*International Journal of Engineering &Technology*, 7 (4) (2018) 6544-6546

**International Journal of Engineering & Technology**

*Website: www.sciencepubco.com/index.php/IJET*
*doi: 10.14419/ijet.v7i4.28615*
***Research paper***

# Coplanar band-pass filter for GSM applications based on novel metamaterial unit cell

**Badr Nasiri [1] *, Abdelhadi Ennajih [1], Ahmed Errkik [1], Jamal Zbitou [1], Mounir Derri [2]**

*[1] LMEET, FST of Settat, Hassan 1st University, Settat, Morocco*
*[2] LSE, Hassania School of Public Works, Casablanca, Morocco3Affiliation of the third author*
**Corresponding author E-mail: b.nasiri@uhp.ac.ma*

**Abstract**

This letter presents a novel compact bandpass filter. The proposed coplanar filter is intended to be a good solution for GSM applications corresponding to the 1.8GHz resonance frequency. The design of this circuit was carried out in two main stages. The first is the choice and proposition of a new metamaterial resonator with unusual characteristics. Then, our resonator is implemented in the structure using bandwidth adjustment methods in order to improve the reflection and transmission coefficient matching in the desired range of frequencies and the two rejection bands. By using different techniques of miniaturization and optimization, we have obtained a miniaturized final circuit which is implemented on a FR4 epoxy substrate. The simulated results are carried out by using CST Microwave and ADS Agilent. They illustrate that this filter achieves very good electrical performances in the passband with a low insertion loss of 0.3 dB. Moreover, two transmission zeros are noticed in the rejected bands.

***Keywords***: *Coplanar; Filter; Band-Pass; Metamaterial; Negative Permeability.*

## 1. Introduction

Newly, the modern radio frequency and wireless communication systems lead to great attention to the development and design of the new microwave components having a small size and high electrical performances [1-3]. These specifications are not available by using traditional and conventional methods. The microwave band-pass filters have been extensively analyzed, studied and used as important circuit blocks with operating functions of in-band transmission and out-of-band rejection [4][5]. To achieve a good slope of transition, we can introduce numerous reactive elements in the pass-band structure, which increases the electrical performances in the passband but this method increases the layout area of the filter. Accordingly, the use of novel techniques such as metamaterials and defected ground structure allowed us to achieve all these requirements simultaneously [6-9].

Recently, the metamaterial has attracted the attention of researchers and savants. Especially in the microwave and RF engineering. This artificial material gives the possibility to control the electromagnetic waves by implementing the metamaterial resonators in radiofrequency devices [10]. We can distinguish three types of metamaterials. The first one consists of the resonators having a negative permeability such as the square split ring resonator. The second one consists of the metamaterial cells possessing a negative permittivity among them the complementary split ring resonator which is very used to design and develop new planar components such as filter, coupler and antenna. The last kind of these unusual materials is the resonators having the negative permittivity and permeability [11-13].

In this paper, we propose a novel band-pass filter employing a new metamaterial structure having a negative permeability around the desired frequency. The effect of the chosen resonator on the pass-band performances is investigated. The obtained results are verified by using two electromagnetic solvers so as to validate the proposed approach.

## 2. Proposed resonator

The square SRR is one of the famous metamaterial kinds and it was introduced by Pendry in 1999. This resonator having a magnetic response as a result of the presence of artificial magnetic dipole moments by their rings. At its resonant frequency, the artificial magnetic dipole moments are larger than the applied field, for this reason, this resonator possessing unusual electromagnetic properties which give rise to the presence of the real part of negative effective permeability close to its resonant frequency.

The classical SRR and its equivalent LC circuit are shown in figure 1. The resonator dimensions are chosen to achieve a resonant frequency around 1.8GHz. Where Lout = 18mm, Lin=12mm and W=S= 1.5mm.

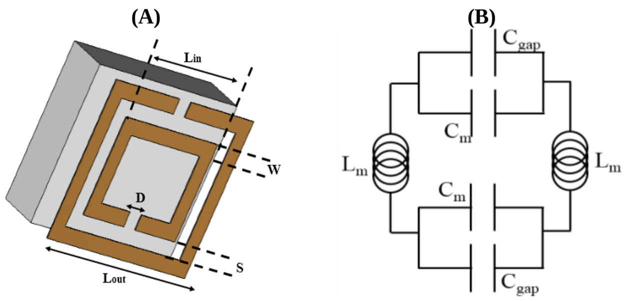


**Fig. 1:** (A) Geometry of the Square SRR. (B) Square SRR LC-Circuit.

Where the $C_m$, $C_{gap}$, and $L_m$ can be calculated by using the following formulas

