

# CSRR Loaded CPW Bandpass Filter for WLAN Application

U. Surendar, G. Revathi, J. William

**Abstract** – Metamaterial is an artificial material which is used to produce negative effects in the materials. In this paper a bandpass filter is proposed by introducing the metamaterial effect in the normal substrate. A coplanar waveguide transmission line is loaded with complementary split ring resonators for providing the structure with negative effects. The proposed filter is simulated and characterized using Method of Moments based IE3D simulator. The designed filter has a bandwidth of 2.23 to 3.13 GHz with the return loss of -25dB and the 0 dB insertion loss. The size of the filter is about 16 x 16 mm<sup>2</sup>. With the above properties the proposed metamaterial filter can be used for the WLAN application.

**Keywords** – CPW-Coplanar Waveguide, BPF-Bandpass Filter, CSRR-Complementary Split Ring Resonator, IL-Insertion Loss, RL-Return Loss, SRR- Split Ring Resonator.

## I. INTRODUCTION

In the latter years, the possibility of taking advantage of the unusual properties of the so-called metamaterial technology has led to a great deal of research activity. For instance, many efforts have been aimed at reducing the size and improving the performances of, among others, phase shifters, baluns, couplers, power dividers and filters [1]. In the above cases the achievement of both negative permittivity and permeability in a given frequency range by an appropriate engineering of the dispersion characteristics [2]. At microwave frequencies, a medium that supports backward wave propagation can be fabricated from a transmission line loaded with split-ring resonators (SRRs) [1-3] and/or reactive elements [4],[5]. Such loading elements enable one to efficiently control the response characteristics simply by adjusting its dimensions and the position.

These structures generally incorporate resonant particles such SRRs, open SRRs (OSRRs), and their dual counterparts i.e., complementary split-ring resonators (CSRRs) or open CSRRs [6,7]. Due to the resonant nature of these transmission lines, special efforts have been made to the synthesis of artificial lines exhibiting improved (i.e., wider) bandwidths.

A broadband response can be obtained when the right- and left-handed behaviour coincide. This is known as the balanced composite right/left-handed (CRLH) response [8-12]. The frequency selectivity of a coplanar transmission was improved using the split ring resonators with a higher rejection level, increasing the Q factor[10].

A coplanar transmission line with split ring resonators exhibited a high bandpass response with right handed characteristics [9]. An improved lumped model of split ring resonators with a pi-network, and implemented an improved left-handed behavior[13]. The structure model

of complementary split ring resonators were discussed with both circular and rectangular complementary split ring resonators demonstrating the left-handed behavior. Interresonator coupling can be neglected since the SRRs are circular in shape thus reducing the interaction between them. Besides, only a single cell is considered. [15]. The right handed behavior was analyzed with split ring resonators connected in series, shunt wired and were demonstrated to operate on C-band. It had a effective control on phase and magnitude responses [12]. An edge-coupled SRR's and broadside coupled SRR's were demonstrated for measuring the polarizabilities of split ring resonators [14]. In [16] it has been demonstrated that a larger bandwidth (even with FBW close to 110%) can be achieved by employing other structures and technologies. Generally, this kind of periodically loaded line has compact dimensions, due to the electrically small size of the resonators used. It also yields low insertion loss characteristics and a broad fractional bandwidth.

This paper presents a CPW transmission line loaded with CSRR's. The structure is loaded with stepped impedance resonators, placed opposite to each other. The main advantage of the proposed filter is compact circuit size and wide band coverage. In SECTION II, the design of the filter is discussed and SECTION III gives the results obtained for the proposed structures. In SECTION IV gives the conclusion.

## II. METAMATERIAL CPW BASED BPF'S LOADED WITH CSRR'S

The CPW transmission line is loaded with circular shaped complementary split ring resonators. Here three sets of complementary split rings are used for producing a good negative effect in the structure. Here FR-4 substrate is used for designing the bandpass filter. The value of the dielectric constant ( $\epsilon_r$ ) is 4.4. The thickness of the substrate is chosen as 0.8mm.

The designed filter is estimated to have a circuit size of (16 x 16) mm<sup>2</sup>. Here the signal plane was divided into three sections on the top and bottom layer. The circular shaped CSRR's were placed in top layer. The simulated structure of the proposed filter is shown in figure 1.

The rings in the above designed filter has the radius as follows: 1<sup>st</sup> ring's inner radius is 1.4mm and the outer radius is 1.6mm. The 2<sup>nd</sup> ring's inner radius is 1.8mm and the outer radius is 2mm. The 3<sup>rd</sup> ring's inner radius is 2.2mm and the outer radius is 2.4 mm.

