Design of Bandpass Filter with High Selectivity Using Stepped Impedance Resonator

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Abstract-**In this paper, a novel bandpass filter (BPF) with high selectivity and great out-of band suppression is proposed by using stepped impedance resonators (SIR) and defected ground structure. The measured 3-dB bandwidth of the proposed BPF is 2.62-2.72GHz; the maximum simulated insertion loss is 0.4 dB within passband. Besides, there are four transmission zeros located at 2.12, 2.54, 2.84, and 3.80 GHz, the out-of band suppression is better than 20 dB, indicating that the proposed BPF has great suppression. Moreover, the measured and simulated filter characteristics are in agreement, which means that this design is effective. The characteristic of high selectivity is meaningful in wireless communication.**

Keywords-high selectivity; stepped impedance resonator; bandpass filter; wireless communication

I. INTRODUCTION

Modern development in wireless communication systems has induced a increasing demand for planar microstrip microwave device. Specially, microstrip filter is a major component in communication systems. As various application requirements occur, great deals of filters with different characteristics are proposed [1]-[9]. In [1], a compact ultrawideband (UWB) bandpass filter (BPF) with wide notched-band is proposed; the structure is composed of a U-shaped open-circuited line. In [2], a compact filter using defected stepped impedance resonator (DSIR) is presented. The resonator property of DSIR is studied and compared with microstrip SIR. Besides, stepped-impedance resonators are utilized to realize the dual-band bandstop filter [3], and a meandered-line stepped-impedance resonator [4] is used in the design of dual-band bandstop filter. In [5], a bandpass filter with two transmission poles in passband using a single ring resonator is designed. In [6], simple designs of dual bandpass and bandstop filters using microstrip open-loop resonator are presented. It uses a simple technique avoiding the method of extracting coupling coefficient matrices to realize the filter. In addition, a compact UWB bandpass filter with tunable notch band based on folded SIR is fabricated in [7]. Transversal signal-interaction with three paths [8] and meandered slot defected microstrip structure [9] are also used in the design of dual-band bandstop filter. In recent years, many novel filters [10]-[12] are fabricated adopting different structure. Stepped impedance resonator and defected ground structure are usually adopted in these novel designs [13]-[18].

In this letter, a bandpass filter with high selectivity is proposed, to get better out-of band suppression and four transmission zeros, stepped impedance resonators (SIR) and defected ground structure are adopted. The 3-dB bandwidth of the proposed BPF is 2.62-2.72GHz. The result of S-parameter has four transmission zeros, the creation is due to the cross coupling in stepped impedance resonators and mode of feeding.

II. STRUCTURE OF BANDPASS FILTER

The geometries of stepped impedance resonator is shown in Fig. 1. The size of the structure are l1=5.3mm, l2=9.8mm, w1=2.5mm, w2=2mm.
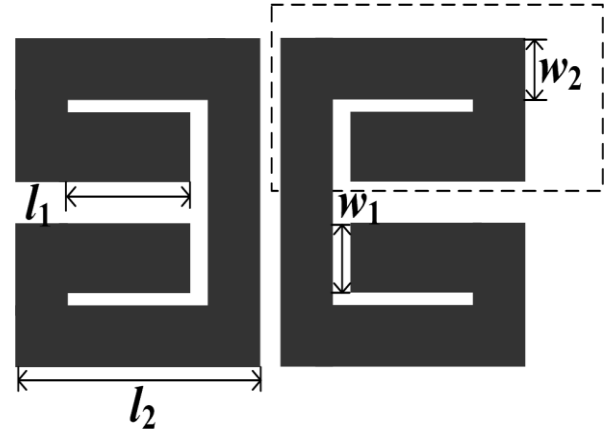

Figure 1. The structure of stepped impedance resonators.

Proposed resonator is consisted of two stepped-impedance resonators. As shown in Fig. 2, to obtain the input impedance (Zin), the SIR is partitioned into two sections: the first section has characteristic impedance (Z1) and electrical length (θ1); the second section consists of stubs with characteristic impedance (Z2) and electrical length (θ2). It is apparent to evaluate the overall input impedance by cascading the ABCD matrix of section 1 and 2. The ABCD matrix of section 1 is deduced as (1)

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_1 = \begin{bmatrix} \cos\theta_1 & jZ_1\sin\theta_1 \\ j\dfrac{1}{Z_1}\sin\theta_1 & \cos\theta_1 \end{bmatrix} \quad (1)$$

The ABCD matrix of section 2 is deduced as (2)