$$C_m = \frac{A\varepsilon_0\varepsilon_r\left(2L_{out} + 2L_{in} - D\right)}{2S} \quad (1)$$

$$C_{gap} = \frac{\varepsilon_0\varepsilon_r t_c}{D} \quad (2)$$

$$L_m = \frac{\mu_0 S}{W}\left[L_{out} + L_{in}\right] \quad (3)$$

$$A = \frac{C^2}{4\pi^2\left(L_{out} + L_{in}\right)^2 f_0\varepsilon_r} \quad (4)$$

$\varepsilon_0$: The permittivity of vacuum
$\mu_0$: The permeability of vacuum
$\varepsilon_r$: Relative permittivity
C: The speed in a vacuum electromagnetic waves
The unusual characteristics of the Resonator are verified using the Nicolson-Ross-Weir (NRW) approach which is based on two composite terms V1 and V2 represent respectively the addition and subtraction of reflection and transmission coefficients. The real and imaginary of the effective permeability are extracted using equation 7 and 8.

$$V_1 = S_{21} + S_{11} \quad (5)$$

$$V_2 = S_{21} - S_{11} \quad (6)$$

$$\mu_{eff} = \frac{2}{JK_0 d}\frac{1 - V_2}{1 + V_2} \quad (7)$$

$$\varepsilon_{eff} = \frac{2}{JK_0 d}\frac{1 - V_1}{1 + V_1} \quad (8)$$

The $K_0$ is wave number equivalent to $2\pi/\lambda_0$ and d is the thickness of the substrate. Figure 2 and Figure 3 illustrate respectively the scattering parameters of the classical square SRR and its effective medium parameters.

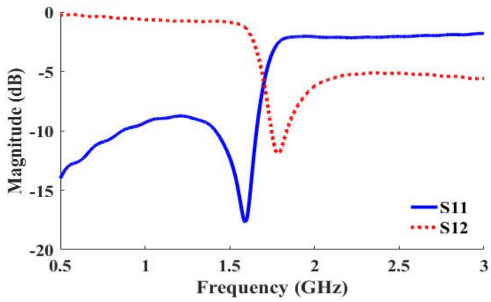


**Fig. 2:** S-Parameters of Square SRR.

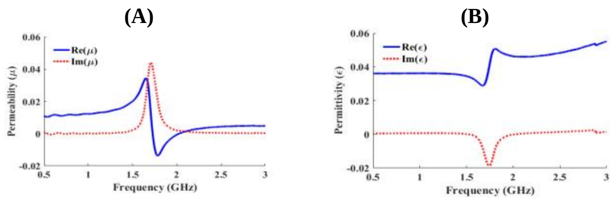


**Fig. 3:** (A) Permeability of Square SRR. (B) Permittivity of Square SRR.

After the validation of the conventional Square split ring resonator having a negative permeability at 1.8 GHz, we can pass to our principal goal which is to design and develop a new metamaterial resonator that has a compact size compared to the classical resonator and resonant frequency equal to 1.8 GHz.
Following various series of optimization by using two electromagnetic solvers CST Microwave and ADS Agilent, The proposed resonator is implemented on a 1.6 mm thick FR4 and all its parameters have been investigated and analyzed Figure 4 and 5 show respectively the geometry of the proposed metamaterial unit cell and the calculated real and imaginary of the effective permeability versus frequency.
As might be seen from figure 5, the proposed metamaterial unit cell has a negative effective permeability from 1.5 GHz to 2.2 GHz. furthermore, it has a compact miniature size compared to its resonant frequency. This studied resonator can be very useful to design and achieve a miniature planar filter.
L=W=15mm, L1=6.5mm, L2=4.5mm, W1=9mm and W2=3mm.