The strip width was taken to be 5.6mm. the gap width between the resonators and the strip were taken as 0.2mm. The width of the ground plane was considered as 5.2mm. The structure was considered to be symmetrical. The

widths between the split rings and the successive rings were considered to have same dimensions, that is 0.2mm.

The stepped impedance resonators of length 4.6mm and width of 0.2mm were placed facing opposite to each other in the top and bottom section of the signal plane. The signal plane is divided into three sections in which the distance between each resonator is of 0.2mm, which helps in increasing the capacitive effect of the filter.

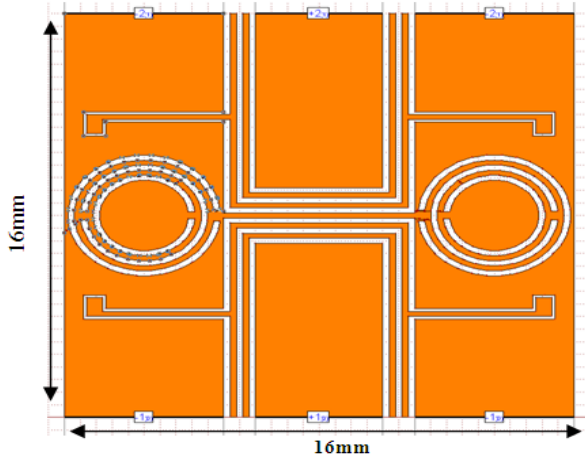


Fig.1. Structure of the simulated filter

### III. RESULTS AND DISCUSSIONS

The above discussed filter is simulated using the Method of Moments based IE3D simulator. The simulated result of the above discussed bandpass filter is shown in fig.2.

The result shows that the designed filter covered the frequency 2.4 GHz, the RL was found to be -25dB. This design is applicable for Wi-Fi and Bluetooth applications. It was found from the simulated result that it has a wideband coverage and has a good performance.

The above mentioned structure was tested for its negative effects by using the formula given below

$$n = (1/1.6) \{ \cos(2S_{21}) / (1 - S_{11}^2 - S_{21}^2) \} \quad (1)$$

$$z = \{ ((1 + S_{11})^2 - S_{21}^2) / ((1 - S_{11})^2 - S_{21}^2) \} \quad (2)$$

where z is the impedance value.

The calculation for the negative values of the designed CPW bandpass filter using the above mentioned formula for verification of the metamaterial effect is done by using the MATLAB software, the results for negative permittivity( $\epsilon$ ) and permeability ( $\mu$ ) values are shown in figure 3 and figure 4 respectively.

From the figures 3 and 4, it is evident that the proposed filter achieves negative values of both permittivity( $\epsilon$ ) and permeability ( $\mu$ ) values and achieved the negative effect so called metamaterial effect at the given frequency range.

The group delay, being an important filter parameter is calculated by using equation (3) which is found to be in appropriate level.

$$d = -(d / d \omega) \quad (3)$$

The guided wavelength ( $\lambda_g$ ) is calculated as 82mm. The fractional bandwidth (FBW) was found to be 33%. The group delay variation is about only maximum of 1ns over the operating frequency shows that the filter has a minimum good group delay which is required. It is shown in figure 5.

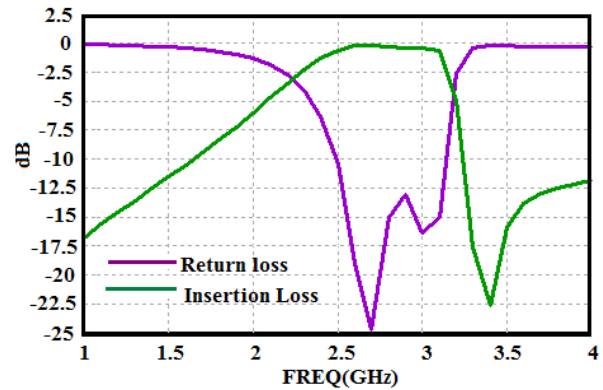


Fig.2. Simulated result of the above structure

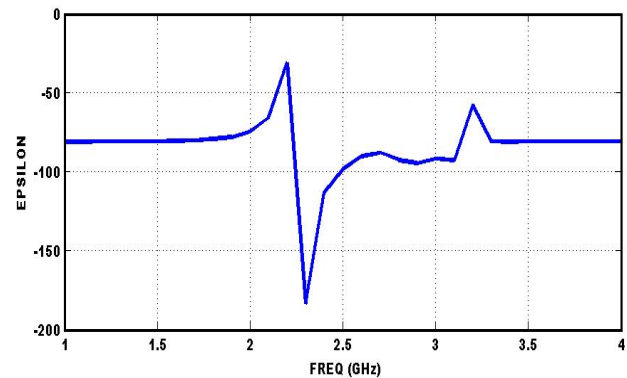


Fig.3. Simulated MATLAB result for negative permittivity ( $\epsilon$ ) value.

