Zaria Journal of Electrical Engineering Technology, Department of Electrical Engineering, Ahmadu Bello University, Zaria – Nigeria.
Vol. 10 No. 2, September 2021. ISSN: 0261 – 1570.

A DUAL BAND SNG METAMATERIAL ANTENNA FOR LTE AND WLAN APPLICATIONS

B.D Bala[1], S.M Lawan[1], A. Tijjani[1], U. Abubakar[1]
[1]Electrical Engineering Department, Kano University of Science and Technology, Wudil, 713281, Kano- Nigeria.
[*]*Corresponding author email: bdbala2@kustwudil.edu.ng*

Keywords: –
Antenna, CSRR (Complementary split ring resonator), Dual band, LTE (Long term evolution), SNG (Single negative), WLAN (Wireless local area networks)

Article History: –
Received: March, 2021.
Reviewed: June, 2021
Accepted: August, 2021
Published: September, 2021.

ABSTRACT

In this paper, A dual band single negative (SNG) metamaterial antenna is proposed. The antenna employs a complementary split ring resonator (CSRR) etched on the ground plane for the dual band characteristics. The proposed antenna takes the advantages of infinite wavelength, smaller footprint, and reduced design complexity offered by metamaterials for dual band characteristics. The constitutive parameters of the CSRR were obtained and validated. A peak realized gain of 5.49 dB and 6.16 dB and an efficiency of 64% and 68% were obtained at 1.8 GHz and 2.4 GHz respectively. A directional E-plane and omnidirectional H-plane patterns are obtained. The antenna has potential applications for LTE (1.88-1.92 GHz) and WLAN (2.39-2.45 GHz) networks.

1. INTRODUCTION

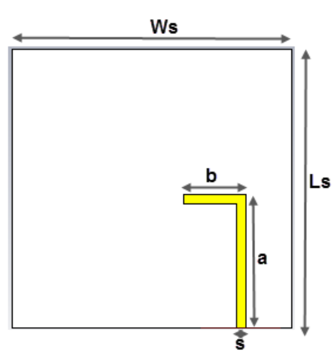
The race to exploit the exotic properties of metamaterials (MTM) began almost decades ago when V.G Veselago published his findings in [1] on materials with engineered characteristics. Metamaterials are artificially engineered materials whose properties cannot be readily found in naturally occurring materials but concocted [2]. The findings in [1] were validated by [3] to give ways for the applications of MTM on antenna. Typically a single metallic inclusion of MTM can affect either of electric and magnetic moment of electromagnetic field media [4]. Inclusions that affect electric moments are Complementary split ring resonators (CSRR), Electric coupled field resonator (ELC) and thin wire (TW) while those inclusions that affects the magnetic moments of the electromagnetic field are split ring resonator (SRR) Complementary electric field resonator (CELC), and capacitor loaded strips (CLS). However, combination of any of the magnetic and electric inclusions can results into lefthanded or double negative (DNG) phenomenon[5], [6]. These unusual electromagnetic properties of MTM of supporting infinite wavelengths pave ways for their applications in microwave and millimeters wave devices [7].The major challenges of dual band MTM antenna is to obtain a dual band characteristics' using a single inclusion so that small footprint and design complexity is reduced.

Several MTM antennas for dual band applications have been reported in [5]–[8]. In [7] a single negative (SNG) based MTM inclusion is employed as the main radiating element. Despite the bandwidth enhancement but single band is reported. In [8] a MTM inspired L-loaded antenna is presented for dual band applications, the resonating element is SRR based. However, the dual bands are not as a result of the MTM structures. A MTM employing ECL and electromagnetic band gap (EBG) loading in presented in [5] for dual band applications. Also, the dual band is as a results of the individual inclusions couple with large footprint of the design. Dual band characteristics is obtained in [6] only when the EBG structure is reconfigured. However, non-resonant or transmission line approach can be employed to design MTMs, it is worth noting that dual band applications is a serious challenges as presented in [9].

