Square Complementary Split Ring Resonator (CSRR) Low Pass Filter

Mohammed Bendaoued[1], Rachid Mandry[1], Larbi El Abdellaoui[1], Aytouna Fouad[2] and Mohamed Latrach[3]

[1] *FST, Hassan II, University, Settat, Morocco*
[2] *ENSA, Abdelmalek Essaadi, University, Tetouan, 93000, Morocco*
[3] *RF& Microwave Group, ESEO, Angers, France*

Abstract. A novel CPW Low pass filter structure using square complementary split ring resonator (CSRRs) is presented in this work. The CSRRs are etched periodically in each ground plane of the CPW line which permit to suppress the spurious response. The low pass filter shows a good rejection in the stop band. The cut-off frequency at -3dB is equal to f_c = 5.28GHz. This filter has total area of 35.48x21.16 mm^2.

Keywords: CPW, LPF, CSRR, Resonator, Metamaterial.

1 Introduction

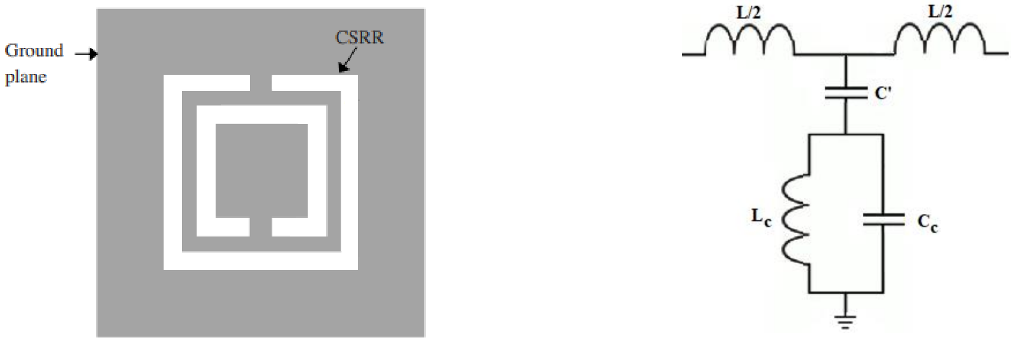
Metamaterials are artificial materials that exhibit singular electromagnetic properties that we do not find in nature or in their constituents taken separately. The most interesting feature is the possibility to control or modify the permittivity and permeability of the material to obtain a behaviour adapted to a specific application [**1**]. Metamaterials are used to improve the performance of antennas, filters and couplers. Their main advantage is the miniaturization of the microwave circuits. Thanks to these left-handed materials as Calls them, which are used the split-ring resonators (SRR) and Complementary Split Ring Resonators (CSRRS), it may be possible to build compact microstrip low pass filters, stop band filters and band pass filters for microwave frequency uses, etc... These resonators have a structure (cell of base) very small in front of the guided wavelength. It is accepted that the limit of homogeneity is fixed at sizes less than $\lambda g/4$.

The SRR is one of the essential structures of metamaterials. It produces a negative Permeability effect close to the resonance frequency While the metal wires behave like a two-dimensional plasma, with negative Permittivity to the plasma frequency. The use of CSRRs metamaterials is to promote the miniaturization of band-stop and UWB filters [2-3]. The CSRRs are formed by parallel combinations of inductances (s) and Capacitors (C), with the electromagnetically coupled LC circuit to the host transmission line. The equivalent circuit model for CSRRs loaded by transmission lines, and its relevant values of inductances and capacitors can be calculated using the methods described in [4]. At resonance, the CSRR provides

ICCWCS 2019, April 24-25, Kenitra, Morocco

DOI 10.4108/eai.24-4-2019.2284083

negative effective permittivity and produces a sharp rejection stop band. **Figure 1.** shows the geometry of the CSRR cell structure with it's equivalent lumped elements.



(a) (b)

Fig. 1. (a) Geometry of a CSRR unit cell (b) Lumped-element equivalent circuit of the CSR.

The zero transmission frequency of each CSRR coupled to the transmission line is given by:

$$f_z = \frac{1}{(2\pi\sqrt{LC[C_c+C]})} \qquad (1)$$

The resonance frequency of CSRR can be tuned for the desire application.

