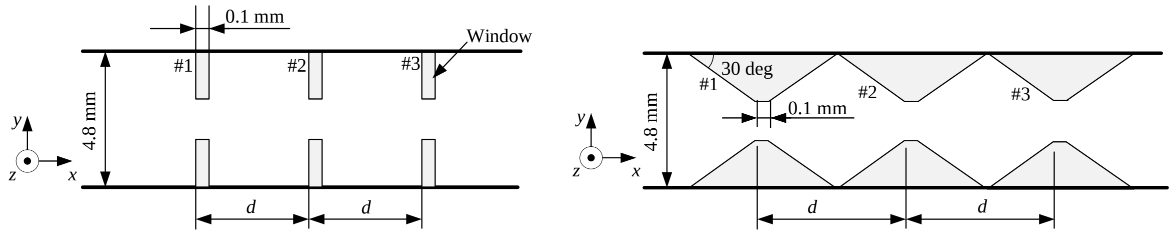


Fig.1: Analysis model



(a)Conventional model (b)Proposed model

Fig.2: The Cross-section of waveguide BPF

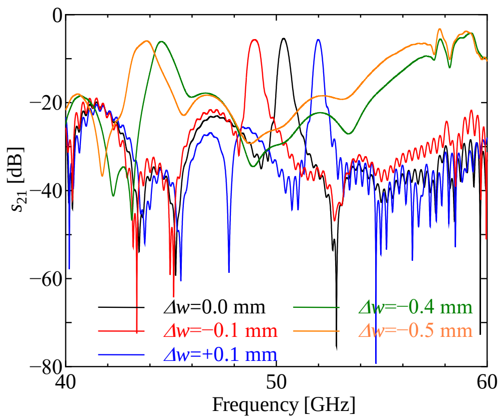


Fig.3: Calculation results (Δw is variation of iris width w)

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References

[1] J. Shen, M. W. Aiken, M. Abbasi, D. P. Parekh, X. Zhao, M. D. Dickey, D. S. Ricketts, Rapid Prototyping of Low Loss 3D Printed Waveguides for Millimeter-wave Applications, IEEE MTT-S International Microwave Symposium, pp.41-44, 2017.

[2] G. P. Le Sage, 3D Printed Waveguide Slot Array Antennas, *IEEE Access*, **4**, pp.1258-1265, 2016.

[3] G. Apaydin, L. Sevgi, An FDTD-based waveguide filter simulator: Calibration against analytical models, International Journal of RF and Microwave Computer-Aided Engineering, **23**, 4, pp.466-470, 2013.

[4] K. Watanabe, F. Campelo, Y. Iijima, K. Kawano, T. Matsuo, T. Mifune, H. Igarashi, Optimization of Inductors Using Evolutionary Algorithms and Its Experimental Validation, *IEEE Trans. Magn.*, **46**, pp.3393-3396, 2010.