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A NOVEL DUAL-BAND BANDSTOP WAVEGUIDE FILTER USING SPLIT RING RESONATORS

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Abstract—In this paper, the potential use of split ring resonators (SRRs) to design very compact dual-band bandstop waveguide filters is proposed. Two square SRRs are placed on the same transverse plane realizing two independent reject bands. By adjusting the SRRs lengths, the stopbands can be targeted at the desired frequencies. In addition, a simple circuit model for this resonator is introduced. Good agreement between the experimental and full-wave simulated results has been achieved.

1. INTRODUCTION

Bandstop filters are used in RF/microwave and millimeter-wave applications for suppressing higher harmonics and spurious signals. Recently, split-ring resonators (SRRs), originally introduced by Pendry [1], are used to design compact bandstop waveguide filters [2–4].

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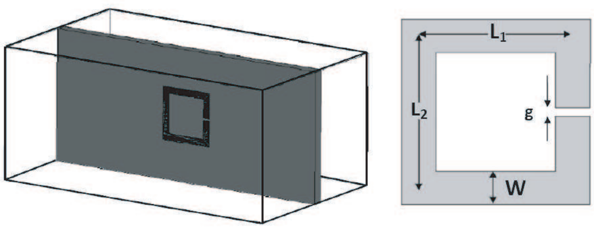
Most previous research studies have reported methods that use one single filter to treat multi-band in order to save space and cost of the filter [4–7].

In this paper, two split ring resonators which are placed on the same transverse plane are used for designing a very compact dualband bandstop waveguide filter. The considerable distance between two resonators on the transverse plane eliminates the coupling effect. Consequently, both the resonant frequencies and the stop bandwidths of dual bands of the filter can be independently controlled. The total length of the resonator and its physical width determine the resonant frequency and relative bandwidth, respectively. In addition, based on the full-wave simulation results, a circuit model is retrieved. The measurement has validated the theoretical design.



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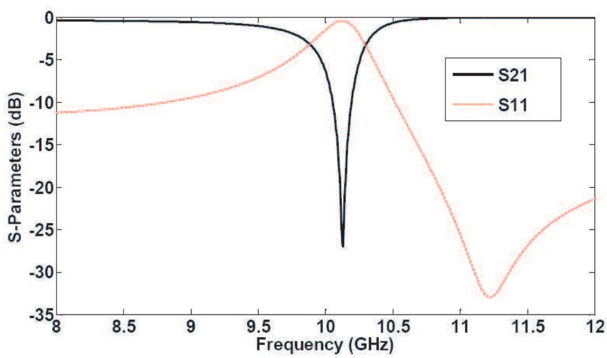


(b)

Figure 1. (a) Configuration of SRR loaded waveguide, (b) simulated scattering parameters for $l_1 = l_2 = 2.9\,\text{mm}$, $g = 0.2\,\text{mm}$ and $W = 0.15\,\text{mm}$.

2. DESIGN OF SINGLE BAND BANDSTOP FILTER

Figure 1 shows configuration of SRR loaded in a waveguide to realize a band-reject filter.

The substrate RT/Duroid 5880 with the thickness of 31 mil and relative dielectric constant of 2.2 is used for all simulations.

The resonant frequency of SRR depends only on its total physical length $(2L_1 + 2L_2)$ for a constant value of space gap (g). The variation of resonant frequency versus geometrical parameter of $(2L_1 + 2L_2)$ for $g = 0.2$ mm is illustrated in Fig. 2.

The resonant frequency is independent of the physical width (W) of the SRR. The physical width determines bandwidth of frequency response. Fig. 3 shows 3 dB bandwidth of the resonator for different values of physical width (W) for the case where $L_1 = L_2$.

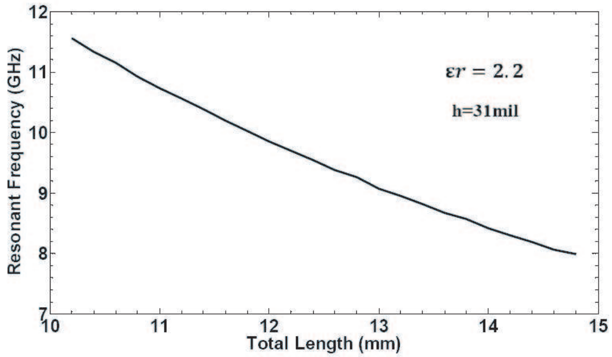


Figure 2. Resonant frequency versus total length of resonator.