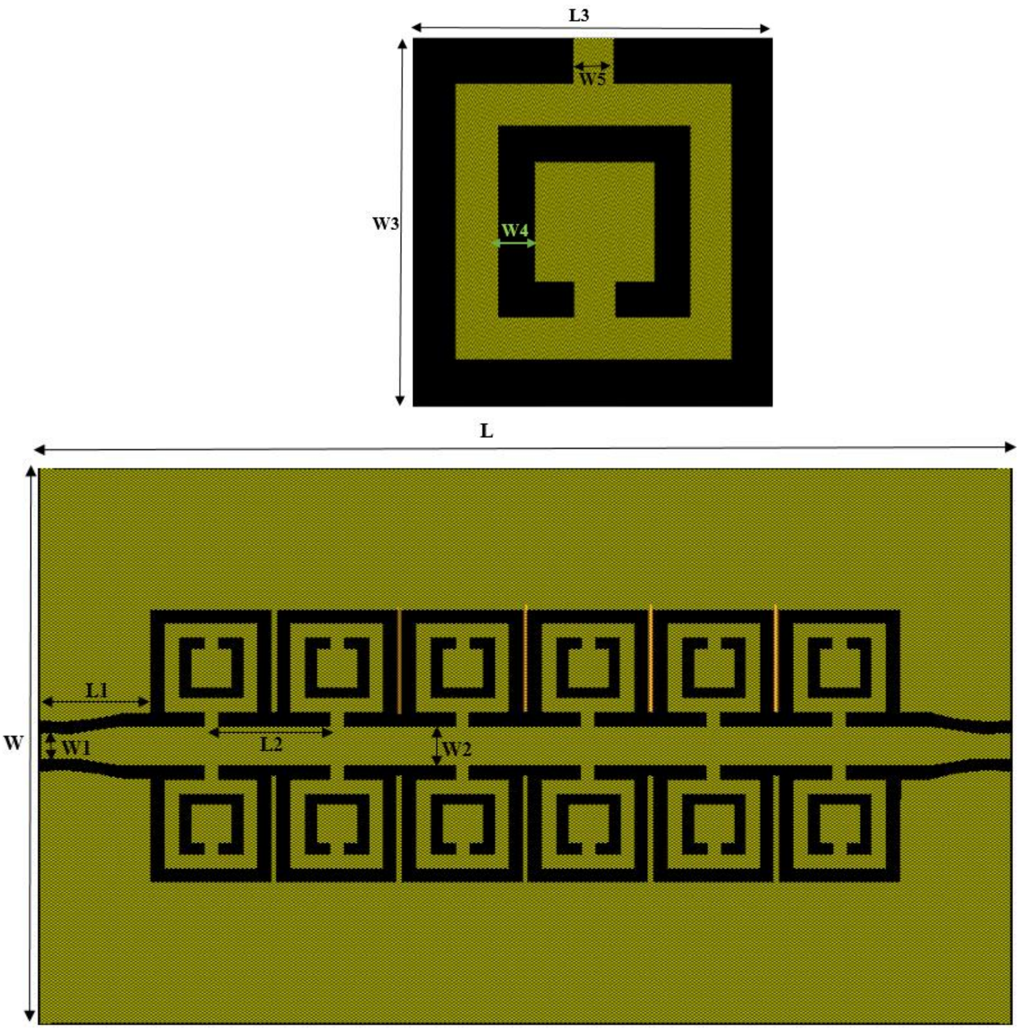
It is shown by many publications [5-9] that for a band stop filter, CSRR can greatly reduce the size of the filter while retaining very high stop band attenuation. This is because the evanescent modes can propagate in CSRR structures. In other side the periodic integration of these complementary split ring resonator on coplanar waveguide (CPW) provide some different design advantages in comparison with the conventional microstrip technology, e.g. the easy realization of shunts and the possibility of mounting active and passive lumped components [10-11]. in this paper we will present a CPW low pass filter loaded with six CSRR etched periodically in the two sides of the ground plane.

2 Design procedure

2.1 Theoretical study of the CSRR

2.2 Design procedure by ADS Solver

We have started the design of this filter by studying the unit cell of CSRR structure, which permit to adapt our filter structure to the desire applications, then we have inserted six complementary split ring resonator shape periodically in each ground of CPW line. After many series of optimization using methods integrated in ADS (Advanced Design System), we have validated into simulation the proposed CPW LPF. **Figure 2** presents the geometry of the proposed low pass filter (a) and CSRR unit cell (b).



(b)

Fig. 2. (a) Geometry of a CSRR unit cell (b) Proposed CPW LPF structure.

The optimized dimensions are presented in Table 1.

Table 1. Dimensions of the proposed LPF structure.