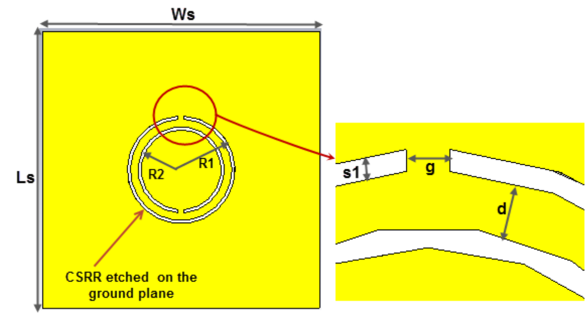
In this paper, a dual band MTM based antenna for 1.8 GHz LTE and 2.4 GHz WLAN applications is presented. The antenna employs CSRR as the main radiating elements. Since the electric moments is dominance in the CSRR structure the constitutive parameter is validated the theoretically. The antenna is designed on Taconic substrate and fed via L-shaped transmission line with CSRR etched on the full ground plane which accounts for the resonance frequencies. The rest of the paper is organized as follows: Section 2 presents the theories and antenna design parameters, constitutive parameters retrieval and results discussions, Section 3 concludes the paper, Section 4 presents the acknowledgements, and Section 5 presents the references.

2. THEORIES AND ANTENNA DESIGN

The geometry of the proposed metamaterial antenna is shown in Fig. 1. The antenna is design on flame retard substrate FR-4 of permittivity of 4.3, tangential loss of 0.0025 and height of 1.6 mm. An L-shape 50Ω transmission line is used to fed the antenna of length a and b and thickness of s. A complete ground plane of same size as the substrate is employed of dimension (Ws x Ls). A CSRR is etched on the ground plan with radius R1 and R2 for the outer and inner slotted rings respectively. The slot width is S1, with gap g and the distance between the lotted rings is d. The optimized dimension of the antenna is shown in Table 1.



(a)



(b)

Fig. 1. Geometry of the proposed dual band MTM antenna (a) Front view (b) back view

Table 1. Optimized antenna parameters

Parameters	*Value (mm)*	*Parameters*	*Value (mm)*
Ws	90.0	R1	15.0
Ls	90.0	R2	17.5
a	43.0	S1	1.0
b	20.0	G	2.0
s	3.0	d	1.5

2.1 Retrieval of constitutive parameters of the CSRR

Theoretically, the constitutive parameters of SNG MTM are retrieved to reveal the region of negative permittivity. This is achieved using the widely known Nicholson Wier-Ross (NWR) algorithm as reported in [10]. Computer Simulation Technology (CST) microwave studio is use to simulate the CSRR unit cell shown in Fig. 2. The unit cell is placed in waveguide with perfect electric condition (PEC) boundary condition sets on y-axis, perfect magnetic condition on z-axis and open boundary condition on x-axis. An E-field of incidence wave is polarized on z-axis and H-field of incidence wave is polarized on z-axis. The reflection coefficients S11 of port 1 and S22 of port 2 were obtained and effective constitutive parameters are calculated using equations (1)-(2)[11].

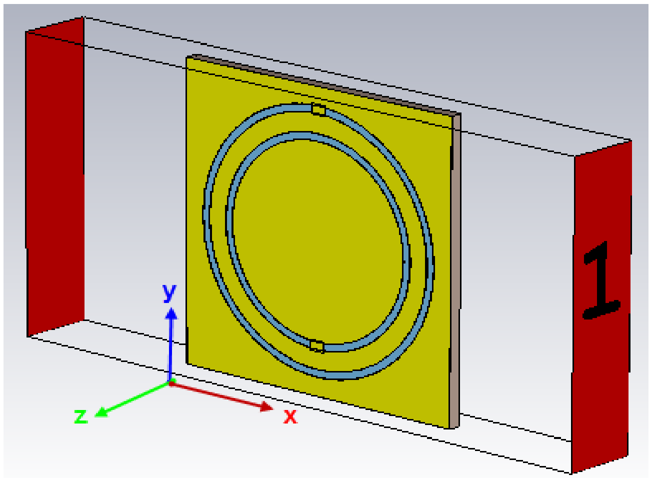


Fig. 2. CSRR in a simulation waveguide

$$\varepsilon_r = \frac{2}{jkd} * \frac{1 - S_{21} - S_{11}}{1 + S_{21} - S_{11}} \quad (1)$$

$$\mu_r = \frac{2}{jkd} * \frac{1 - S_{21} + S_{11}}{1 + S_{21} - S_{11}} \quad (2)$$

Where, $k = {}^{\omega}/_{c}$, d, ω and c are the wave number, slab thickness, radian frequency and speed of light respectively.