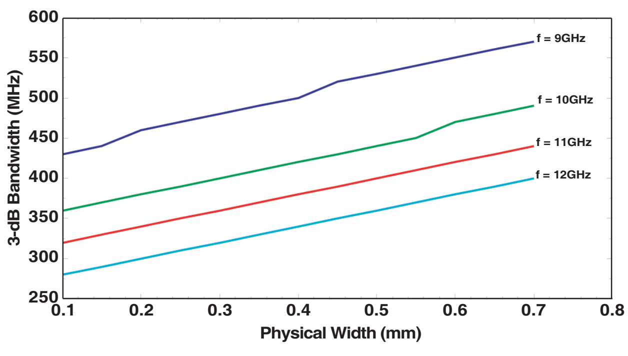


Figure 3. 3 dB bandwidth of resonator for different values of physical width (W) for the case where $L_1 = L_2$.

3. DESIGN OF DUALBAND BANDSTOP FILTER

Figure 4 depicts the structure of proposed dualband bandstop resonator which is composed of two SRRs. Because of large distance between resonators, the coupling effect between two resonators is very poor. Therefore, both the stopband frequencies of the filter can be controlled independently.

Figure 5 depicts variations of the first stopband frequency versus total length of the first resonator while the second stopband is unchanged.

A simple lumped element model is set up for proposed dualband resonator which is shown in Fig. 6(a). From the illustrated full-wave simulation results, the circuit model parameters can be extracted as

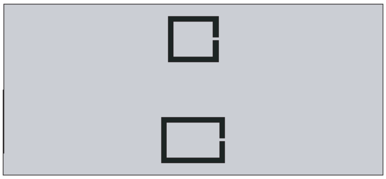


Figure 4. Structure of dualband bandstop resonator.

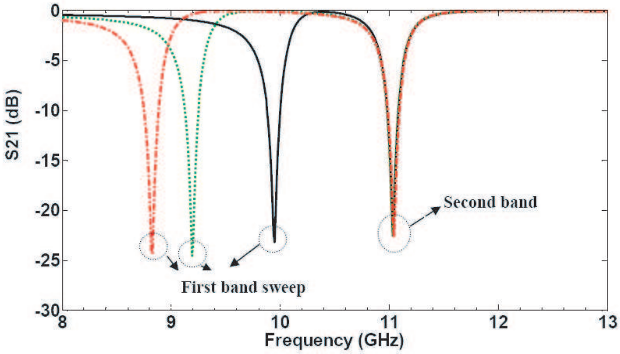


Figure 5. Simulated transmission-coefficient for the dimensions of first resonator ($L_1 = 2.7\,\mathrm{mm}$, $L_2 = 2.4\,\mathrm{mm}$, $W = 0.3\,\mathrm{mm}$, $g = 0.2\,\mathrm{mm}$) and second resonator ($L_1 = 3.8\,\mathrm{mm}$ (solid line), $L_1 = 4.4\,\mathrm{mm}$ (dotted line), $L_1 = 4.6\,\mathrm{mm}$ (dashed line), $L_2 = 2.4\,\mathrm{mm}$, $W = 0.3\,\mathrm{mm}$, $g = 0.2\,\mathrm{mm}$).

follows:

$$R_i = 2Z_0 \left(1/\left|S_{21,i}\right| - 1\right)\big|_{f=f_i}$$
$$C_i = \frac{\sqrt{0.5(R_i + 2Z_0)^2 - 4Z_0^2}}{2.83\pi Z_0 R_i B_i}$$
$$L_i = \frac{1}{(2\pi f_i)^2 C_i} \qquad i = 1, 2$$

where f_i is the resonant frequency; B_i is the 3 dB bandwidth of $S_{21}|_{f=f_i}$; Z_0 is the characteristic impedance. For the dimensions of first ($l_1 = 2.7$ mm, $l_2 = 2.4$ mm, $w = 0.3$ mm, $g = 0.2$ mm) and second resonators ($l_1 = 3.5$ mm, $l_2 = 2.4$ mm, $w = 0.3$ mm, $g = 0.2$ mm), the circuit model parameters are: $C_1 = 5.284$ pF, $L_1 = 0.0494$ nH, $R_1 = 1487\,\Omega$, $C_2 = 5.284$ pF, $L_2 = 0.0371$ nH and $R_2 = 1487\,\Omega$.