Parameters	Values (mm)
L	35.48
W	21.16
L1	4
L2	4.11
L3	4.4
W1	1
W2	1.5
W3	3.9
W4	0.44
W5	0.5

The final CPW LPF is mounted on FR4 substrate having a thickness of 1.6mm, a dielectric permittivity εr =4.4 and loss tangent tanδ=0.025. The proposed CPW low pass filter using metamaterial structures is simulated by using electromagnetic solver ADS. The **Figure 3** illustrates the S parameters of the filter structure.

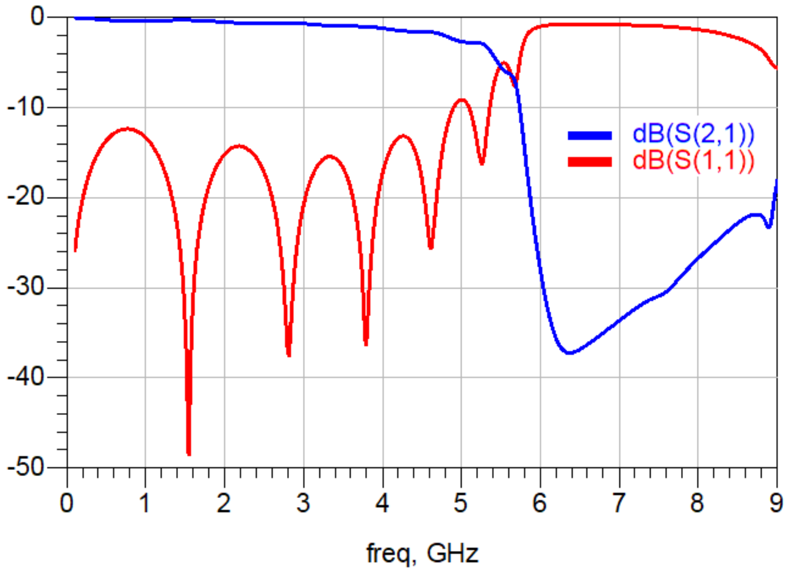


Fig. 3. The S parameters of the proposed LPF structure.

As depicted in **Figure 3**. We have obtained a low pass filter having a large pass band with a cut-off frequency around 5.28GHz at -3dB. This frequency can be tuned to achieve any low pass filter by controlling the dimensions and values of capacitance and inductance when we pass from lumped elements to distributed elements. The filter presents a good result in term of insertion loss around -0.5dB, a good rejection band until 9 GHz which is about -38dB. This rejection is due to the insertion of periodic square complementary split ring resonator shape into the CPW line ground plane.

2.3 Design procedure by another Solver

After validation of the proposed filter using ADS electromagnetic solver, we will proceed to design the same filter structure by using another electromagnetic solver in order to compare the simulation results and to confirm the validation of the final CPW low pass filter integrating CSRR structures. The topology of this filter is depicted in the **Figure 4**.

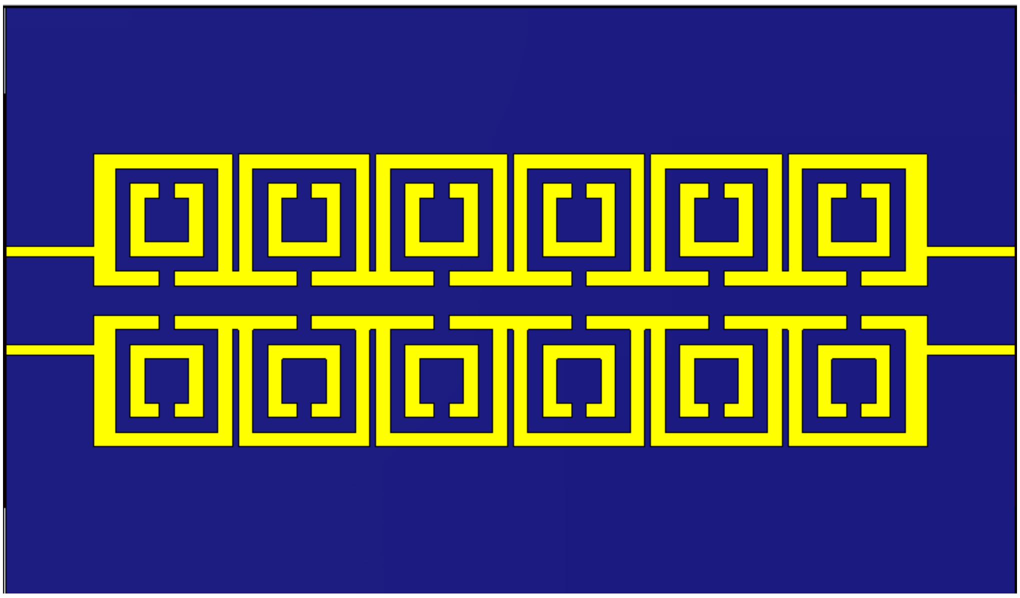


Fig. 4. Geometry of the proposed CPW LPF structure by ANOTHER SOLVER Solver.