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_2 = \begin{bmatrix} \cos\theta_2 & jZ_2\sin\theta_2 \\ j\dfrac{1}{Z_2}\sin\theta_2 & \cos\theta_2 \end{bmatrix} \quad (2)$$

After cascading section 1 and 2, the ABCD parameters of SIR could be got. The overall input impedance (Zin) of the SIR is deduced as (3)

$$Z_{in} = \frac{R_z(1-\tan^2\theta_1)(1-\tan^2\theta_2)-2(1+R_z^2)\tan\theta_1\tan\theta_2}{j\dfrac{1}{Z_2}(R_z-\tan\theta_1\tan\theta_2)(R_z\tan\theta_1+\tan\theta_2)} \quad (3)$$

Yin=1/Zin, at the resonance condition, Yin=0 such that

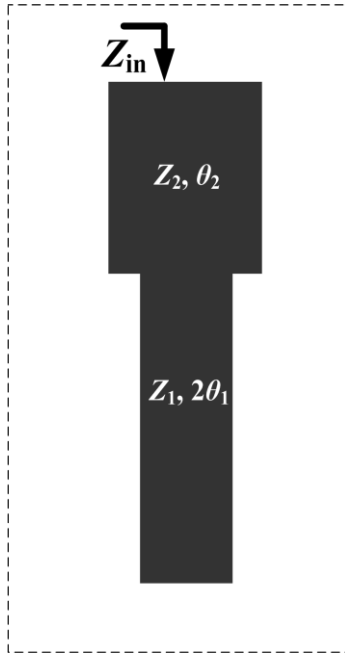$$R_z = Z_2/Z_1 = \tan\theta_1\tan\theta_2 \quad (4)$$

Figure 2.   The general SIR.

The schematic of the proposed bandpass filter is demonstrated in Fig. 3. In this design, two stepped impedance resonators are symmetrically-arranged. The substrate has a relative dielectric constant of 2.2 and the thickness of 0.508mm, at the bottom side of the substrate, there is defected ground structure. A ring and a smaller ring form a unit; defected ground structures have six units totally. At the top side of the substrate, it is the structure of stepped impedance resonators. The distance between two stepped impedance resonators is chosen as d2=0.8mm which results in a external coupling. These stepped impedance resonators have the same dimensions and they are symmetrically-arranged. Other parameters are d1=0.4mm, l3=18.4mm, l4=14.1mm, l5=6mm, l6=7.9mm, w3=3mm.
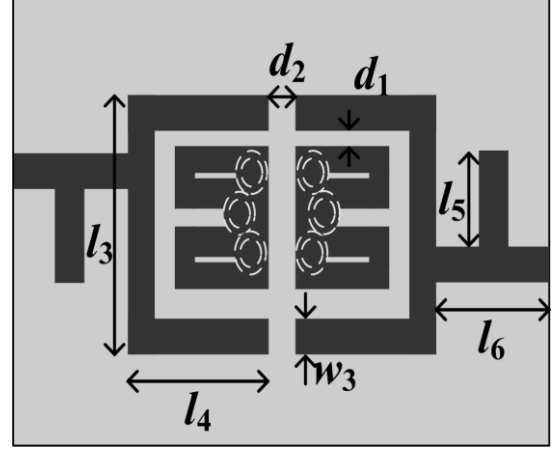

Figure 3.   The schematic of bandpass filter.

III.   SIMULATION AND MEASUREMENT

Based on the proposed structure, the results of S-parameter are obtained by using High Frequency Structure Simulator (HFSS) software as shown in Fig. 4. As can be observed, the result curve of S-parameter has four transmission zeros and the filter has great out-of band suppression. The characteristic of passband is also great.
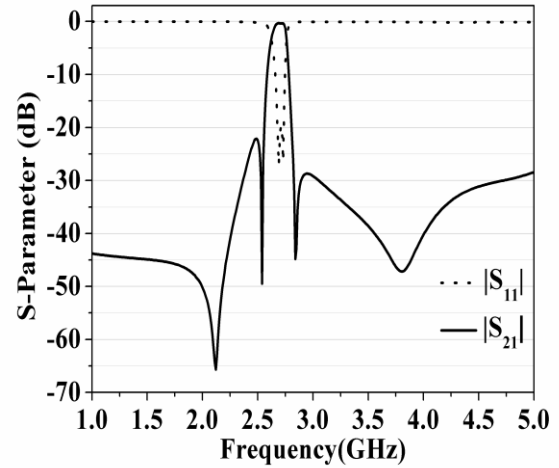

Figure 4.   Simulated results.

