A Novel Design of a Compact Microstrip Band-stop Filter Based on CSRR

Badr Nasiri
LMEET FST of Settat
Hassan 1st University
Morocco
b.nasiri@uhp.ac.ma

Ahmed Errkik
LMEET FST of Settat
Hassan 1st University
Morocco
ahmed.errkik@uhp.ac.ma

Abdelali Tajmouati
LMEET FST of Settat
Hassan 1st University
Morocco
tajmoua@gmail.com

Larbi El Abdellaoui
LMEET FST of Settat
Hassan 1st University
Morocco
elabdellaoui20@hotmail.com

Mohamed Latrach
Microwave Group
ESEO, Angers
France
Mohamed.latrach@eseo.fr

ABSTRACT

This work presents a novel compact band-stop filter by using Complementary Split-Ring Resonator connected with 50 Ω microstrip line mounted on an FR4 substrate. The simulation results of the proposed BSF demonstrates a good characteristic rejected band with stopband fractional bandwidth of 58% at f_0= 1.7GHz resonant frequency. The insertion loss is more than 40 dB and return loss is less than 0.1 dB at f_0. The designed filter has a good electrical performance in the first and second bandpass. The proposed BSF is designed, simulated and optimized by CST microwave studio. To validate the feasibility of the designed BSF, another simulation has been carried out by using ADS. This filter is an adequate solution for ISM, AMPS and GSM Applications.

.

KEYWORDS

Microstrip, band-stop filter, CSRR, metamaterials

1 INTRODUCTION

The demand of microstrip band-stop filter is tremendously increasing in the microwave systems and modern wireless communication. It provides the desired rejection of fundamental frequencies that has been widely used in order to avoid noise, spurious signals, and unwanted range of frequencies. [1-4].

*ICCWCS'*17, November 14–16, 2017, Larache, Morocco

ACM ISBN 978-1-4503-5306-9/17/11…$15.00
https://doi.org/10.1145/3167486.3167490

The conventional band-stop filters by using shunt open-circuited stubs experience a narrowly rejected band and large size. Nowadays, this circuit have been developed by diverse technical methods such as defected ground structure (DGS), microstrip line with etched spiral resonators, open-loop resonator and particularly metamaterials which are used in designing microwave band-stop filters due to their special characteristics. [5-11].

Recently, the possibilities of applying many advantages of the unusual electromagnetic wave propagation properties have led to numerous research activities. These novels engineered materials called metamaterials have a negative permittivity, negative permeability or simultaneously negative permittivity and negative permeability. They take their properties from their structures rather than their compositions. In microwave engineering, there are several metamaterials types such as a split ring resonators (SRRs) and its dual counterpart (CSRRs) that can be useful in microstrip devices. [12-17].

The split-ring resonator and complementary split-ring resonator are extensively used to design of new planar filters especially band-pass and band-stop filters. The greatest benefit of using this type of resonators for microwave component design is that they have significantly smaller area than classical resonator structures. In general, its size is less than one-tenth of a wavelength which enables to design a compact and small circuit size. [14-17].

This paper proposes a novel compact and high rejection level band-stop filter by using complementary split ring resonator. The proposed circuit characterized by compact size, low cost, easy fabrication, wide rejected band and stopband fractional bandwidth FBW of 58%. Moreover, it has good passband and stopband performances.

2 DESIGN PROCEDURES

2.1 Complementary Split-Ring Resonator

Complementary Split-Ring Resonator or called slotted split-ring resonator was firstly introduced by Falcone in 2004, it play a remarkable role in the miniaturization of wireless communication components implemented in planar technology. The CSRR structure has an electric response, its resonant frequency due to a strong electric dipole generated by the electric field which was applied parallel to the CSRR plane. It behaves as LC circuit and exhibits a rejected band near its resonant frequency which is given by equation (1).

$$f = \frac{1}{\pi\sqrt{L_{CSRR}C_{CSRR}}} \tag{1}$$

Where

$$L_{CSRR} = P \times L_{pul} \tag{2}$$

The total inductance is presented by L_{CSRR} and the total capacitance can be modeled by C_{CSRR}. L_{pul} is the per unit length inductance of the microstrip line. If the equivalence capacitance of the complementary split ring resonator increases by its dimensions or space between the inner and outer rings, the resonant frequency decreases. The Fig. 1 shows the conventional layout of the CSRR unit cell and Fig. 2 illustrates its LC equivalent circuit.

