Quadruple-Mode Wideband Filter Using Slotted Substrate Integrated Waveguide Circular Cavity

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***Abstract* - In this article, a way to design a quadruple-mode bandpass SIW filter with single circular cavity has been investigated. The proposed filter is implemented using slotting technology and has a simple and symmetrical structure. It focuses on the multiple-mode resonator (MMR) technology to miniaturize the overall size of a wide bandpass filter (BPF). Totally five metallic perturbation via and slots are introduced to shift the resonant modes. The insertion loss of the filter with the quadruple-mode SIW cavity resonator is around 1.1dB. The passband is 14.8 GHz to 17.8 GHz, and the measured return loss is lower than -18 dB.**

***Index Terms* —Quadruple-mode, SIW filter, multiple-mode resonator (MMR), frequency shifting.**

1. Introduction

In recent years, multimode SIW filters become popular for the integration and compaction. The substrate integrated waveguide (SIW) technology has been successfully applied to design of various filters with high quality factor, low insertion loss and easy integration with planar circuits. A microstrip-line ultra-wideband (UWB) bandpass filter was proposed and implemented using a multiple-mode resonator [1]. A super-wide SIW bandpass filter was designed by using the periodic structure, such as electromagnetic bandgap (EBG) [2]. A wideband FSIW filter combined with stripline resonant cells was proposed [3]. A wideband HMSIW filter was proposed with large circuit size in [4]. In [5], a wideband fifth-order bandpass filter was proposed using the U-slotted substrate integrated waveguide (SIW) cavities. The proposed fifth-order SIW BPF needs two SIW cavities, thereby achieving significant size reduction by 2.5 times.

This paper proposes a first way to design a quadruple-mode bandpass SIW filter with single circular cavity. It mainly focuses on the multiple-mode resonator (MMR) technology to miniaturize the overall size of a wide BPF.

2. Design and Simulation

Compared among various shapes of planar substrate cavity, a circular cavity has the highest unloaded Q factor, which can be used for lower insertion loss in filter.

Fig. 1 depicts the top view of the circular SIW cavity resonator with five metallic perturbation via and slots. The circular metallic via is located at the center of the SIW cavity with a diameter d and the other four metallic slots are located at the diagonal lines.

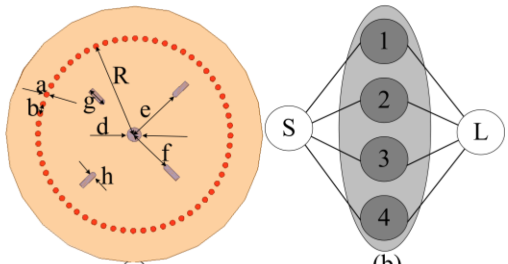

Fig. 1. Circular SIW cavity resonator configuration.

In our design, the center frequency and bandwidth of the filter are 16 GHz and 3 GHz, respectively. The substrates used to design a SIW cavity are Taconic TLT (tm). The thickness of the substrates is 0.5mm, the permittivity of the filling material is 2.55, and the dielectric loss tangent of the material is 0.0006.

In the present design, the first step is to decide the dimensions of the cavity. The diameter of metallized hole is 0.5 mm. The initial radius is calculated 8.7 mm. The resonant frequencies are at 8.15 GHz, 13 GHz and 17.4 GHz without metallic perturbation via and slots, and the corresponding modes are TM_{010}, TM_{110}, TM_{110},(in different directions) and TM_{210}. The modes of the circular cavity are simulated in HFSS by eigenmode solution type. Then with metallic perturbation via and slots, the radius of the cavity becomes 9 mm. The second step is to adjust parameters e, f, and g to construct a specified passband. The method of scanning parameters is adopted. The third step is to realize the input-and-output matching slot size which determines the bandwidth and the out-of-band performance.

Fig. 2 demonstrates the simulated resonant frequencies with different perturbation via and slots. The metallic slots located at the diagonal lines are allocated to two groups. They affect the TM_{110} mode in different directions. The parameter f affects one higher TM_{110} mode and parameter e affects the other lower TM_{110} mode besides TM_{010} mode. The via in center adjusts higher modes slightly, and has a stronger effect on TM_{010} mode.