2.2 Results and Discussions

The single negative (SNG) properties of the CSRR are validated and antennas parameters were simulated via Computer simulation Technology (CST) software.

2.2.1 Constitutive Parameters

The retrieved constitutive parameters are shown in Fig. 3. Electric-field moment is the dominant response in CSRR, this can be observed from the figure where epsilon (ε) lies on the negative region over the operating frequency range of the antenna while the permeability (μ)lies on the positive region. Hence CSRR can be considered as SNG metamaterial inclusions.

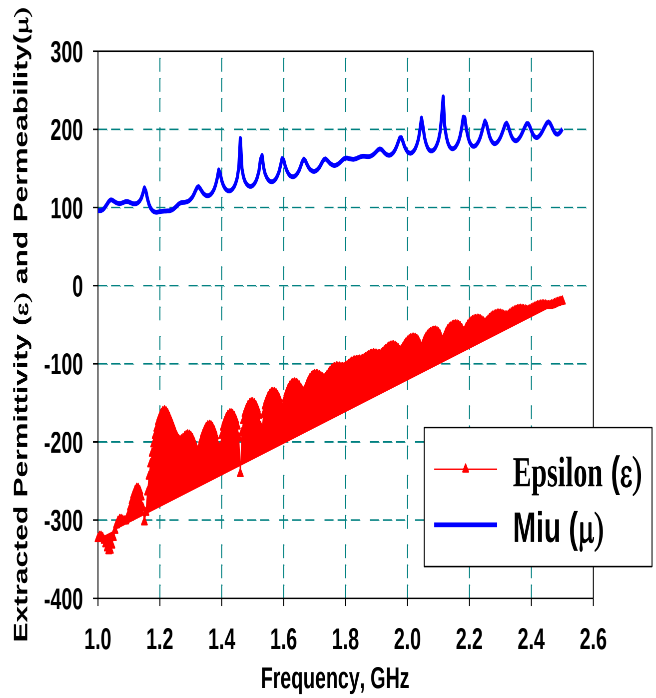


Fig. 3. Retrieved parameters

2.2.2 Parametric studies on CSRR

Parametric studies on CSRR have been carried out to investigate the effects of the radius R1 and R2 of the inclusions. R1 is the outer radius of the CSRR which is varied from 11 mm through 13 mm via four iterations. The resultant effect is the shift in the resonant frequency of the upper band which reveals that increase in the resonator size results in decrease in the resonant frequency as shown in Fig. 4. On the same vein, Fig. 5. shows the effects of the inner radius of the CSRR on the first band of the resonator. Increase in R2 from 14mm to 16.5 mm for four iterations shows corresponding decrease in resonance frequency of the first band. Hence it is worth noting that the main resonating elements of the antenna is the CSRR.