The **Figure 5** illustrate a comparison of simulation results obtained by using two electromagnetic solvers.

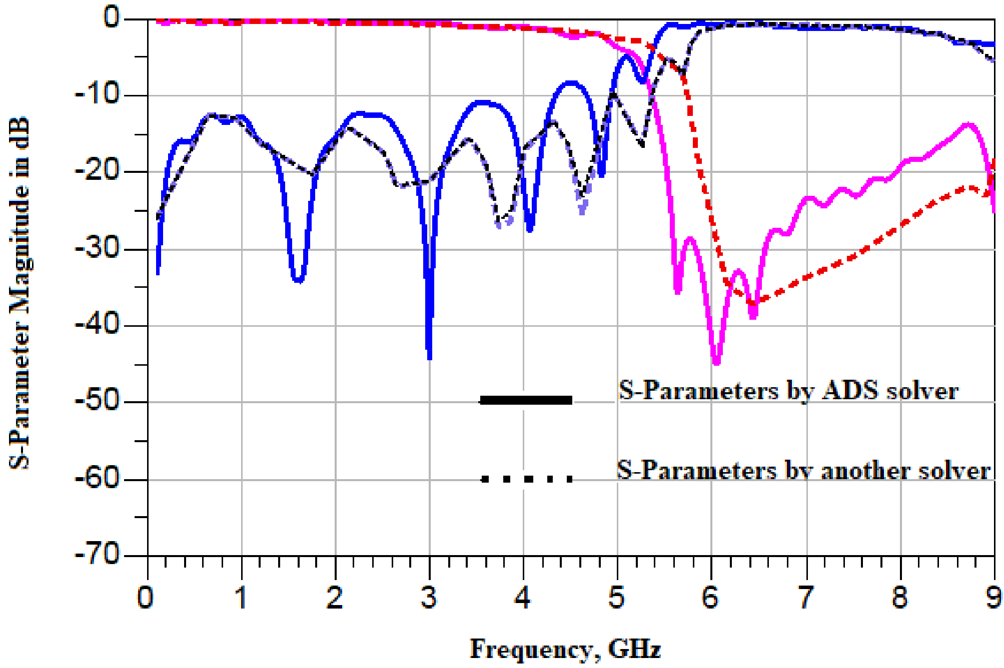
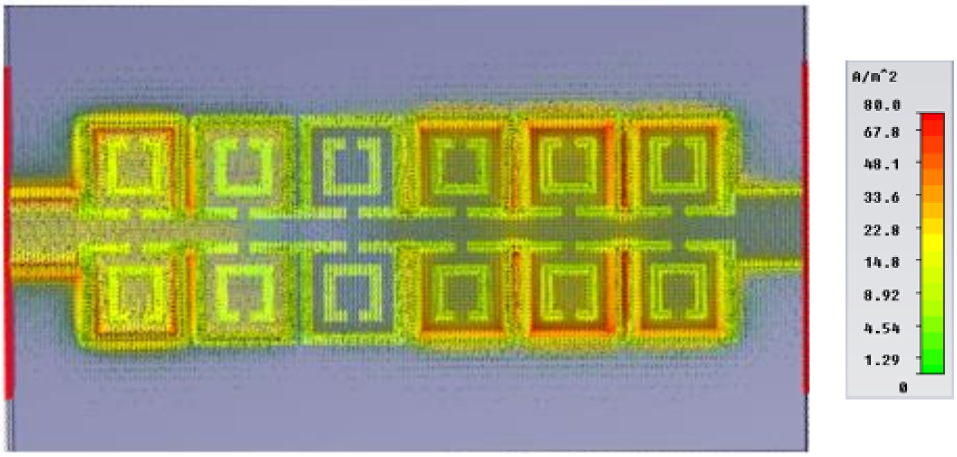