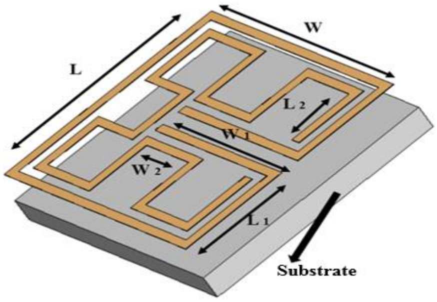


**Fig. 4:** Geometry of the Proposed Resonator.

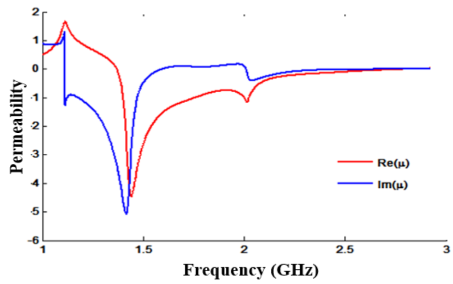


**Fig. 5:** Effective Permeability of the Proposed Resonator.

## 3. Proposed bandpass filter

So as to obtain a bandpass behaviour, the chosen resonator which is studied above is implemented on the top layer of the coplanar structure. Precisely in the middle plane of the proposed design. This permitted us to establish a miniature passband circuit with low insertion losses in GSM band 1.8 GHz and an excellent attenuation in both rejected bands.
Figure 7 describes the S-parameters of the final proposed circuit based on metamaterial unit cell. We can see that the proposed circuit shows band-pass characteristic at the centre frequency of 1.8 GHz.
For the verification and validation of the results obtained by CST Microwave, another study is carried out with ADS Agilent. As shown in the figure below, we obtained approximately similar results. Nevertheless, a slight deviation of frequency is observed which can be explained by the different methods and techniques used in the two electromagnetic software during the simulation and the calculation of the S-parameters. Where L=24mm, W=20mm and d=1mm.

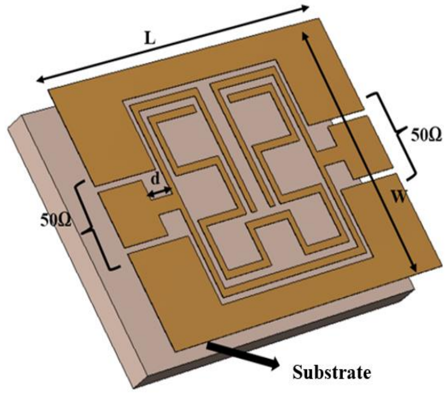


**Fig. 6:** Geometry of the Proposed Band-Pass Filter.

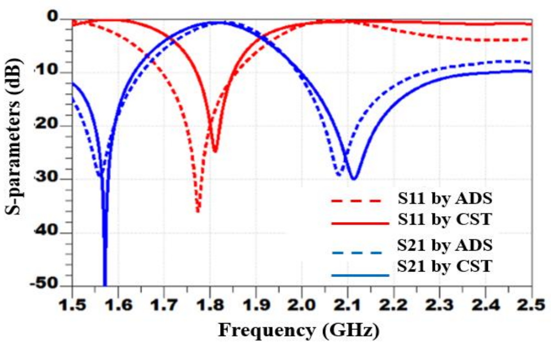


**Fig. 7:** Frequency Response of the Proposed Filter.

Another verification study is performed using the distribution of surface currents on the filter for two frequencies 1.8GHz in the bandwidth and 2.2GHz in the second attenuated band. As can be seen in the first figure, the current distribution is very strong throughout the proposed filter, which means that there is a propagation of the signal from the input port to the output port.

On the other hand, the second figure shows that the current distribution is very strong on the resonator and there is no current close to the output port 2 which implies that there is no transmission of the radiofrequency power from the input port to the output port in the designed circuit.

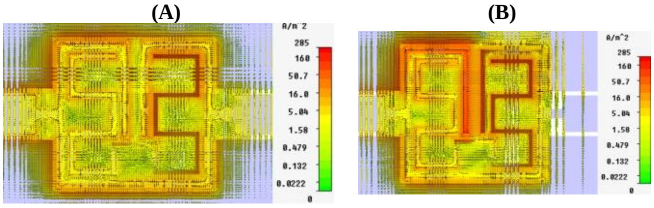


**Fig. 8:** (A) Distribution of Surface Currents at 1.8 GHz, (B) Distribution of Surface Currents at 2.2 GHz.

## 4. Conclusion

A new compact miniature coplanar BSF based on novel metamaterial is proposed and studied. The proposed resonator has been added to achieve a band-pass behaviour in the GSM band. The desired range frequencies made with only one resonator. This filter was designed, simulated and optimized using CST Microwave studio and ADS Agilent. The two simulation results are verified and show a good agreement with each other. This device possesses a good return loss and low insertion loss in the passband. Additionally, an excellent attenuation level is seen in the first and second rejected-band. This filter can be considered as a qualified solution for GSM systems and applications.