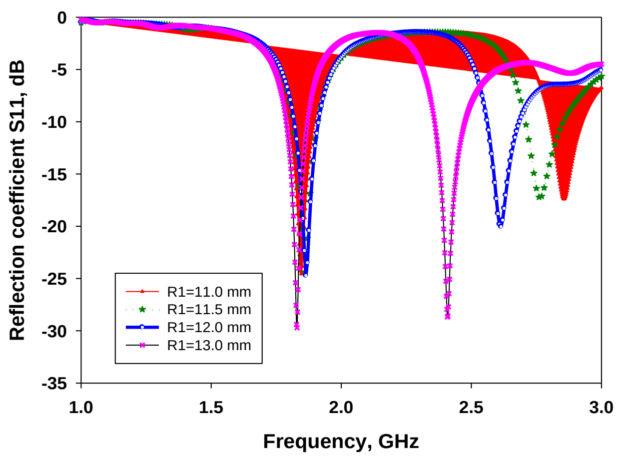


Fig. 4. Effects of R1 on resonance frequency at 1.8 GHz

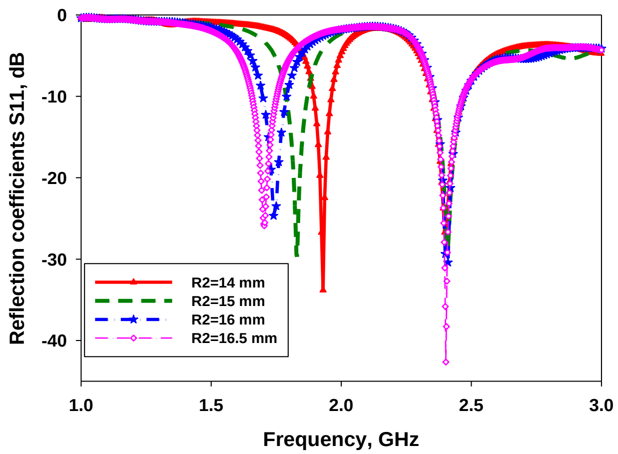


Fig. 5. Effects of R2 on resonance frequency at 2.4 GHz

2.2.3 Antenna Parameters

The simulated reflection coefficient (S11) of the antenna is shown in Fig. 6. The antenna resonates at 1.8 GHz and 2.4 GHz for LTE and WLAN applications respectively. A good impedance matching is obtained for the two bands as S11 < -10 dB is obtained. Fig. 7 shows the realised gain (dB) of the antenna over a range of frequency of 1-3 GHz. The gain at 1.8 GHz and 2.46 GHz are 2.57 dB and 4.16 dB respectively. The gains obtained seems to be low for the LTE and WLAN applications therefore, a reflector placed at the back of the ground plane at a quarter wavelength distance of the LTE band. The reflector is place in order to reflects back the incidence wave from the slots of CSRR thereby improving the antenna gain. The gain of the antenna improved from 2.5783 dB to 5.4987 dB for LTE band and from 4.1659 dB to 6.1687 dB for WLAN band.

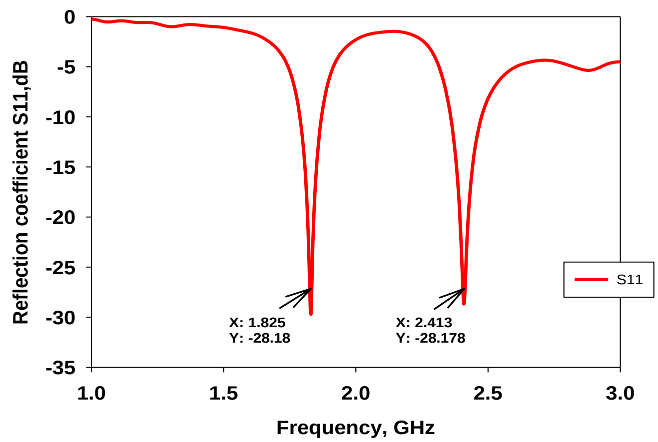


Fig. 6. Reflection coefficients (dB)

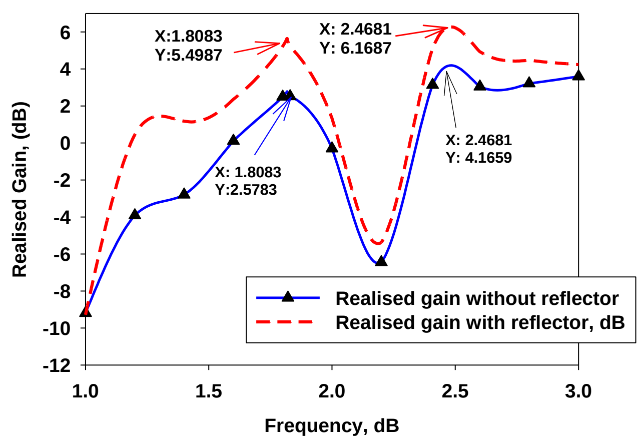


Fig. 7. Realized gain (dB).