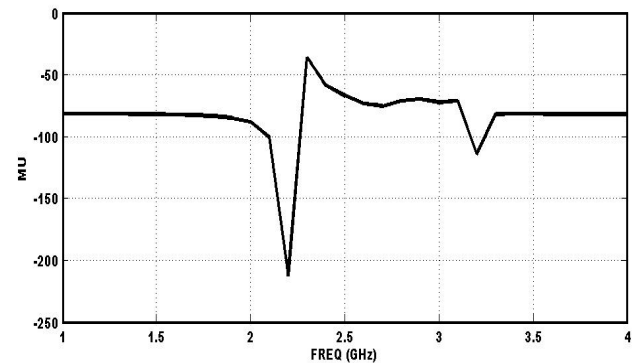


Fig.4. Simulated MATLAB result for negative permeability ( $\mu$ ) value.

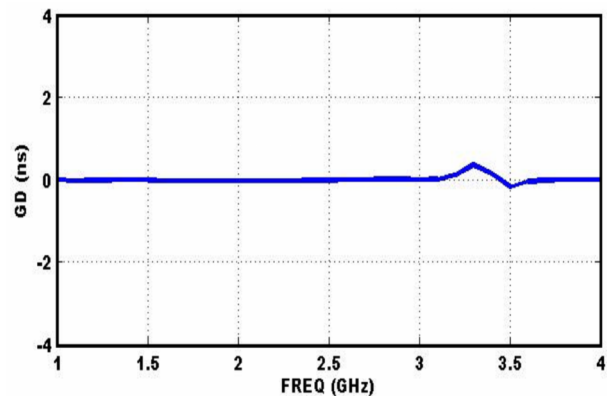


Fig.5. Plot for group delay

Table 1: Comparison of structures

Reference papers	Circuit size(mm <sup>2</sup> )	Insert-ion loss (dB)	Return loss (dB)	Operating band(GHz)
[2]	35	0	40	7.7
[3]	20	1.9	13	2.5
[7]	27	0.7	14	3.8-7.4
<b>Proposed work</b>	<b>16</b>	<b>0.2</b>	<b>25</b>	<b>2.23-3.13</b>

The combination of complementary split rings in the structure gives the negative refraction which are not found in the usual materials. The negative refraction being the new property, it achieves a wide passband coverage from 2.23GHz - 3.13GHz in reduced circuit size. The negative refraction is given as

$$n = -(\mu)^{1/2} \quad (4)$$

The measured size and the operating bands are compared and tabulated in table 1. From the table 1, it is evident that the proposed bandpass filter using a coplanar transmission line loaded with complementary split ring resonators have better filter characteristics and exhibits a wide passband coverage.

#### IV. CONCLUSION

This paper presented a bandpass filter designed using a coplanar waveguide transmission line. It was found that it achieved a metamaterial effect and it had a wideband coverage. This structure was simulated using the IE3D simulator and this filter was found to operate by covering the frequency of 2.4 GHz, which is suitable for WLAN application. The negative effects were tested using the MATLAB software. The electrical size of the filter is 0.2<sub>g</sub> x 0.2<sub>g</sub> offered a good performance with better return loss and insertion loss. Specifically, the FBW of around 33% can be achieved with an acceptable return loss from the proposed filter design. The compact size of the proposed structure offers a wide passband coverage.

#### REFERENCES

[1] R. Marques, F. Martin, and M. Sorolla, *Metamaterials With Negative Parameters: Theory, Design and Microwave Applications*. Hoboken, NJ: Wiley, 2008.

[2] F. Martín, J. Bonache, F. Falcone, M. Sorolla, and R. Marques, "Split-ring resonator-based left-handed coplanar waveguide," *Appl. Phys. Lett.*, vol. 83, no. 22, pp. 4652-4654, 2003.

[3] J. Bonache, I. Gil, J. García-García, and F. Martín, "Novel microstrip bandpass filters based on complementary split-ring resonators," *IEEE Trans. Microw. Theory Tech.*, vol. 54, no. 1, pp. 265-271, Jan. 2006.

