Indonesian Journal of Electrical Engineering and Computer Science
Vol. 15, No. 3, September 2019, pp. 1436~1442
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v15.i3.pp1436-1442

Wideband frequency reconfigurable metamaterial antenna employing SRR and CSRR for WLAN application

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Article Info

Article history:

Received Jan 9, 2019
Revised Mar 20, 2019
Accepted May 3, 2019

Keywords:

Complementary ring (CSRR)
Frequency reconfiguration
Metamaterial (MTM)
Split ring resonator (SRR)

ABSTRACT

This paper presents the design of Wideband Frequency Reconfigurable Metamaterial Antenna by Employing Split Ring Resonator (SRR) and Complementary Split Ring Resonator (CSRR) for Wireles Area Network (WLAN) Apllication. The design is based on reconfiguring wideband metamaterial antenna by applying frequency reconfiguration technique. This was achieved by employing SRR and CSRR for bandwidth enhacement and two PIN Diode switches at different position for reconfiguration. The antenna has electrical dimention of $0.18\lambda_0 \times 011\lambda_0$ at 2.4 GHz. Computer Simulation Technology (CST) Software was used to determine the effectiveness of the technique. This design has several advantages like wider bandwidth which cover 2.4 GHz and 5.2 GHz WLAN bands, with three different single bands. From the simulation results, it was found that, the antenna has a bandwidth which covered 2.4 to 5.6 GHz, single bands at 2.5 GHz, 3.0 GHz and 3.5 GHz, with realized peak gain of 2.24 dBi and 3.9 dBi at 2.4 GHz and 5.2 GHz respectively and average efficiency of 96%. The antenna can be used for wireless application and cognitive radio application.

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1. INTRODUCTION

Recent development in wireless communication and mobile devices widen the door of challenges for the researchers to develop a compact, low cost and highly efficient antenna which will cover different application band for efficient operation and reduce traffic congestion. This goal can be achieved by designing miniaturized wideband reconfigurable metamaterial antenna for multi functions operation Academic activities related to metamaterial was started by Russian physicist Victor Veselago in year 1968 [1]. Then in the year 2000 practical prove on metamaterial was done by Smith [2]. Metamaterial are not naturally occurring material special properties of negative permeability and permittivity unit cell size **p** much smaller than guided wavelength λ_g ($p < \frac{\lambda_g}{4}$) [3]. Classification of metamaterial depends on the positive or negative sign of permeability $\boldsymbol{\mu}$ and permittivity $\boldsymbol{\varepsilon}$ as double positive when **(**$\varepsilon > 0, \mu > 0$ Dielectric), epsilon negative for ($\varepsilon < 0, \mu > 0$ Plasma), double negative if ($\varepsilon < 0, \mu < 0$) and mu negative for ($\varepsilon > 0, \mu < 0$) [4]. Constitutive parameters are basically generated by using resonant metamaterial structures split ring resonator SRR for (negative permeability) and complementary split ring resonator CSRR for (negative permittivity) [5]. Negative value of μ and ε can be obtain by using Nicolson-Rose-Weir (NRW) numerical method with generated S-parameters as presented in (1), (2), (3) and (4) [6].