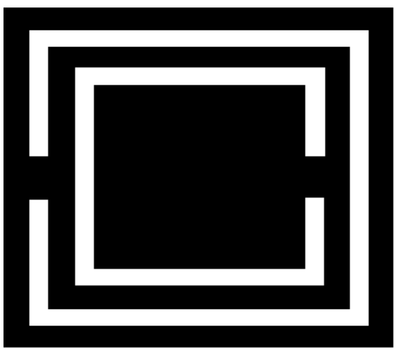

Figure 1: Conventional layout of the CSRR unit cell.

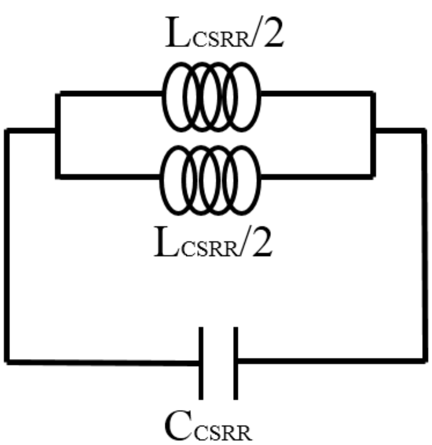

Figure 2: Equivalent circuit of the CSRR unit cell

2.2 Proposed band-stop filter

Theoretically, a band-stop filter can be achieved by using long open circuited stubs separated by a quarter wavelength long transmission lines [18]. The basic conventional structure of the optimum band stop filter is shown in Fig. 3 The characteristics of the BSF totally depend on the design of Z_i and $Z_{i,i+1}$ which present respectively characteristic impedances of the open-circuited stubs, the transmission line elements and both terminating impedances Z_{in} and Z_{out}.

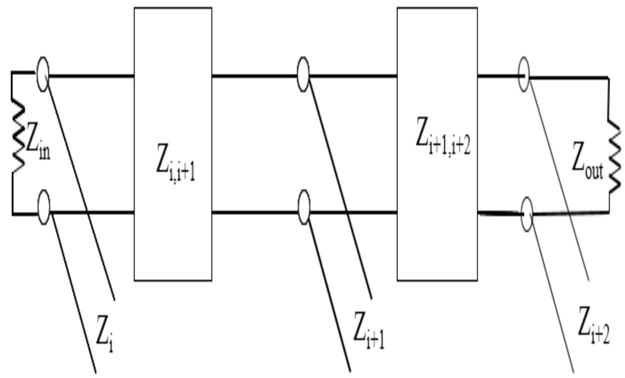

Figure 3: Transmission line network representation of open stub band stop filter

The synthesis of the conventional BSF network shown in Fig .2 is based on transfer function given by equation (3).

$$|S_{21}(f)| = \frac{1}{1+\varepsilon^2 A_n^2(f)} \tag{3}$$

$$A_n = B_n\left(\frac{t}{t_c}\right)B_{n-1}\left(\frac{t\sqrt{1-t_c^2}}{t_c\sqrt{1-t^2}}\right) - C_n\left(\frac{t}{t_c}\right)C_{n-1}\left(\frac{t\sqrt{1-t_c^2}}{t_c\sqrt{1-t^2}}\right) \tag{4}$$

t and t_c are Richards' transform variables which are given by equation (5) and (6).

$$t = jtan\left(\frac{\pi f}{2f_0}\right) \tag{5}$$

$$t_c = jtan\left[\frac{\pi}{2}(2-FBW)\right] \tag{6}$$

The fractional band width of the filter is defined in equation (7), where f_0 is the center frequency of the band-stop filter.

$$FBW = \frac{(f_2 - f_1)}{f_0} \times 100\% \tag{7}$$

$$B_n(x) = cos(ncos^{-1}x) \tag{8}$$

$$C_n(x) = sin(ncos^{-1}x) \tag{9}$$

$B_n(x)$ and $C_n(x)$ present respectively Chebyshev functions of the first and second kinds of order n. The characteristic impedances Z_i, Z_{i+1}, Z_{in} and Z_{out}.

$$Z_{in} = Z_{out} = Z_0 \tag{10}$$

$$Z_i = \frac{Z_0}{g_i} \tag{11}$$

$$Z_{i,i+1} = \frac{Z_0}{J_{i,i+1}} \tag{12}$$

Where g_i and $J_{i,i+1}$ present respectively the element values of the low pass prototype and admittance inverters.

The conventional microwave band-stop filter with open stub is used for its excellent characteristics. However, a filter with small size and high performance is widely desired and difficult to achieve.

The low insertion loss and the attenuation level are the most important parameters in a BSF in wireless communication system because they determine the system high-quality signal processing. The main purpose of this work is to design a compact miniature microwave BSF based on metamaterial CSRR. Moreover, it's characterized by high performance in the passband and good attenuation in the undesired range frequencies.