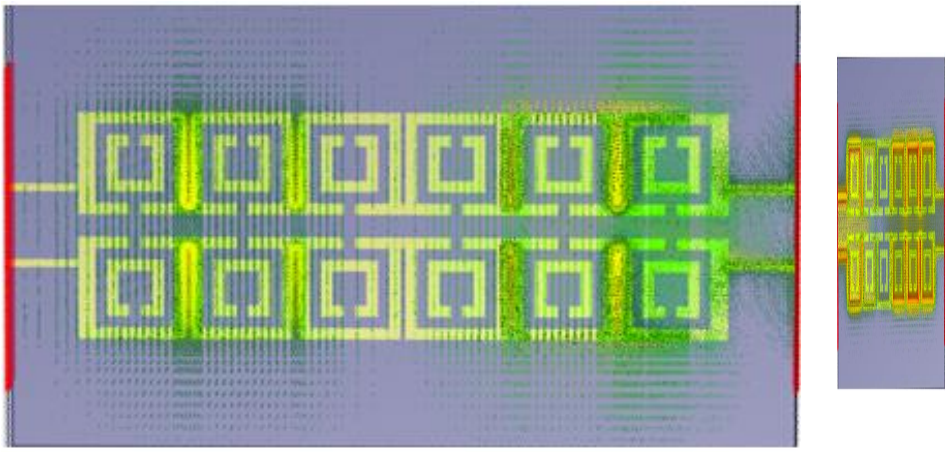
Fig. 5. The S parameters ADS and another solver Comparison results of the proposed CPW LPF

As depicted in **Figure 5**, we have obtained a good agreement between simulation results using ADS and another electromagnetic solver which confirm the operation of the proposed filter.

To validate this filter in term of current density we have launched a simulation at two frequencies one at 2 GHz in the pass band and another one at 7 GHz in the rejection band. As shown in **Figure 6**, we have the current density presented in the both ports at the two frequencies which confirm the operation frequency bands of the proposed filter.



(a) At 2 GHz



(b) At 7 GHz

Fig. 6. Presents the current distribution (a) at 2 GHz and (b) at 7 GHz

3 Conclusion

In this work we have presented a novel CPW low pass filter structure based on the use of metamaterial structures placed periodically in the ground plane of coplanar waveguide line. The circuit is designed, simulated and validated by using two electromagnetic solvers. As results we have developed a low pass filter structure with a good rejection which is due to the use of CSRR structures. The LPF can be used for several microwave applications.

Acknowledgment

We have to thank Pr. M. Latrach and his research Team RF& Microwave in ESEO Engineering institute in Angers in France for all the support brought to our research studies by permitting us to use Electromagnetic solvers.

References

[1] Veselago, V.: The electrodynamics of substances with simultaneously negative values of and. Soviet Physics Uspekhi. (1968)

[2] Smith, D. R., Padilla, W. J., Vier, D. C, Nemat-Nasser, S. C. and Schultz, S.: Composite medium with simultaneously negative permeability and permittivity. Physical review letters. pp. 4184-4187 (2000)

[3] Zeng, H. –Y, Wang, G. –M, Zhang, C. –X. and Zhu, L. : Microwave & Optical Technology Letters. (2010)
[4] Gil, M., Bonache, J. and Martin, F.: Metamaterial Filters: A Review. Science Direct. pp. 186-197 (2008)
[5] Kehn, M.N.M., Quevedo, O.T. and Rajo, E.I. :Split-ringresonator loaded waveguides with multiple stopbands. Electronics Lett., pp.714–716 (2008)
[6] Kim, J., Cho, C.S. and Lee, J.W. :CPW bandstop filter using slot-type SRRs. Electronics Lett., pp.1333–1334 (2005)
[7] Lin, X. and Cui, T. :Controlling the bandwidth of split ring resonators. IEEE Microwave and Wireless Components Lett., pp.245–247 (2008)
[8] Xu, Y. and Alphones, A. : Propagation characteristics of complimentary split ring resonator (CSRR) based EBG structure. Microwave and Optical Tech. Lett.,pp.409–412 (2005)
[9] Baena, J.D., Bonache, J., Martin, F., Sillero, R.M., Falcone, F., Lopetegi, T., Laso, M.A.G., Garcia-Garcia, J., Gil, I., Portillo, M.F. and Sorolla, M.: Equivalent-circuit models for split-ring resonators and complementary splitring resonators coupled to planar transmission lines. IEEE Microwave Theory and Tech.,. pp.1451–1461 (2005)
[10] Simons, R. N.: Coplanar Waveguide Circuits, Components and Systems. Wiley-IEEE, New York (2001
[11] Wolff, I. :Coplanar Microwave Integrated Circuits. John Wiley & Sons, (2006)