$$\mu_r = \frac{2c(1 - V_2)}{wdi(1 + V_2)} \quad (1)$$

$$\varepsilon_r = \frac{2c(1 - V_1)}{wdi(1 + V_1)} \quad (2)$$

$$V_1 = S_{11} + S_{21} \quad (3)$$

$$V_2 = S_{21} + S_{11} \quad (4)$$

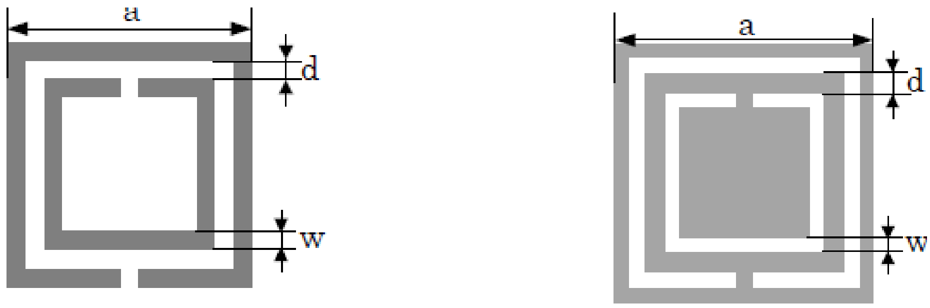


Figure 1. Effects of selecting different switching under dynamic condition

Reconfigurable antennas are define as antennas that have the capability to choose it operating parameters which include polariztion, frquency, or radiation pattern to redistribute it current for frequency selectivity and reuse [7]. Reconfigurable antennas are classified based on frequency, polarization and radiation pattern [8]. Which have the advantage of multi operation and cognitive radio for selectivity [9]. Several researches have been presented by using metamaterial in order improve the performance of the antenna in terms of bandwidth or multiband. Among the research include bandwidth enhancement by merging zero order resonance and first order resonance by increasing the value of left-handed inductance [10]. Author [11] introduce interdigital capacitor which reduce the value of Q factor for better bandwidth. Hybrid technique was applied in asymmetrical coplanar waveguide by [12] with **H** slot for bandwidth enhancement. Series gap G_1 and G_2 are utilizes by [13] to combine fundamental mode and higher order modes for bandwidth enhancement. Author [14] shows the influence of substrate for enhancing bandwidth. Furthermore, metamaterial have the ability to design antenna for multiband purpose. **L** slot contributed in obtaining dual-band in monopole [15]. Interdigital capacitor and meander line contributed in obtaining multiband in [16]. Miniaturization and multiband was obtained in [17] by using FR4 and metamaterial substrate. Triangular split ring resonator provide negative mu which resulted to multiband antenna [18]. Complementary split ring resonator metamaterial structure in ground plane with **C**-shape slot radiating element provide multiband operating antenna in [19]. Also, research of frequency reconfigurable metamaterial antenna was presented by several researchers. Among the researches include, activating and deactivating two resonant structures by applying switch operation [20]. Also, [21] and [22] achieved reconfiguration by introducing switch in split ring resonator. Similarly, [23] modify split ring resonator with closed ring resonator to switch antenna to obtain multi bands. Connecting CPW-fed via **IDC** slot and **I** shaped slot by [24] result to multiband antenna. In contrast, [25] employed split ring resonator at the back side of the substrate to generate negative permeability for proper reconfiguration. Miniaturization and tunability was achieved by introducing substrate integrated waveguide and interdigital capacitor based on CRLH effect [26]. Interestingly, [27] exploit epsilon negative by using coplanar strip line with meander for reconfiguration purpose. Author [28] and [29] modified monopole antenna by activating and deactivating circular split ring resonator and ohm's shaped strip to achieved reconfiguration to obtained multi bands. Lastly, some junction in metamaterial structure by considering current distribution are introduce for reconfiguration purposes in [30]. Despite the improvement of the antennas by using metamaterial and reconfiguration technique, still they exhibit several disadvantages which include large size which is not suitable for future communication, insufficient bandwidth to cover different application and limited bands.

In view of these shortcoming, a wideband frequency reconfigurable metamaterial antenna design by using split ring resonator and complementary split ring resonator is proposed. The fundamental objective of this design is to enhance the bandwidth and reconfigure it for multi band operation. the simulation work was done by using computer simulation technology (CST MWS) software.

2. RESEARCH METHOD

The antenna design in this paper is the extension of the work originally reported in the International Conference of Electrical, Electronic, Communication and Control Engineering (ICEECC2018). Figure 2 shows the physical geometry of the proposed antenna. As mentioned earlier this antenna was design based on the antenna design and presented in the above-mentioned conference, but there are some physical changes in order to improve it operation. First, we replace bottom and top ring with the rectangular split ring resonator and complementary split ring resonator to generate negative permeability and permittivity respectively. Then introduce two PIN Diode switches at different position for frequency reconfiguration. Low cost FR4 substrate with 1.6 mm thickness and dielectric constant of 4.3 ($\varepsilon_r = 4.3, \delta = 0$). The structure has the overall dimension of 16.8 by 30.0 mm^2 with the following dimensions in millimeters: **A = 16.8, B = 30.0, C = 8.9, D = 10.0, E = 8.8, F = 8.4, G = 5.9, and H = 6.5.**

