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A Controllable Planar Wideband Bandpass Filters using the Combination of Microstrip and Substrate Integrated Waveguide Structure

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Abstract

This paper presents a planar wideband bandpass filter using a combination of microstip structure and substrate integrated waveguide (SIW). To control the bandwidth of the wideband bandpass filter, the proposed filter is designed by cascading structure between the high pass filter and low pass filter characteristic. The SIW, which is a high pass filter characteristic, is designed to determine the lower cutoff frequency. Then, the microstrip, which is a and low pass filter characteristic, is designed to determine the higher cutoff frequency. To verify the concept of the proposed filter design, three wideband bandpass filters, e.g., 2-5 GHz, 3-5 GHz and 4-5 GHz, have been simulated and achieved, resulting in fractional bandwidth of 80%, 50% and 20%, respectively. To prove the simulated results, the 4-5 GHz wideband bandpass filter is selected to fabricate on the low-cost FR-4 substrate with a thickness of 1.6 mm. The results show that measured and simulated results are agreed well in the reflection and insertion responses.

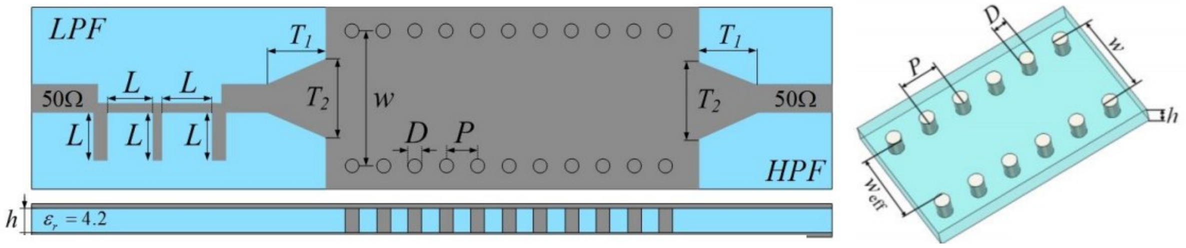
Keywords: wideband bandpass filter, substrate integrated waveguide, microstrip

1. Introduction

Bandpass Filter (BPF) is a basic component in communication systems that is normally applied for the measurement and several electronics circuits. It is the important part for noise rejection at receiver on specified frequency range with lower and upper cutoff frequencies. To create BPFs, many structure types are used such as coaxial, waveguide, microstrip, and etc. Recently, a substrate integrated waveguide (SIW) has been introduced [1-4]. It is easily synthesized by introducing two rows of metalized holes into the substrate layer of printed circuit board (PCB). By this formation, SIW can exhibit the wave propagation mode similar to rectangular waveguides, including the field pattern and hig hpass filter (HPF) characteristics. Moreover, it can provide the benefits of power capability, high *Q*-factor, low loss and low cost [5]. Therefore, in this work, HPF response of SIW structure is applied to combine with a conventional microstrip low pass filter (LPF) for controllable BPF. Results show that its operating bandwidth and center frequency can be freely designed and controlled by structure reconfiguration on SIW and microstrip.

2. Filter Design

The proposed BPF consists of two main parts as shown in Fig. 1(a) that is designed on FR4-substrate (ε_r = 4.2, $\tan\delta$ = 0.019, and h = 1.6 mm.). Firstly, to define the higher cutoff frequency (f_H) of BPF, a microstrip lowpass filter with the 3 th order of Chebychev is basically designed [6]. Its parameter L of LPF is optimized by 5 mm. to generate the cutoff