Figure 6(b) shows the circuit model response which is in good agreement with full-wave simulated result.

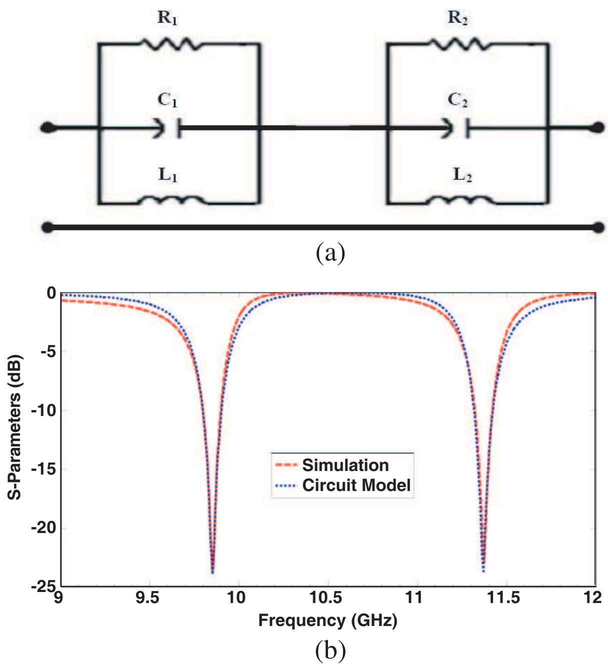
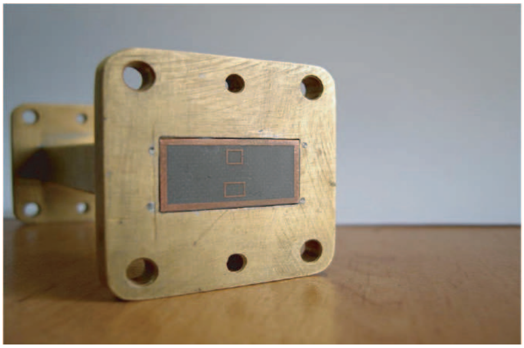


Figure 6. (a) Circuit model of the proposed filter, (b) comparison of the circuit model response and full-wave simulated result.

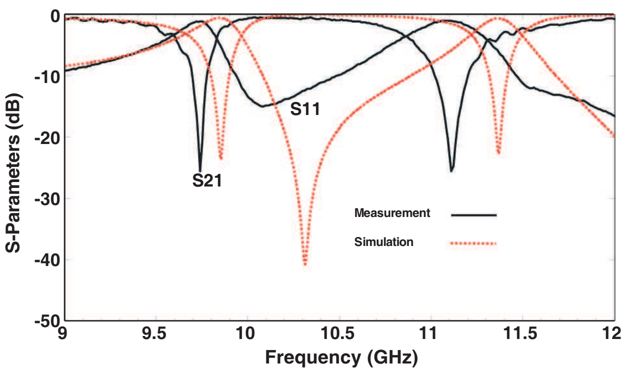
4. FABRICATION AND MEASUREMENT

A new dual notch structure with center frequencies of 9.8 GHz and 11.4 GHz has been fabricated on a 31 mil thick RT/Duroid 5880 substrate with dielectric constant 2.2 and loss tangent 0.0009, which is placed in WR90 waveguide.

A photograph of the fabricated filter, measured and full-wave simulated results are shown in Fig. 7.



(a)



(b)

Figure 7. (a) Photograph of the proposed filter, (b) comparison of the measurement (solid line) and fullwave simulated (dotted line) results with the following parameters for the first resonator ($L_1 = 2.7$ mm, $L_2 = 2.4$ mm, $W = 0.3$ mm, $g = 0.2$ mm) and the second resonator ($L_1 = 3.5$ mm, $L_2 = 2.4$ mm, $W = 0.3$ mm, $g = 0.2$ mm).

5. CONCLUSION

In this paper, a new compact dual-band waveguide bandstop filter using double SRR structure with center frequencies of 9.8 GHz and 11.4 GHz is designed, fabricated, and tested. A simple RLC model is introduced for this resonator. Then, the parameters of the circuit model are extracted from full-wave simulation result. Finally, the performance of the filter has been demonstrated experimentally.

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