To separate two modes TM_{110} (in different directions), while keeping the wave energy concentrated in the center, the following requirements should be satisfied:

$$f < \frac{1}{2}R, e > \frac{1}{2}R, g + f > \frac{1}{2}R \quad (1)$$

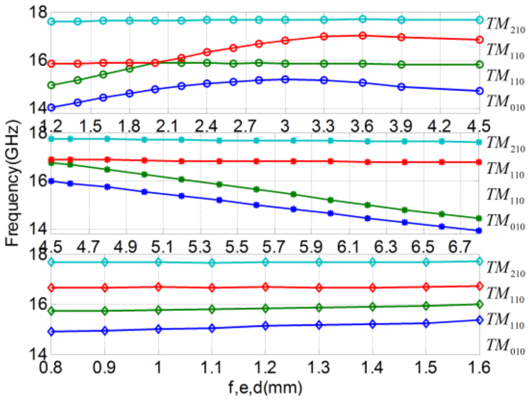

Fig. 2. The simulated resonant frequencies with (1) different f when e=5.4 mm, (2) different e when f=3 mm, and (3) different central perturbation via diameter d.

Distances e and f represent the farther and nearer slots respectively

3. Fabrication and Measurement

The electric field distributions of the circular SIW cavity are depicted in Fig. 3. The simulated insertion loss is -0.706 dB and the simulated return loss is below -22 dB. We chose the angle of 90 degrees to achieve the optimal passband performance. The dimensions for the filters are listed in Table I. The resonant frequencies simulated are changed to 14.73 GHz, 15.8 GHz, 16.8 GHz and 17.7 GHz.

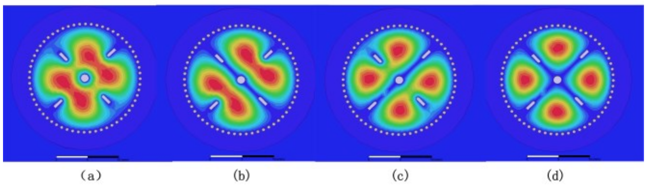

Fig. 3. Electric field distributions of four modes.

TABLE I
Filter Parameters

R	9 mm	e	4.3 mm	x	2.4 mm	y	0.2 mm
a	0.5 mm	f	5.4 mm	W1	6 mm	W2	1.4 mm
b	0.84 mm	g	2 mm	W3	7 mm		
d	1.3 mm	h	0.5 mm				

The fabricated filter demonstrated in Fig. 4 is measured using an Agilent E8363B vector network analyzer and the VNA is calibrated with the short-open-load-thru (SOLT) technique 85056D. The filter is tested with a universal test fixture and a universal test fixture right angle launcher.

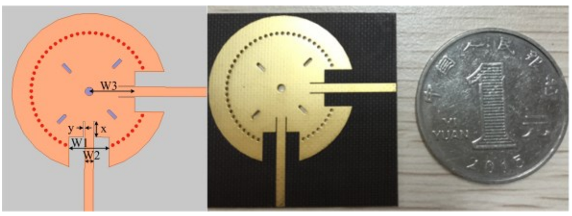

Fig. 4. Photograph of the fabricated circular SIW filter.

The simulated and measured insertion loss and return loss of the circular cavity SIW filters are demonstrated in Fig. 5. The insertion loss of the filter with the quadruple-mode SIW cavity resonator is around 1.1dB. The central frequency is 16.3 GHz, the passband is from 14.8 GHz to 17.8 GHz, and the measured return loss is lower than -18 dB. The transition of microstrip transmission line and SIW circular cavity is introduced to improve the out-of-band performance.

The proposed fourth-order SIW BPF needs one SIW cavity, thereby achieving significant size reduction by 4 times.

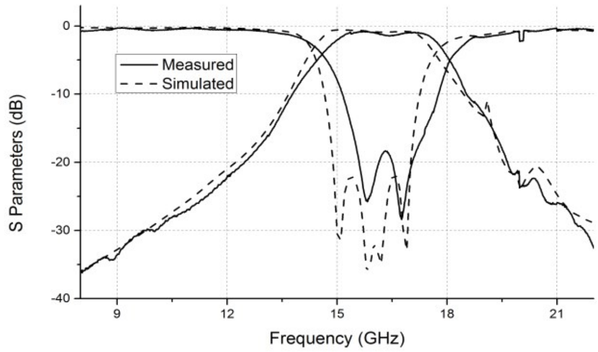

Fig. 5. Simulated and measured S parameters of the filter.

4. Conclusion

This paper has demonstrated a way to design a single-cavity circular cavity SIW quadruple-mode filter. Metallized perturbation via and slots are introduced to shift the resonant modes. The perturbation via and slots can shift the lower resonant mode frequencies of the circular cavity to couple with the highest working mode. One bandpass SIW filter has been fabricated and measured results are given.

Compared to conventional multi-mode filters, it has a simple structure and an easy design method. This work has a much smaller size when compared with conventional cascade filters, and can be used in size-sensitive conditions.

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