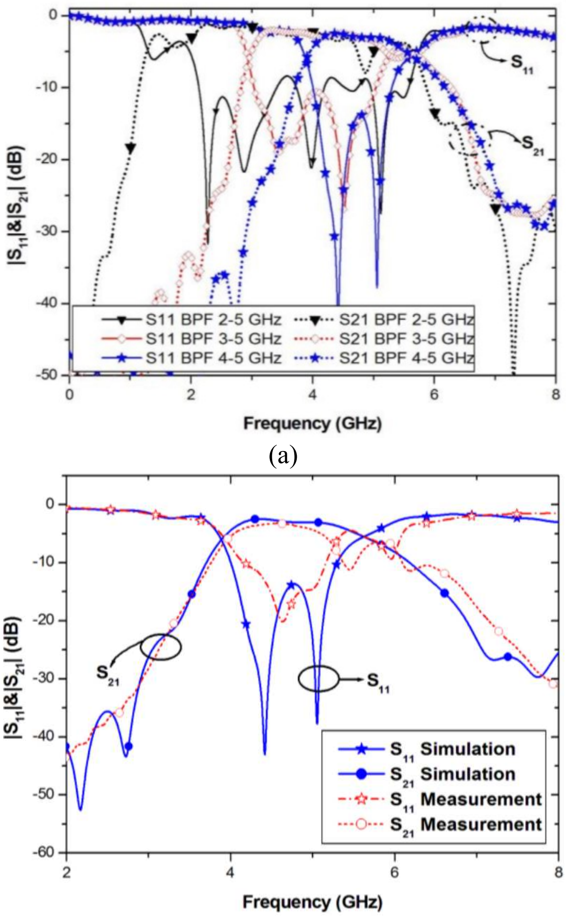


(a) (b)

Figure 1. Configurations of wideband bandpass filter (a) top and cross section view (b) SIW structure.

Table 1: Dimension of SIW at 2, 3 and 4 GHz

f_L (GHz)	w (mm)	T_1 (mm)	T_2 (mm)
2	46	29	17
3	25	10	6
4	20	13	7



(a)

(b)

Figure 2. (a) Comparison simulated results of three bandpass filters and (b) Simulated and measured results of bandpass filter with range of 4 – 5 GHz.

frequency at 5 GHz. Meanwhile, SIW is generated to determine the lower cutoff frequency (f_L) of BPF. Its structure is constructed by using two rows of conducting cylinders in dielectric substrates to connect two parallel metal plates as depicted in Fig. 1(b). To obtain the SIW cutoff frequency (f_c) with TE_{10} mode, it is found by the following equation (1),

$$f_c = \frac{c}{2w_{eff}\sqrt{\varepsilon_r}} \tag{1}$$

where c is the speed of light and w_{eff} is effective width of the rectangular waveguide which the value of w_{eff} can be calculated from equation (2),

$$w_{eff} = w - \frac{D^2}{0.95P} \tag{2}$$

where D is the diameter of the metal vias, w represents their transverse spacing and P is spacing between two vias [7-9]. Besides, to maintain the good impedance matching on the connection between SIW and microstrip structure, the taper transition line is added and adjusted [1].

3. Measurement Results

To inspect adaptable WBPFs, the lower cutoff frequency (f_L) is adjusted by changing transverse space, w, to generate different cutoff frequencies. In this experiment, D and P are fixed with 1 and 2 mm, respectively, where w is varied for lower cutoff frequencies of 2, 3, and 4 GHz. In addition, to improve impedance matching of BPF, taper length (T_1), and width (T_2) are alternated. The proper values of parameters are illustrated in Table 1. Fig. 2(a) shows the simulated results of wideband BPF in distinct frequency ranges of 2−5, 3−5 and 4−5 GHz. The maximum insertion losses of all BPF structures are less than 2 dB. The fractional BWs are also obtained with 80%, 50%, and 20% for operating frequency ranges of 2−5, 3−5 and 4−5 GHz, respectively. From these results, it is clearly seen that the operating frequency BW of filter can be tuned and controlled without restraint. To verify the obtained result in practical view, BPF with range of 4-5 GHz is selected to fabricate the prototype BPF. The compared results between simulation and measurement are depicted in Fig. 2(b). They are in good agreement.

4. Conclusion

Combination of SIW and microstrip structure for controllable wideband BPF is proposed. This concept, can be easily tuned with individual control of lower and higher cutoff frequencies with the desired operating frequency of BPF. Also, the design is suitable and flexible for BPFs construction.

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