Multilayer Substrate Integrated Waveguide Bandpass Filter With Square Complementary Split-Ring Resonators

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***Abstract*—Using the technology of complementary split-ring resonators (SCRRs), a compact substrate integrated waveguide (SIW) filter is developed with multilayer topology in this paper. Compared to the conventional rectangular type, this filter has compact size, a wider bandpass, high out-of-hand rejection and sharp skirt selectivity. By adjusting the sizes, the angles and the position of the SCRRs, the transmission zero can be created and controlled to improve the frequency selectivity and out-of-band rejection. A 4th-mode bandpass SIW filter with the central frequency and bandwidth are kept at 24GHz and about 40%, respectively, minimum passband insertion loss is 32 dB, and in-band return loss is greater than 10 dB is given and the results showed a good out-of rejection performance.**

***Keywords*—SIW; multilayer ; SCRRs; out-of-hand rejection**

INTRODUCTION

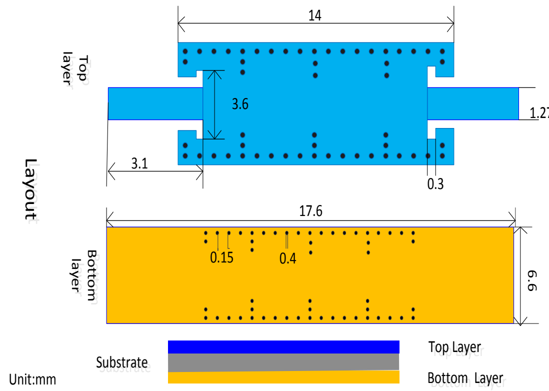
Since its introduction, SIW filters has generated significant interests in the design and development. Especially, With the advantages of high quality factor, low cost, and high power capability, SIW filter were used widely in airborne platforms, communication satellites and wireless base-stations[1]. However, their physical sizes are not small enough when compared with the microstrip filter design [2]. The multiplayer SIW filters proposed in this paper to reduce their whole size greatly.

On the other hand, SCRR can provide a negative permittivity in the vicinity of its resonant frequency and produces sharp rejection band along with property of small electrical compact size [3]. By etching SCRRs on the top or bottom or both layer and adjusting the sizes, the angles and the position of the SCRRs, transmission zeros can be obtained to improve the rejection level of both lower and upper side band and out-of-band rejection characteristics[5]. The filter proposed in this paper is constructed into Rogers RT/duroid 6002 substrate with a dielectric constant $\varepsilon_r = 2.94$ with height=0.508mm.

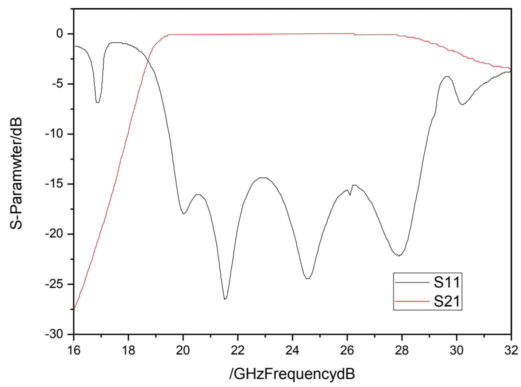
DESIGN AND ANALYSIS OF THE PROPOSED SCRRS SIW BANDPASS FILTER

A. The initial single layer bandpass filter

The initial SIW bandpass is shown in Fig. 1(a), and the simulation result is shown in Fig. 1(b).



(a)

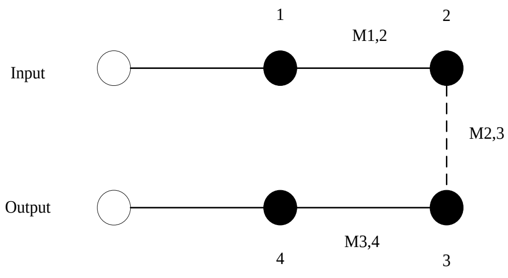


(b)

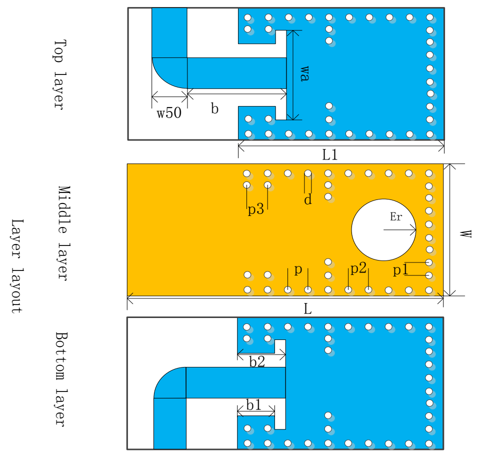
Fig. 1. (a) layout of single layer SIW filter and (b) simulation result