The starting point of this work is to select all parameters constituted the CSRR in order to achieve the desired rejected band and its center frequency. The filter consists of both 50 Ω microstrip line, two sections line and CSRR unit cell which is placed on the middle top layer. The proposed BSF has a circuit size of 24x24mm^2 on a dielectric substrate FR-4. The CSRR dimensions at 1.7 GHz have been found to be 15×14mm^2.

To achieve good electrical performances and small size, various parameters were tuned and optimized using CST Microwave. The layout pattern of the filter is shown in Fig. 4. All proposed BSF parameters are determined as follows, D=3mm, S= W=1mm, L=9mm and W1= 4mm.

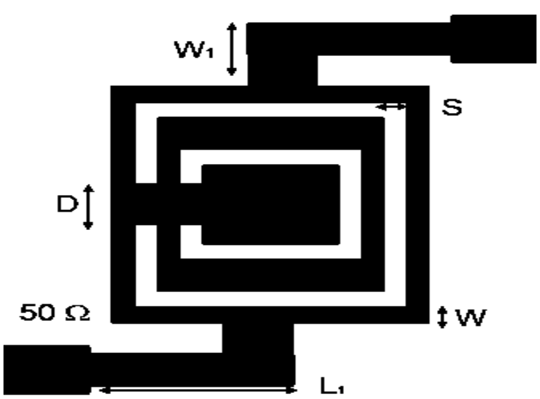

Figure 4: Geometry of the proposed BSF

To investigate the effect of the complementary split ring resonator. The designed structure without the etched resonator was simulated at first Figs. 5 and 6 show respectively the simulated scattering parameters of the proposed design with and without metamaterial unit cell.

From Fig. 6. The proposed filter shows band-stop characteristic at the center frequency of 1.7 GHz, the bandwidth of the stop band as 1 GHz [1.2GHz, 2.2GHz] with a deep rejection band of 40 dB and stopband fractional bandwidth FBW of 58%. Furthermore, the simulated results show a low insertion loss of 0.2 dB and the rejected band frequencies can be controlled by CSRR parameters.

To validate the simulated results obtained by CST Microwave Studio, another simulation has been carried out by using ADS based on a numerical discretization technique called the method of moments. Fig.6 illustrates the computed results obtained by CST Microwave Studio and ADS Agilent. They show a good agreement between both solvers.

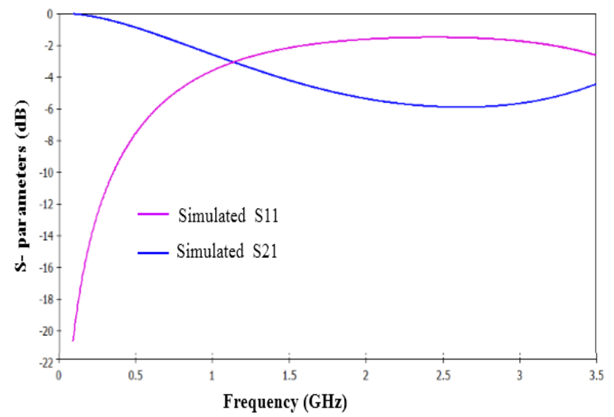

Figure 5: Simuleted results without etched CSRR

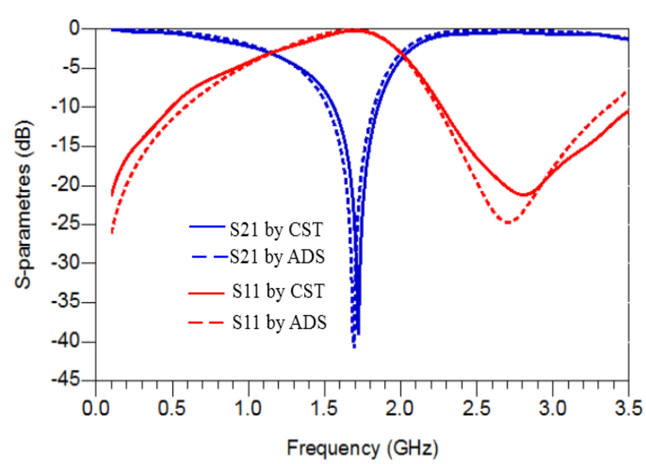

Figure 6: Simulated results by using CSRR

Fig.7 presents the simulated S-parameters phases of the designed filter.

