A SIW Filter With Square Complementary Split-Ring Resonators (CSRRs)

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***Abstract*—A substrate integrated waveguide filter with two reversely arranged square complementary split-ring resonators (CSRRs) etched on the SIW surface is presented in this paper. The proposed filter allow the implementation of a forward-wave passband propagating below the characteristic cutoff frequency of the substrate integrated waveguide. The circuit area of the bandpass filter was only 16 × 16 mm^2. The proposed filter demonstrated a minimum passband insertion loss of 3.5dB and a bandwidth of 5.5% at a center frequency of 5.15 GHz. The filter implementation showed a rejection which was larger than 37 dB at the stopband.**

Keywords—substrate integrated waveguide (SIW); square complementary split-ring resonators (CSRRs)

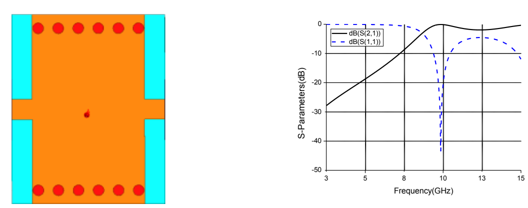
I. INTRODUCTION

Split-ring resonators (SRRs) has potential applications in the synthesis of metamaterials with negative effective permeability [1]. Based on Split-ring resonators (SRRs), complementary split-ring resonators (CSRRs) were introduced as new metamaterial resonators with negative permittivity in 2004 [2]. With the characteristics of the SRRs and the CSRRs have been studied and developed extensively [3]，they were used to realize planar miniaturized microwave devices such as filters [4]. In 2002, a backward-wave transmission below the waveguide cutoff was first proposed with the combination of SRRs and a rectangular waveguide [3]. Substrate integrated waveguide (SIW) is a guided-wave structure which has shown the characteristics of low radiation loss, low insertion loss and high Q. With the advantages presented above, the substrate integrated waveguide (SIW) was selected to combine with the CSRR considering the difficulties in combining the CSRRs with a traditional metallic waveguide. In [5], the characteristics of CSRRs resonant below the substrate integrated waveguide cutoff frequency are discussed with a view to their working principles and possible applications.

In this study, forward-wave propagation below the substrate integrated waveguide cutoff frequency is obtained based on the resonant behavior of the CSRRs. Two transmission zeros can be introduced by the CSRRs which are side-by-side reversely arranged.

II. DESIGN OF THE PROPOSED FILTER

Fig. 1(a) shows the initial substrate integrated waveguide without square complementary split-ring resonators (CSRRs) etched on the surface, and it’s simulation result is shown in Fig. 1(b). It can be seen from Fig. 1(b) that the cutoff frequency of the initial substrate integrated waveguide is 9.86GHz. In the following we will see that the center frequency of the passband to the SIW filter is 5.15 GHz which is below the cutoff frequency of the substrate integrated waveguide. So that the proposed filter allow the implementation of a forward-wave passband propagating below the characteristic cutoff frequency of the substrate integrated waveguide. It can be explained by the theory of evanescent-mode propagation or a waveguide loaded by electric dipoles that an additional passband below the substrate integrated waveguide cutoff frequency can be obtained in this way by loading the CSRRs [6], [7].



(a) (b)

Fig.1 (a) Schematic of the initial substrate integrated waveguide (b) The simulation results of the initial substrate integrated waveguide.

Fig. 2 shows the top view of the proposed design. The dimensions of the filter are given as follows: c_1=0.24mm, c_2=0.22mm, c_3=0.22mm, d_1=1mm, d_2=0.8mm, d_3=0.8mm, t=0.48mm, g=0.33mm, r=0.4mm, l=2.16mm, w=12mm, s=1.48mm, b=4.22mm, b_1=9.44mm, d=1.48mm.

