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A COMPACT MICROSTRIP BANDSTOP FILTER

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Abstract—In this paper, a novel microstrip bandstop filter by etching a square split ring in the center of microstrip line is proposed. Low insertion loss in the passband, high rejection level and integrated structure should be mentioned as advantages for this resonator. A transmission line model for this resonator is introduced and its resonant frequency is calculated analytically. Good agreement between the experimental results, full-wave simulation, transmission line model and analytical result has been achieved.

1. INTRODUCTION

Bandstop filters (BSFs) are important components in microwave and millimeter-wave applications to reject higher harmonics and spurious passbands. The conventional method to design BSFs involves the use of shunt stubs or lumped elements [1]. Furthermore, with the recent advances in microwave integrated circuits, there is a great demand for compact filters. Recently, using Split Ring Resonator (SRR), Complementary Split Ring Resonator (CSRR), Defected Ground Structures (DGS) and Defected Microstrip Structures (DMS) for designing of compact bandstop filters have become attractive in microwave circuits [2–7].

In this paper, a new design of a compact bandstop filter using Defected Microstrip Structure (DMS) by etching Open Square Ring (OSR) is proposed and its resonant frequency is extracted analytically by using lossless transmission line model.

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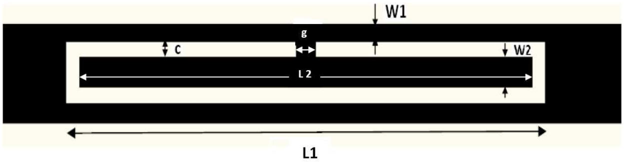


Figure 1. Configuration of Open Square-Slot DMS (OSS-DMS).

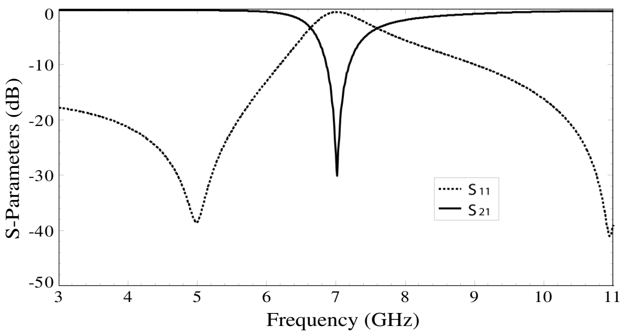


Figure 2. The full-wave simulated scattering parameters of proposed filter.

2. IMPLEMENTATION OF FILTER

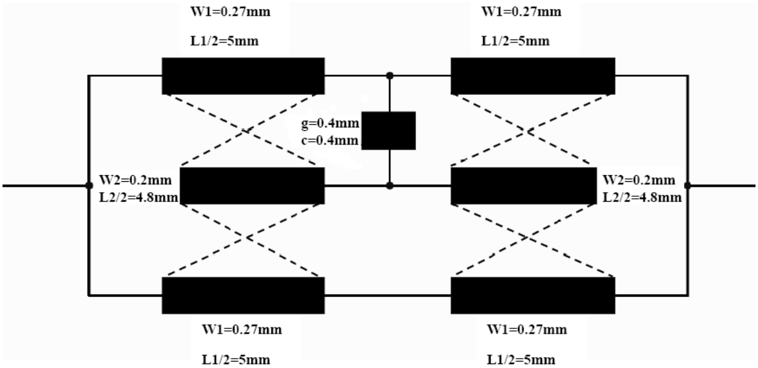
Figure 1 illustrates the configuration of Complementary Open Square Ring-DMS (COSR-DMS) in the center of the microstrip line.

For the dimensions $L_1 = 10\,\text{mm}$, $L_2 = 9.6\,\text{mm}$, $c = 0.4\,\text{mm}$, $g = 0.4\,\text{mm}$, $w_1 = 0.27\,\text{mm}$ and $w_2 = 0.2\,\text{mm}$, the full-wave simulated S-parameters are depicted in Fig. 2. The substrate RT/Duroid 5880 with the thickness of 0.508 mm and fractional dielectric constant of 2.2 is used for all simulations. The designed COSR-DMS provides the band rejection property of 30 dB at the frequency of 7 GHz.