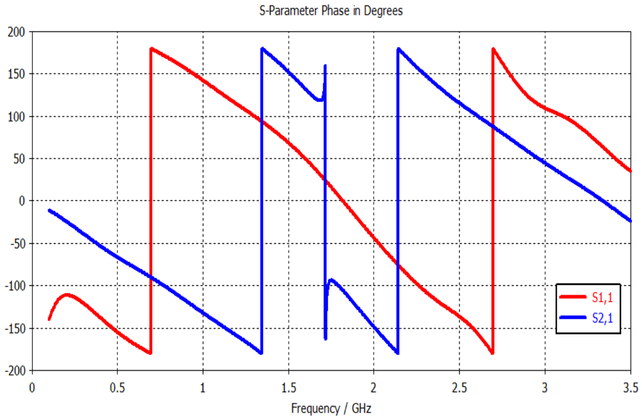

Figure 7: S-Parameter Phase versus frequency

Fig.8.a and Fig.8.b are depicted respectively the current density distributions at attenuation pole of 1.7 GHz and at 2.4 GHz in the second passband. As we can see from the first figure, the radio frequency power is full-reflected in the rejected band. On the other hand, the Fig. 8.b shows that The RF power is transmitted between the input port and output port which implies that there is a propagation signal in the proposed filter.

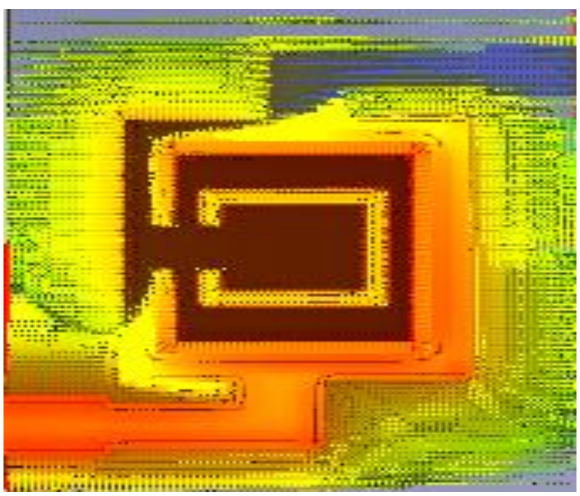

Figure 8.a: Simulated surface current density at the frequency 1.7GHz

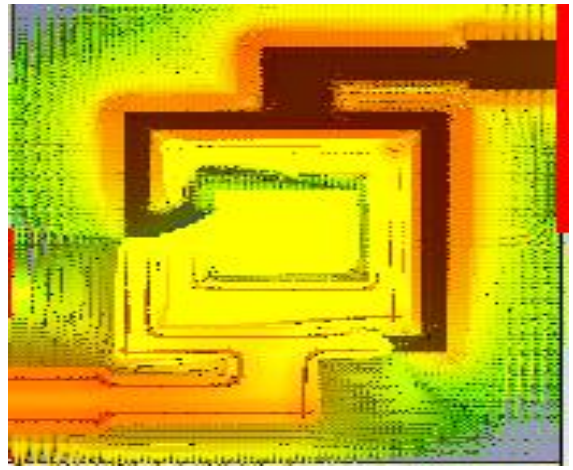

Figure 8.b: Simulated surface current density at the frequency 2.4GHz

The performance of proposed band-stop filter is compared with other published works in Table 1, where FBW is stopband fractional bandwidth that is used to evaluate the rejected band of a BSF.

It can be easily noticed from the Table 1, that this proposed band-stop filter has good features in term of circuit area, rejection level in the stopband, and good quality of transmission in the first and second passband.

Table 1: Performance comparisons among published filters and this work

Parameters /Ref	Rejected Band(GHz)	FBW	S21 Deep	Size mm^2
[8]	[4.4-5.4]	20%	25dB	1041≥
[9]	[1.3-1.7]	26%	30dB	1800
[11]	[0.975-1.02]	5%	35dB	6370
[12]	[9.19-10.25]	30%	30dB	600
This Work	[1.2-2.2]	58%	40dB	576

4 CONCLUSION

In this study, a novel compact microstrip band-stop filter based on CSRR was designed and optimized by using CST Microwave studio and its results were verified by using ADS Agilent. The proposed BSF characterized by rejected band between 1.2 GHz and 2.2GHz, has good electrical characteristics, Such as high return loss and insertion loss is less than 0.2dB in the passband. Moreover, it shows a good attenuation level in the stopband with FBW of 58% and it can be considered as a qualified solution for GSM, ISM, AMPS and wireless video transmitter.

ACKNOWLEDGMENTS

We thank Mr. Mohamed LATRACH Professor in ESEO, Engineering Institute in Angers, France, for allowing us to use all the equipments and solvers available in his laboratory.