## Acknowledgement

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

## References

[1] B. Nasiri, A. Errkik, J. Zbitou, A. Tajmouati, L. El Abdellaoui, M. Latrach, "A Miniature Microstrip BSF Using Complementary Split Ring Resonator", *International Journal of Intelligent Engineering and Systems*, Vol. 11, No. 3, pp. 29-36, June 2018. https://doi.org/10.22266/ijies2018.0630.04.

[2] A. Boutejdar, M. Amzi, S.D. Bennani, "Design and improvement of a compact bandpass filter using DGS technique for WLAN and WiMAX applications", TELKOMNIKA Telecommunication Computing Electronics and Control, Vol. 15, No.3, pp. 1137-1144, 2017, https://doi.org/10.12928/telkomnika.v15i3.6917.

[3] B. Nasiri, A. Errkik, J. Zbitou, A. Tajmouati, L. El Abdellaoui, M. Latrach, "A New Compact and Wide-band Band-stop Filter Using Rectangular SRR", *TELKOMNIKA Telecommunication Computing Electronics and Control*, Vol. 16, No.1, pp. 110-117, February 2018, https://doi.org/10.12928/telkomnika.v16i1.7578.

[4] N. A. Wahab, I. Pasya, M. F. A. Khalid, I. M. Yassin, S. H. Herman, Z. Awang, "Pseudo-Elliptic Bandpass Filters Using Closed-Loop Resonator", *International Journal on Advanced Science, Engineering and Information Technology*, Vol. 7, No. 2, pp. 345-351, March 2017. https://doi.org/10.18517/ijaseit.7.2.1362.

[5] S.-G. Mao, Y.-Z. Chueh, "Coplanar Waveguide Bandpass Filters With Compact Size and Wide Spurious-Free Stopband Using Electromagnetic Bandgap Resonators", *IEEE Microwave and Wireless Components Letters*, Vol.17, No.3, pp.181–183, 2007, https://doi.org/10.1109/LMWC.2006.890461.

[6] B. Nasiri, A. Errkik, J. Zbitou, A. Tajmouati, L. El Abdellaoui, M. Latrach, "A New Microstrip Band-stop Filter Using Square Split Ring resonator", *International Journal Microwave and Optical Technology*, Vol.12, No.5, pp.367-373, 2017. http://www.ijmot.com/ijmot.com/VOL12NO5.ASPX.

[7] T. J. Zeng, C.J. Wang, "Design of a compact wideband microstrip bandpass filter using multiple-mode resonator", *Proceedings Progress in Electromagnetic Research Symposium (PIERS)*, Shanghai, China, pp.2951-2953, 2016, https://doi.org/10.1109/PIERS.2016.7735164.

[8] B. Yang, H. Qian, and X. Luo, "Compact CPW bandpass filter with ultra-wide stopband using slow-wave structure," *Proceedings of IEEE International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM)*, 2016, pp. 1–3, https://doi.org/10.1109/iWEM.2016.7505071.

[9] L. Wang, G. Wang, Y. He, R. Zhang, "Design of microstrip bandpass filters using fragment-type coupling structure based on multiobjective optimization", *Proceedings of IEEE MTT-S International Microwave Symposium*, Honolulu, HI, USA, pp. 1620-1623, 2016, https://doi.org/10.1109/MWSYM.2017.8058946.

[10] L. Magthelin Therase, T. Jayanthy , "Metamaterial loaded circular ring micro strip antenna with CSRR as ground plane for 5g applications", *International Journal of Engineering & Technology*, Vol.7, No.4, pp.3978-3983, 2018.

[11] V. G. Veselago, "The Electrodynamics of Substances with Simultaneous Negative Value of ε and μ", *Soviet Physics Uspekhi*, Vol.10, No.4, pp.509-514, 1968, http://www.phys.nthu.edu.tw/~spin/course/100S/1968,%20Veselago-ChihWeiChang.pdf. https://doi.org/10.1070/PU1968v010n04ABEH003699.

[12] J. B. Pendry, A. J. Holden and W. J. Stewart, "Extremely Low Frequency Plasmons in Metallic Mesostructures", *Physical Review Letters*, Vol.76, No.25, pp.4773-4776, 1996, https://doi.org/10.1103/PhysRevLett.76.4773.

[13] J. B. Pendry, A. J. Holden, D. J. Robbins, W. J. Stewart, "Magnetism from Conductors and Enhanced Nonlinear Phenomena", *IEEE Transaction on Microwave Theory and Techniques*, Vol.47, No.11, pp.2075-2084, 1999, https://doi.org/10.1109/22.798002.