B. The multilayer bandpass without SCRR

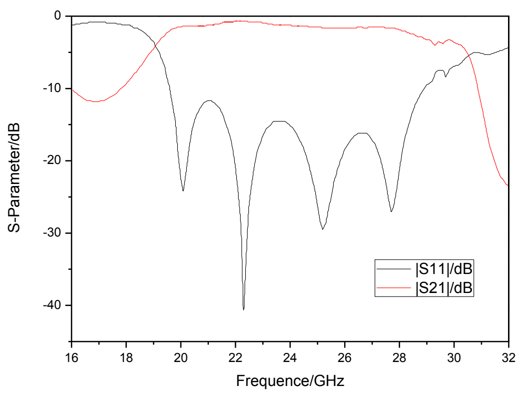
To reduce the size of the filter, the structure of the multi-layer one is called out in Fig. 2(b). The topology of multilayer SIW filter was shown in Fig. 2(a) and that can be seen the magnetic coupling between cavities located on same layer is implemented by using an inductive window, the electric coupling between the cavities on the top layer and bottom layer is realized through the circle etched into the middle layer. Fig. 2(c) illustrates the simulated results in HFSS. The dimensions of the filter are given bellow: *W=8.2mm, d=0.4mm, wa=1.87mm, w50=1.27mm, b=3.63mm, b1=2.2mm, b2=1.9mm, L=14.33, L1=12.33mm, p=0.22mm, p1=0.18mm, p2=0.2mm, p3=0.3mm*. That can be found obviously, the size of the multilayer one reduced sharply when compared with the single layer one. However, it also can be seen that both the single layer filter and the multilayer filter show that the rejection performances are poor.



(a)



(b)



(c)

Fig. 2. (a) topology of multilayer SIW filter (b) layout of multilayer SIW bandpass filter without SCRRs (c) results of multilayer filters without SCRRs

C. The multilayer bandpass with SCRR

In order to improve the poor performance of out-of-band rejection shown above, Fig. 3 shows the layout of the proposed filter design, four SCRRs are etched into the top and bottom surfaces, respectively. By adjusting the sizes, the angles and the position of the SCRRs, two and one transmissions zeros can be created at the lower and upper side of the filter, respectively. The dimensions of the filter are given as follows: *W=8.4mm, wa=1.87mm, w50=1.27mm, b=5.1mm, b1=2.4mm, b2=2.7mm, d=0.4mm, L=14.6mm, L1=11.8mm, p=0.22mm, p1=0.18mm, p2=0.2mm, p3=0.3mm, La=1.3mm, Lm=0.1mm, Ld=0.1mm, s=0.05mm.*

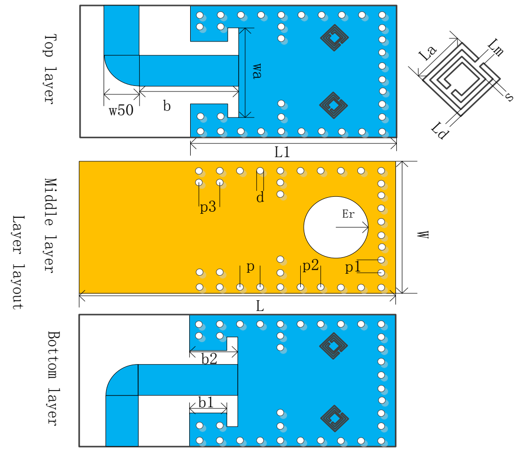


Fig. 3. Layout of multilayer SIW bandpass filter with SCRRs

The simulation results of the multilayer filters with and without SCRRs illustrated in Fig. 4, it can be found obviously, the out-of-band rejection of the filter with SCRRs can be improved significantly rather than the one without it.

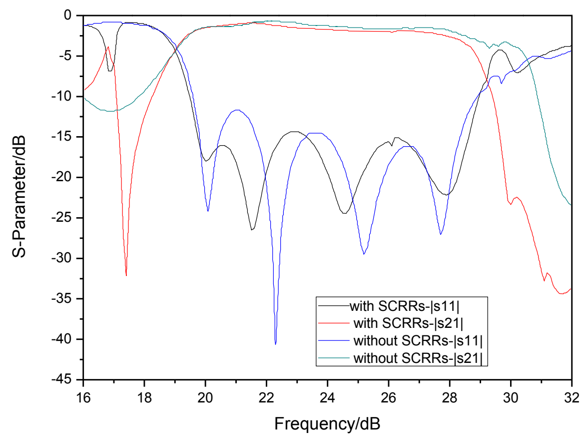


Fig. 4. Results of multilayer filters with and without SCRRs

With the exception of the simulated central frequency located on 24GHz and kept bandwidth about 40%, the proposed SIW filter has three transmission zeros at 17.4 GHz with 32.14 dB rejection, 30 GHz with 22.9 dB rejection and 31.1GHz with 32.3dB rejection, respectively. The passband selectivity and the level of out-of-band rejection were improved by introducing three transmission zeros. Minimum passband insertion loss is 32.3 dB, and return loss is greater than 10 dB in band. The filter exhibits characteristics of compact size and high integration while maintaining high out-of-hand rejection and sharp skirt selectivity.

Conclusion: A fourth-order SIW filter is presented in this Letter, which is realized by using the technique of multilayer SIW. To achieve the sharp out-of-band rejection performance, SCRRs were applied in the resonator and a circle etched on the middle layer in order to suppress the spurious response effectively.

Acknowledgment

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