A Source-Load Coupled Bandpass Filter using One-Eighth Mode Substrate Integrated Waveguide Cavity

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Abstract

A novel compact eighth-mode substrate integrated waveguide (EMSIW) resonator is proposed.The dominant resonant mode of the proposed resonator is TE_{101} mode.Compared with the conventional SIW resonator, the size reduction of the resonator is up to more than 87.5%.By using source-load Cross coupling and magnetic coupling,a new filter with two EMSIW cavities is designed, which has four transmission zeros in the out-band. The measured results show good performance and agree well with the simulated results.

1. Introduction

Substrate integrated waveguide (SIW) can be bisected along a fictitious quasi-magnetic wall and the SIW becomes a half-mode substrate integrated waveguide(HMSIW).HMSIW was exploited to design some high-performance microwave components in [1] and [2].Because the center symmetrical plane of the HMSIW can also be equivalently regarded as a quasi-magnetic wall for some particular modes, the HMSIW can be further bisected into two parts again along the symmetrical plane. Hence, a quarter mode substrate integrated waveguide (QMSIW) is realized.The field distribution of the QMSIW is almost the same as the field distribution of the original SIW[3-5].

To further reduce the size of filters in substrate integrated waveguide,one eighth mode SIW (EMSIW) resonator after bisecting the SIW triple along the symmetrical fictitious magnetic wall is proposed in the letter,Compared with the conventional SIW cavity, the size of the EMSIW is reduced by a factor of about 7/8 while maintaining a lower dominant resonant frequency. By using source-load cross coupling and magnetic coupling,the EMSIW filter using two cavities performs excellently.

2. Analysis

The resonant mode of the proposed EMSIW structure is derived by cutting along the symmetrical planes of a square SIW resonator, all of which can be regarded as perfect magnetic walls. the overall size can be reduced while maintaining its TE101 mode resonant frequency.Fig. 1 shows the evolution process of the proposed EMSIW. The configuration of the EMSIW is shown in Fig. 1(c), and it can be seen as one eighth of a square SIW resonator as shown in Fig. 1(a). Hence, the resonant frequency of the TE101 mode of the EMSIW resonator can be estimated based on the following formulas as the counterpart SIW structure[6]:

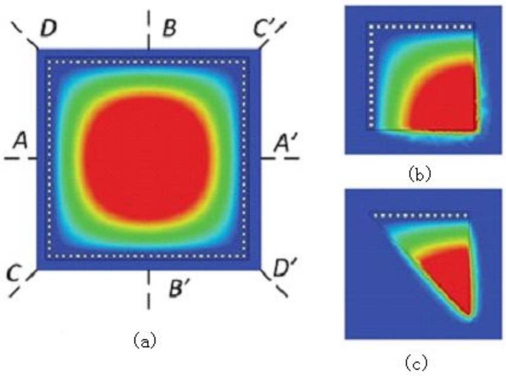

Fig. 1 *Simulated E-field distributions* (a) a Full-mode SIW (b) a Quarter-mode SIW (QMSIW) (c) an Eighth-mode SIW (EMSIW)

$$f_{101}^{EMSIW} = \frac{C}{2\pi\sqrt{u_r \varepsilon_r}} \sqrt{(\frac{\pi}{2W_{eff}^{EMSIW}})^2 + (\frac{\pi}{2W_{eff}^{EMSIW}})^2} \quad (1)$$

$$W_{eff}^{EMSIW} = W_{eff}^{SIW} / 2 + \Delta W \quad (1a)$$

$$W_{eff}^{SIW} = W - 1.08\frac{(2R)^2}{S_2} + 0.1\frac{(2R)^2}{W} \quad (1b)$$

Where u_r and ε_r are the relative permeability and permittivity of the substrate, respectively. C represents the speed of light in a vacuum. W_{eff}^{EMSIW} is the equivalent width of EMSIW. W_{eff}^{SIW} is the equivalent width of the corresponding original square SIW structure. ΔW is the additional width[7]. W is the length and width of the square SIW resonator. $2R$ and S_2 are the via diameter and the spacing between adjacent vias, respectively.