REFERENCES

[1] H. Shaman and J.S. Hong. 2017. Wideband bandstop filter with cross coupling. *In IEEE Transactions on Microwave Theory and Techniques (*Aug. 2007, Volume 55, Issue 8). DOI: 10.1109/TMTT.2007.901600

[2] D.M. Pozar. 2005. *Microwave engineering*. John Wiley & Sons. 3rd Edition.

[3] S. U. Rehman, F. Sheta, M. Alkanhal. *2011*. Compact bandstop filter using defected structure. *In Electronics, Communications and Photonics Conference.* IEEE, Riyadh, 1-4.

[4] L.Murmu, S.Das. 2014. A Simple Wideband Microstrip BandstopFilter for WLAN and WiMAX Band Rejection Purpose. *In International Conference on Electrical and Computer Engineering*. IEEE, Dhaka, Bangladesh, 47-49.

[5] A.Boutejdar, A.Omar, E.Burte. 2010. Miniaturized Lowpass and Bandstop Filters Using Controlled Coupling of Open-Loop-Ring Defected Ground Structure (DGS). *In Microwave and Optical Technology Letters*. (Volume 52, Issue11, November 2010).

[6] A.Boutejdar, A.Omar. A miniature 5.2-GHz bandstop microstrip filter using multilayer-technique and coupled octagonal defected ground structure. *In Microwave and Optical Technology Letters*. (Volume 51, Issue 12, Sept. 2009), 2810-2813.

[7] Ahmed Hameed Reja, Syed Naseem Ahmed, Mushtaq A. Alqaisy and Abdul Kareem Kasim Abdul Raheem. 2014. Design of Metamaterial Stepped-Impedance Microwave LPFs. *In 2014 World Congress on Computer Applications and Information Systems.* IEEE, Hammamet, Tunisia. DOI: 10.1109/WCCAIS.2014.6916560

[8] J.Carver, V.Reignault, F.Gadot. 2014. Engineering of the metamaterial-based cut-band filter. *In Applied Physics A.* (November 2014, Volume 117, Issue 2), 513–516.

[9] R.Ranjan, A. K. Tiwary, N.Gupta. 2014. Design and Development of Bandstop Filter using Spiral Stubs. *In International Conference on Advances in Computing, Communications and Informat*ics. IEEE New Delhi, India, 1360-1363. DOI: 10.1109/ICACCI.2014.6968307

[10] A.Boutejdar. 2016. A new approach to design compact tunable BPF starting from simple LPF topology using a single T-DGS-resonator and ceramic capacitors. *In Microwave and Optical Technology Letters*. (May 2016, Volume 58, Issue 5), 1142-1142.

[11] E. J.Naglich and A. C.Guyette. 2015. Microwave bandstop filters with minimum through-line length. *2015 IEEE MTT-S International Microwave Symposium. IEEE* Phoenix, AZ, USA. DOI: 10.1109/MWSYM.2015.7166739

[12] P M.Esmaeili, J. Bornemann. 2015. Microstrip bandstop filters using L- and T-shaped resonators. *In IEEE Microwave Conference (APMC), 2015 Asia-Pacific*. DOI: 10.1109/APMC.2015.7411622

[13] A. Batmanov, A. Boutejdar, P. Burte, and A. Omar. 2010. Design of Compact Coplanar Bandstop Filter composed on Open-Loop-Ring Resonator and Defected Ground Structure (DGS). *Microwave and Optical Technology Letters.* (February 2010, Volume 52, Issue 2), 478-483.

[14] J. B.Pendry, A. J.Holden and W. J.Stewart 1996. Extremely Low Frequency Plasmons in Metallic Mesostructures. *In Phys. Rev. Lett*. (Jun 1996), 4773-4776.

[15] J. B.Pendry, A. J.Holden, D. J.Robbins, et al. 1999. Magnetism from conductors and enhanced nonlinear phenomena. *In IEEE Transactions on Microwave Theory and Techniques.* (Volume 47, Issue 11), 2075–2084.

[16] V. G.Veselago. 1968. The Electrodynamics of Substances with Simultaneous Negative Values of ε and μ. *in Soviet Physics Uspekhi*. (Volume 10, Issue 4), 509-514. DOI: https://doi.org/10.1070/PU1968v010n04ABEH003699

[17] Y.Yang, Z.Xi, N.C. Karmakar.2012. Microstrip lowpass filter based on split ring and complementary split ring resonators. *In Microwave and Optical Technology Letters*. (Volume 54, Issue 7 July 2012), 1723–1726.

[18] D.Morgan and R.Ragland. 1986. Lumped element filters for electronic warfare systems. *Microwave Journal.* (Feb. 198, volume. 29), 127–136.