The total radiation efficiency of the antenna is shown in Fig. 8. An efficiency of 64% and 68% is obtain at LTE and WLAN frequencies respectively. The surface current distribution in the CSRR is shown in Fig. 9. Strong current distributions along the inner ring are indicating it’s the main radiating element at

1.8 GHz for LTE application Also the outer ring contributed at 2.4 GHz for WLAN applications.

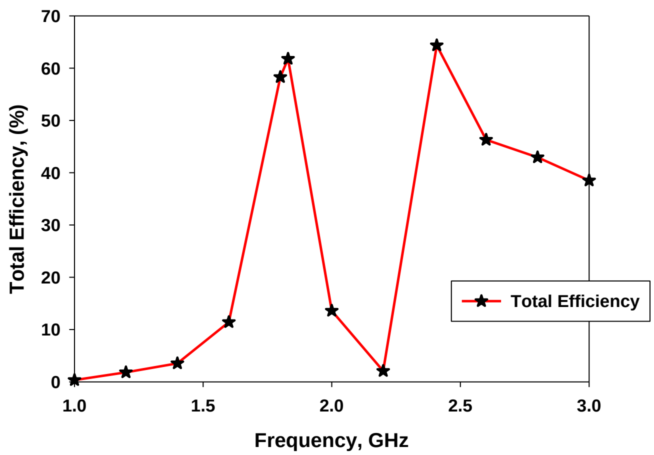
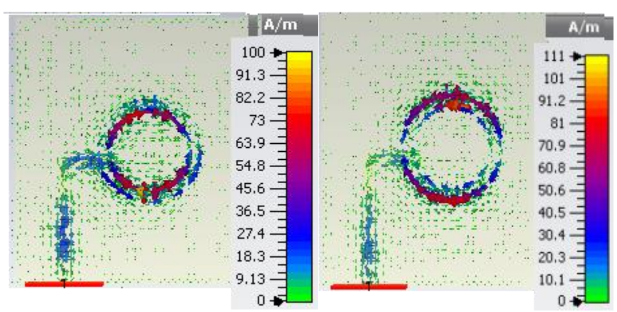


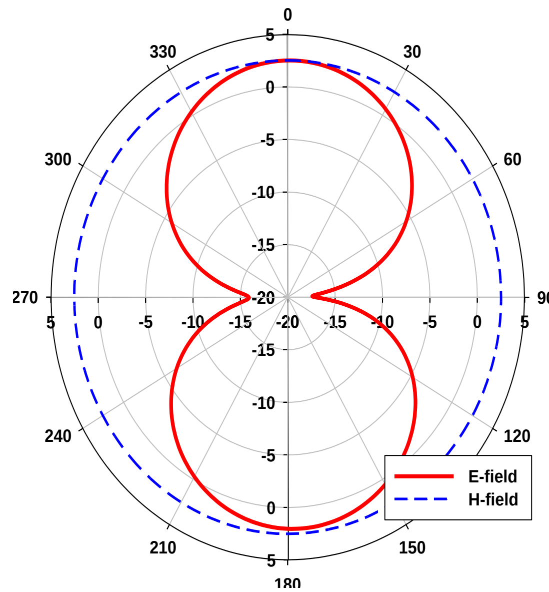
Fig. 8. Realized gain (dB).



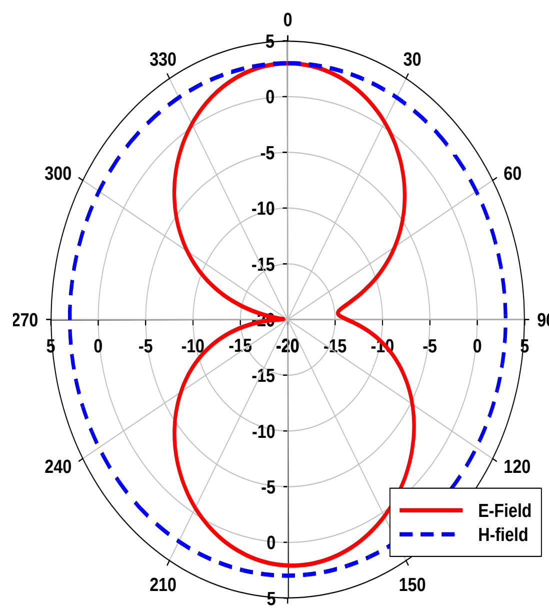
(a) (b)

Fig. 9. Surface current distributions (a) at 1.8 GHz, (b) at 2.4 GHz.