By adjusting the size of structure, the filtering effects of structures are different. Fig. 5 demonstrates the S-parameter variations according to the value of l1. In this case, l1 varies from 4.3 to 5.3mm, while the values of other parameters are fixed. Results display that the characteristics of 3-dB bandwidth and out-of band suppression are affected by value of l1. When l1 varies from 4.3mm to 5.3mm, the selectivity of filter is getting greater.

From the above mentioned, we could know that the dimensions of structure are critical for the selectivity of the proposed filter. Changing the value of l1, the working frequency band is affected.

Fig. 6 exhibits comparison of the S-parameter via changing the value of d2. Simulated results indicate that the out-of band suppression is being better when d2 varies from 0.6mm to 0.8mm, being worse when d2 varies from 0.8mm to 1.0mm. It also displays that the characteristics of 3-dB bandwidth and out-of band suppression are affected by value of d2. When d2 is 0.8mm, the performance of structure is great.
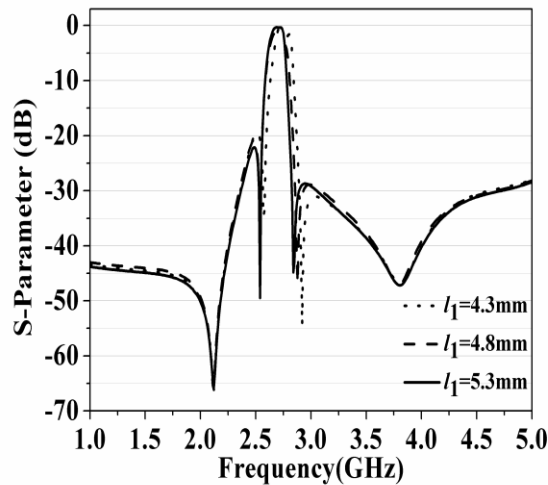

Figure 5.   S-parameter variations according to the l1.

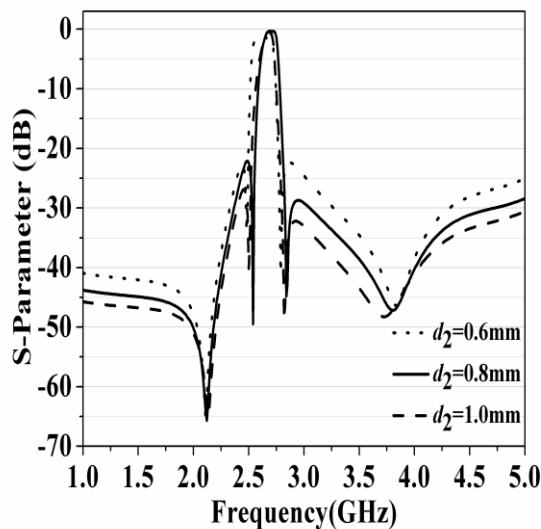
Figure 6.   S-parameter variations according to the d2.

Fig. 7 plots the simulated and measured S-parameter curves against frequency. The bandpass filter has four transmission zeros located at 2.12, 2.54, 2.84, and 3.80 GHz and the insertion loss within passband is getting worse. In totally, the simulated results agree with measurements.
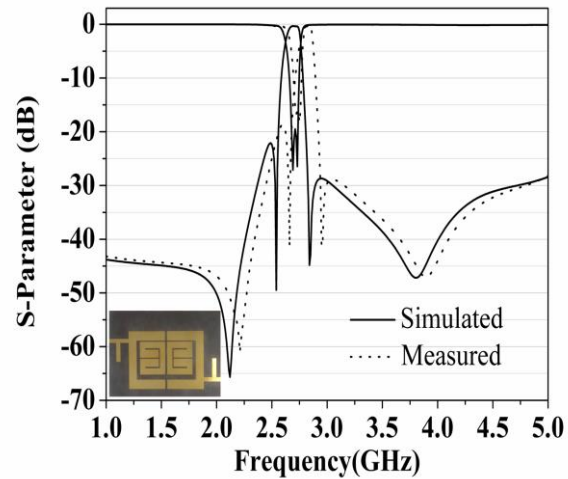

Figure 7.   Simulated and measured results.

IV.   CONCLUSION

A bandpass filter (BPF) with high selectivity and four transmission zeros is proposed. Low insertion loss and great out-of band suppression are introduced by the defected ground structure. Stepped impedance resonators are symmetrically-arranged, defected ground structure consists of six rings units. Owing to the cross coupling in stepped impedance resonators and mode of feeding, four transmission zeros are induced. Results indicate that the proposed filter has great selectivity; it can be used in wireless communication.

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