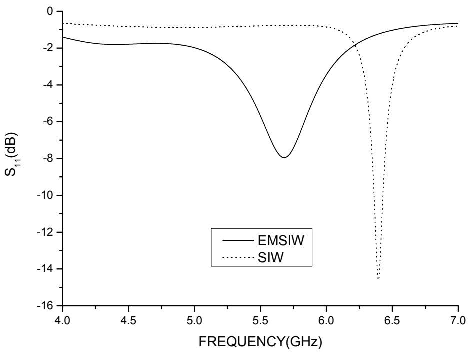

Fig. 2 *Simulated reflection coefficient against frequency of the Eighth-mode SIW and Full-mode SIW resonator*

In fact, the additional width ΔW makes that the resonant frequency of the EMSIW is shifted compared with the frequency of the counterpart SIW resonator at the TE_{101} mode, This is because the fringing field at the two open edges. Therefore,the size reduction of the resonator is up to more than 87.5% compared with the conventional SIW resonator. As shown in Fig. 1(a), the width and the length of the SIW are the same(W =22.6mm) to make preparations for the following analysis of EMSIW,and the square SIW resonator is designed on Rogers RT5880 substrate with the thickness of $h = 1.57$mm, low dielectric constant $\varepsilon_r = 2.2$, and low loss tangent $\tan\theta = 0.001$ .The TE101 mode resonant frequency of EMSIW is simulated by using ANSOFT HFSS as shown in Fig. 2 .It should be pointed that the TE_{101} mode resonant frequency of the proposed EMSIW is lower than that of the corresponding SIW cavity, and this is because radiation happens at the two open edges.

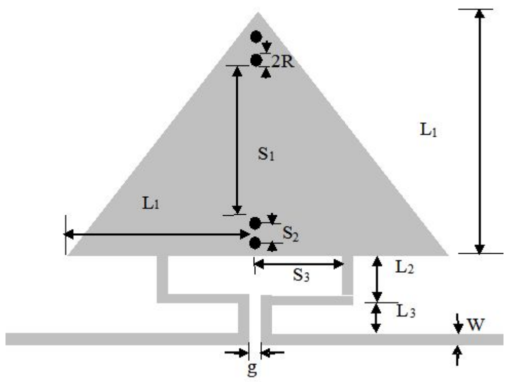

Fig. 3 *Configuration of the proposed EMSIW filter with source-load coupling*

3.Filter design

Based on above analysis, a two-order cross-coupled bandpass filter implemented with EMSIW cavity is designed. the layout of the proposed band-pass filter is shown in Fig.3. It is built on the Taconic TLT substrate with dielectric permittivity ε_r = 2.55 and thickness h=0.508 mm. the dimensions are given below: L1 = 18.0mm, L2 =7mm, L3 = 3.5mm,S1= 12.4mm, S2=1.2mm, S3= 10mm, W =1.4mm, R=0.4mm, g = 0.3mm.The center frequency of the filter is determined by the resonant frequency of the constitutional resonators, while the bandwidth is mainly affected by the coupling strength. The measured frequency responses of the filter are shown in Fig. 4, agreeing well with the simulated ones. The measured central frequency is 3.29GHz, and 3-dB bandwidth is 830 MHz. The in-band insertion and return loss is better than -2.80dB and -21dB, respectively. The transmission zeros are located at f_1 = 1.68GHz , f_2 = 2.05 GHz, f_3 = 4.30 GHz and f_4 = 5.27 GHz,the rejection level in the stopband is better than -24dB. Obviously, the introduction of source-load coupling can help to create transmission zeros near the passband, thus improving the out-of-band rejection.

4.Conclusion

A novel EMSIW bandpass filter using source-load coupling is fabricated and measured. Both the simulated and measured results show the proposed filter has good performance, while the size reduction is even up to more than 87.5% area compared with the conventional SIW cavity resonator. The transmission zeros close to the passband edges are generated by source-load coupling, resulting in high skirt-selectivity.

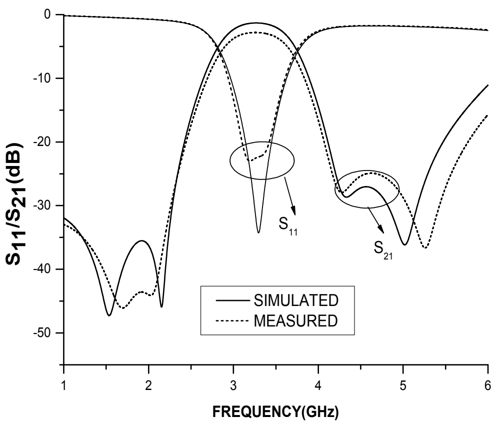

Fig. 4 *Measured and simulated results of the proposed filter*

5. Acknowledgments

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6. References

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