[4] G. V. Eleftheriades, A. K. Iyer, and P. C. Kremer, "Planar negative refractive index media using periodically L-C loaded transmission lines," *IEEE Trans. Microw. Theory Tech.*, vol. 50, no. 12, pp. 2702-2712, Dec. 2002.

[5] C. Caloz and T. Itoh, *Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications*. New York: Wiley, 2005.

[6] M. Gil, J. Bonache, J. Garcia-Garcia, J. Martel, and F. Martin, "Composite right/left-handed metamaterial transmission lines based on complementary split-rings resonators and their applications to very wideband and compact filter design," *IEEE Trans. Microw. Theory Tech.*, vol. 55, no. 6, pp. 1296-1304, Jun. 2007.

[7] A. Velez, F. Aznar, J. Bonache, M. C. Velazquez-Ahumada, J. Martel, and F. Martin, "Open complementary split ring resonators (OCSRRs) and their application to wideband CPW band pass filters," *IEEE Microw. Wireless Compon. Lett.*, vol. 19, no. 4, pp. 197-199, Apr. 2009.

[8] Borja A.L, A. Belenguier, J. Cascón, H. Esteban, and V. E. Boria, "Wideband Passband Transmission Line Based on Metamaterial-Inspired CPW Balanced Cells", *IEEE Antennas and Wireless Propagation Letters*, vol.10, 2011.

[9] A. L. Borja, J. Carbonell, V. E. Boria, and D. Lippens, "Symmetrical frequency response in a split ring resonator based transmission line," *Appl. Phys. Lett.*, vol. 93, p. 203505, Nov. 2008.

[10] A. L. Borja, J. Carbonell, V. E. Boria, and D. Lippens, "Highly selective left-handed transmission line loaded with split ring resonators and wires," *Appl. Phys. Lett.*, vol. 94, no. 14, p. 143503, 2009.

[11] A. L. Borja, J. Carbonell, V. E. Boria, J. Cascon, and D. Lippens, "A 2% bandwidth C-band filter using cascaded split ring resonators," *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 256-259, 2010.

[12] J. Carbonell, A. L. Borja, V. E. Boria, and D. Lippens, "Duality and superposition in split ring resonator loaded planar transmission lines," *IEEE Antennas Wireless Propag. Lett.*, vol. 8, pp. 886-889, 2009.

[13] F. Aznar, J. Bonache, and F. Martin, "Improved circuit model for lefthanded lines loaded with split ring resonators," *Appl. Phys. Lett.*, vol. 92, p. 043512, 2008.

[14] R. Marques, F. Mesa, J. Martel, and F. Medina, "Comparative analysis of edge- and broadside-coupled split ring resonators for metamaterial design—Theory and experiments," *IEEE Trans. Antennas Propag.*, vol. 51, no. 10, pp. 2572-2581, Oct. 2003.

[15] I. Gil, J. Bonache, M. Gil, J. García-García, F. Martín, and R. Marqués, "Accurate circuit analysis of resonant-type left handed transmission lines with inter-resonator coupling," *J. Appl. Phys.*, vol. 100, p. 074908, 2006.

[16] H. V. Nguyen and C. Caloz, "Broadband highly selective bandpass filter based on a tapered coupled-resonator (TCR) CRLH structure," in *Proc. Eur. Microw. Assoc.*, 2006, vol. 2, pp. 44-51.

#### AUTHOR'S PROFILE



##### **U. Surendar**

from Trichy completed Bachelors degree in Electronics and Communication Engineering, in Coimbatore Anna University in the year 2011. Presently doing M.E. Communication Systems, in K. Ramakrishnan College of Engineering, Samayapuram, Trichy. Email: surendarsuriya@outlook.com



##### **G. Revathi**

Trichy, completed Bachelors degree and Masters degree in Anna University, Chennai. She is working as Asst. prof. ECE Dept. in MAM College of Engineering, Trichy, from the year 2010. She has expanded her area of works in Wireless Communications and Microwave Engineering. Email: revathi@mamce.org



##### **Prof. J. William**

Trichy, is the Head of ECE Dept. in MAM College Of Engineering, Trichy. He is a member of Indian Society of Technical Education. His field of research interest are RF and wireless design, Antenna and Filter Design. He is a member of Institute of Engineers (India). He completed his masters in Anna University 2006. He completed his research work on "Ultra-wide band antenna". He is also a member of Institute of Electronics Information and Communication Engineering (JAPAN). He has worked in Riyadh House Estd, Riyadh, from 1998-99. From Jan 2000-July 2000, he worked as lecturer in Rajeshwari Engineering College, Chennai. From July 2000, he is working as professor in MAM College of Engineering, at present he is the Head of the Department. Email: william@mamce.org