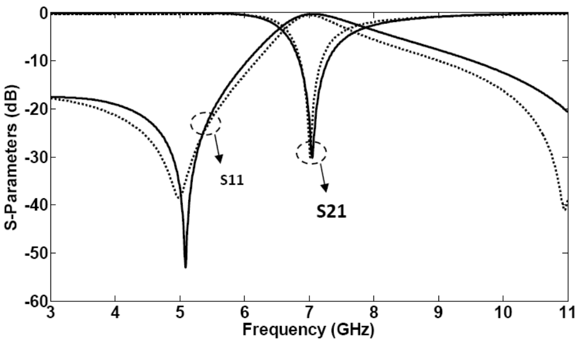
3. ANALYSIS OF THE COSR-DMS RESONATOR

Microstrip coupled lines model is used for analysis of this resonator. The transmission line model of corresponding resonator and simulation results are shown in Fig. 3.

To extract an equation for the resonant frequency of the resonator, the coupling effect in the transmission line model is ignored because of very narrow physical width of the microstrip coupled lines. Therefore, Fig. 3(a) is transformed to a simple model that is depicted in Fig. 4.



(a)



(b)

Figure 3. (a) Coupled lines model of OSRS-DMS resonator. (b) Comparison of coupled lines model's response (solid line) and fullwave simulation results (dotted line).

The length of middle section is added to length L_2. Therefore, $L_1/2 \approx L_2/2 \approx L$ and the middle section is removed.

Considering the Fig. 4 and based on the lossless transmission line model, the transmission coefficient of the filter is

$$S_{21} = \frac{2}{A + B/Z_0 + CZ_0 + D} \tag{1}$$

where Z_0 is the port impedance and the $ABCD$ parameters of the

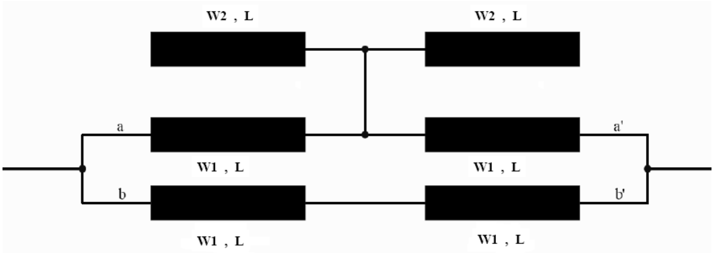


Figure 4. Lossless transmission line model of corresponding resonator.

resonator with $Z_0 = 50$ are

$$\left\{\begin{array}{l} A = \dfrac{\left(-5\cos^2\theta + 4\cos^4\theta + 1\right) Z_1 + \left(-2\cos^2\theta + 4\cos^4\theta\right) Z_2}{2Z_2\cos^2\theta - Z_1\sin^2\theta} \\ B = \dfrac{iZ_1\sin 2\theta\left(Z_2\cos^2\theta - Z_1\sin^2\theta\right)}{2Z_2\cos^2\theta - Z_1\sin^2\theta} \\ C = \dfrac{2iZ_1\sin 2\theta\left(2Z_2\cos^2\theta + 2Z_1\cos^2\theta - Z_1\right)}{Z_1\left(2Z_2\cos^2\theta - Z_1\sin^2\theta\right)} \\ D = A \end{array}\right. \tag{2}$$

where $\theta = \beta L$, Z_1 and Z_2 are the impedances of the lines with $W = w_1$ and $W = w_2$, respectively.

The filter creates transmission zeros at the frequencies where

$$|S_{21}| = 0 \tag{3}$$

This condition yields to the following equation:

$$2Z_2\cos^2\theta + Z_1\cos^2\theta - Z_1 = 0 \tag{4}$$

Using Equation (4), the fundamental resonant frequency will be defined as:

$$\theta = \cos^{-1}\left(\sqrt{\frac{Z_1}{Z_1 + 2Z_2}}\right) \tag{5}$$

$$f_r = \frac{c}{2\pi L\sqrt{\varepsilon_{re}}}\cos^{-1}\left(\sqrt{\frac{Z_1}{Z_1 + 2Z_2}}\right) \tag{6}$$

Where $c = 3 \times 10^8$ m/s and ε_{re} is effective microstrip permittivity.

For example, by referring to Fig. 1 and geometrical dimensions $L_1 = 10$ mm, $L_2 = 9.6$ mm, $c = 0.4$ mm, $g = 0.4$ mm, $w_1 = 0.27$ mm and $w_2 = 0.2$ mm the parameters of Equation (6) will be: $L = 5$ mm, $Z_1 = 120\,\Omega$, $Z_2 = 132.75\,\Omega$ and $\varepsilon_{re} = 1.7$. Subsequently, the resonant frequency is obtained as $f_r = 7.1$ GHz that is in good agreement with fullwave simulation result (See Fig. 2).