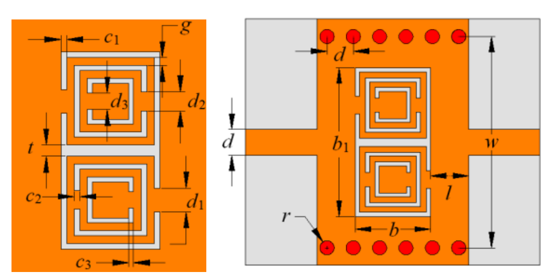


Fig. 2. Top view of the proposed design

The two linear arrays of metallized vias with the radius of 0.4mm and pitch of 1.48mm are used as the electric sidewalls of the waveguide. A pair of identical CSRRs are adopted and etched on the metal cover of the SIW. The CSRR can be achieved by nesting three different sized opening rings. It can been seen from Fig. 2 that the two CSRR structures are side-by-side reversely arranged without gaps and this arrangement can introduce transmission zeros on either sides of the passband. Two CSRRs work as two resonators in this filter and it can be clearly seen that there are two paths from the input to the output through two CSRRs, respectively. The phase shift of the two paths is opposite so that two transmission zeros are generated. The 50Ω microstrip feed line can be realized by setting the value of d to 1.48mm and it can be used for the purpose of measurement.

III. FILTER APPLICATION AND MEASRUREMENT

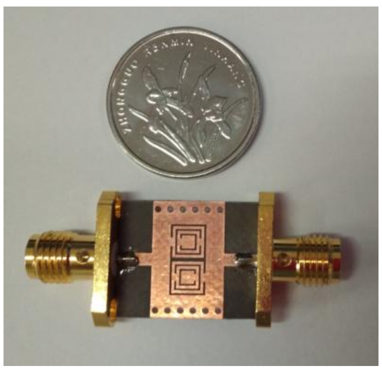


Fig. 3 The fabricated SIW filter

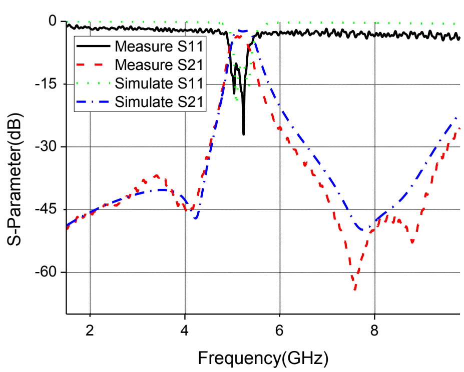


Fig. 4 The simulation results and measurement results

As shown in Fig. 3, the proposed bandpass filter was fabricated on a Rogers RT/Duroid 5880 substrate with a dielectric constant of 2.2 and a thickness of 0.508 mm. The filter is measured with E8363B PNA Network Analyzer. Fig. 4 shows the simulated and measured frequency responses of the fabricated filter, which are in good agreement. The measured central frequency is 5.15 GHz with a bandwidth of about 5.5%, minimum passband insertion loss is 3.5 dB, and in-band return loss is greater than 10 dB. In addition, the proposed SIW filter has two transmission zeros at 4.02 GHz with 45.19 dB rejection and 7.58GHz with 64.19 dB rejection, respectively. These transmission zeros improve the passband selectivity. Furthermore, the total area of the proposed filter is only 16 × 16 mm^2. The filter exhibits characteristics of compact size and high integration while maintaining good frequency selectivity.

It can be seen from Fig. 4 that both the simulation results and measurement results show relatively large loss. There are two main reasons to cause this loss. First the radiation happens in a parallel plane to the ground inside the waveguide, which is confined by the via-walls. Then the structure used in this paper is not fully closed structures and it has slot coupling so that the filter exhibits relatively larger radiation loss.

IV. CONCLUSION

A design of Square Complementary Split-Ring Resonators (CSRRs) filter is implemented in planar substrate using SIW technology. With the use of the side-by-side reversely arranged CSRRs, transmission zeros are introduced on both sides of the passband and the performance of the filter is improved. The proposed filter had a planar structure, so that it is suitable for printed circuit boards (PCBs). Therefore, the proposed structure is very suitable for compact microwave circuits.

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