Figure 10 shows the antenna radiation pattern for both E- and H-plane at 1.8 GHz and 2.4 GHz. In both cases, a directional and omnidirectional pattern are obtained for E-plane and H-plane respectively which make them a potential candidate for LTE and WLAN applications.



(a)



(b)

Fig. 10. Radiation Patterns (a) at 1.8 GHz, (b) at 2.4 GHz

3. CONCLUSION

In this paper, A dual band SNG metamaterial antenna is presented. The CSRR is etched on the antennas ground plane and an L-shape 50Ω transmission line is used as the feeding elements. The constitutive parameters of the antenna are obtained to verify the dominance of electric-field moments in the CSRR inclusions. Parametric studies on the CSRR rings and the surface current distributions reveals the CSRR as the main antennas radiating element. The antenna gain improved to the peak value of 5.49 dB and 6.16 dB at 1.8GHz and 2.4 GHz respectively when a reflector was place at the back of the ground plane. Directional and omnidirectional patterns was obtained for both E-plan and H-plane at the operating frequencies. The design can be extended to covers double negative (DNG) parameters so that focusing effects of DNG for bandwidth enhancements can be exploited. The antenna is a good candidate for LTE and WLAN applications.

4. ACKNOWLEDGEMENT

This work is supported by Tertiary Education Trust Fund (Tetfund) under the IBR research grant: Tetfund/dess/uni/wudil/RP/vol.II

REFERENCES

[1] V. G. Veselago, "The electrodynamics of substances with simulteneously negative values of ε and μ," *Sov. Phys. Uspekhi*, vol. 10, no. 4, pp. 509–514, 1968.

[2] G. V Eleftheriades, S. Member, A. K. Iyer, S. Member, 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, 2002.

[3] A. Lai, K. M. K. H. Leong, and T. Itoh, "Infinite Wavelength Resonant Antennas With Monopolar Radiation Pattern Based on Periodic Structures," *IEEE Trans. Antennas Propagation.*, vol. 55, no. 3, pp. 868–876, 2007.

[4] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, "Magnetism from Conductors and Enhanced Nonlinear Phenomena," *IEEE Trans. Microw. Theory Tech.*, vol. 47, no. 11, pp. 2075–2084, 1999.

[5] K. Li, C. Zhu, L. Li, and Y. Cai, "Design of electrically small metamaterial antenna with ELC and EBG loading," *IEEE Antennas Wirel. Propag. Lett.*, vol. 12, pp. 678–681, 2013.

[6] R. Dewan, M. K. A. R. Mohamed, and H. M. R. Hamid, "Multiband frequency-reconfigurable antenna using metamaterial structure of electromagnetic band gap," *J. Appl. Phys.*, pp. 1–7, 2017.

[7] B. D. Bala, M. K. A. Rahim, and N. A. Murad, "Small electrical metamaterial antenna based on coupled electric field resonator with enhanced bandwidth," *Electron. Lett.*, vol. 50, no. 3, pp. 138–139, Jan. 2014.

[8] J. Malik and M. V. Kartikeyan, "Metamaterial Inspired Patch Antenna With L-Shape Slot Loaded Ground Plane for Dual Band (WIMAX/WLAN) Applications," *Prog. Electromagn. Res. Lett.*, vol. 31, no. February, pp. 35–43, 2012.

[9] B. D. Bala, M. K. A. Rahim, and N. A. Murad, "Composite Right / Left-Handed Dual-Band Metamaterial Antenna with Improved Gain and Efficiency," *Microw. Opt. Technol. Lett.*, vol. 56, no. 7, pp. 1575–1579, 2014.

[10] H. A. Majid and M. K. A. Rahim, "Left Handed Metamaterial incorporate with Microstrip Antenna Array Design and," *J. Telecommun.*, vol. 6, no. 1, pp. 10–18, 2010.

[11] H.-X. Xu, G.-M. Wang, M.-Q. Qi, and Z.-M. Xu, "Theoretical and experimental study of the backward-wave radiation using resonant-type metamaterial transmission lines," *J. Appl. Phys.*, vol. 112, no. 10, p. 104513, 2012.