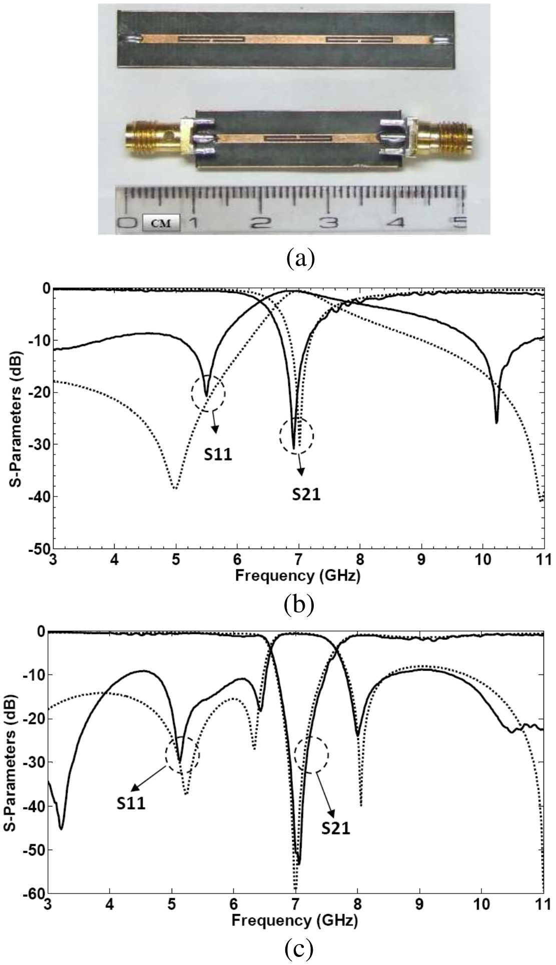


Figure 5. (a) Photograph of the single and two-period bandstop resonator. (b) Fullwave simulation (---) and measured results (—) of the single bandstop resonator. (c) Fullwave simulatrion (---) and measured results (—) of the two-period bandstop filter.

4. FABRICATION AND MEASUREMENT

Two BSFs, first and second order prototype, have been fabricated on a 0.508 mm thick RT/Duroid 5880 substrate with dielectric constant of 2.2 and loss tangent of 0.0009.

A photograph of the fabricated filters and their measured results are shown in Fig. 5. The line impedance of the BSFs is 50 Ω.

5. CONCLUSION

This paper proposed a new compact and high rejection level bandstop filter by using defected microstrip structure. The transmission line model is introduced for this resonator and the corresponding resonant frequency is extracted analytically. This new compact microstrip bandstop filter can be very attractive for the application of MMIC design.

ACKNOWLEDGMENT

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REFERENCES

1. Hong, J. S. and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, Wiley- Interscience, New York, 2001.
2. Wang, C. J. and C. S. Lin, "Compact DGS resonator with improvement of Q-factor," *Electronics Letters*, Vol. 44, No. 15, 908–909, 2008.
3. García-García, J., F. Martín, F. Falcone, F. Bonache, T. Lopetegi, M. A. G. Laso, M. Sorolla, and R. Marqués, "Spurious passband suppression in microstrip coupled line band pass filters by means of split ring resonators," *IEEE Microwave and Wireless Compon. Lett.*, Vol. 14, No. 9, 416–418, 2004.
4. Marqués, R., F. Martín, and M. Sorolla, *Metamaterials with Negative Parameters*, Wiley-Interscience, New Jersey, 2007.
5. Kazerooni, M. and A. Cheldavi, "Simulation, analysis, design and applications of array defected microstrip structure (ADMS) filters using rigorously coupled multi-strip (RCMS) method," *Progress In Electromagnetics Research*, PIER 63, 193–207, 2006.
6. Kazerooni, M., G. Rezai Rad, and A. Cheldavi, "Behavior study of simultaneously defected microstrip and ground structure (DMGS) in planar circuits," *PIERS Proceedings*, 895–900, Beijing, China, March 23–27, 2009.
7. Tirado-Méndez, J. A. and H. Jardón-Aguilar, "A simplified method to reduce dimensions of planar passive circuits using defected ground and defected microstrip structures," *Microwave Journal*, Vol. 50, No. 11, 58, 2007.