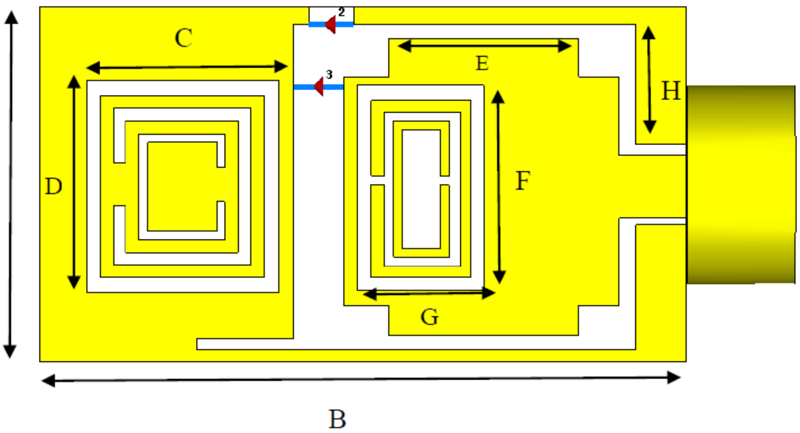


Figure 2. Geometric Configuration of Proposed Antenna

First, we simulated the proposed antenna based on the behavior of current distribution at 2.4 GHz to highlight the appropriate position of the switches. Figure 3 shows the behavior the current distribution at 2.4 GHz.

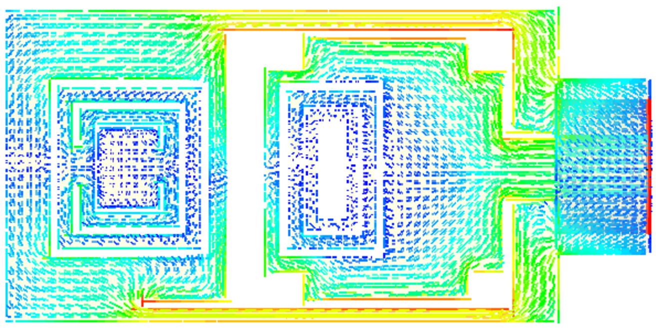


Figure 3. Current Distribution of Proposed Antenna

3. RESULTS AND ANALYSIS

After simulating the proposed antenna based on the effect of current distribution, then we introduce the two PIN Diode switches for frequency reconfiguration operation Figure 4 shows the schematic diagram of the proposed antenna which demonstrated the actual setup of switches.

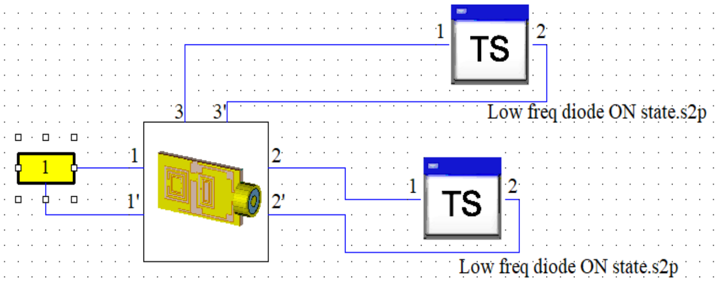
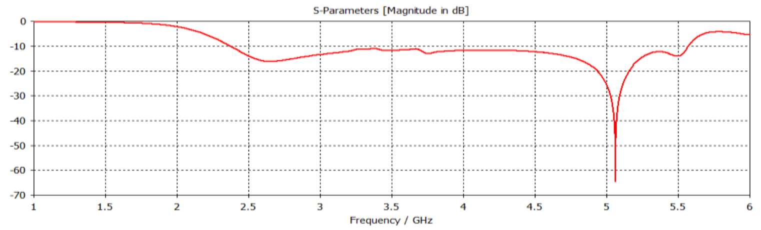


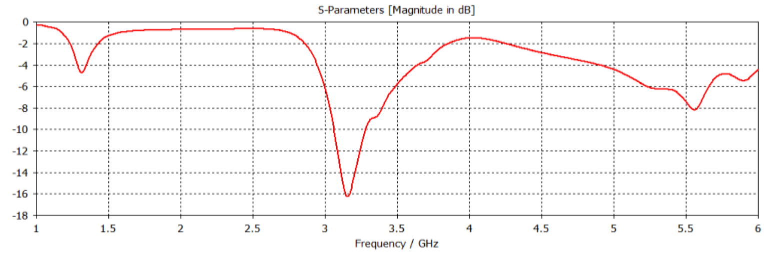
Figure 4. Schematic Diagram of Proposed Antenna

3.1. Switch Configuration

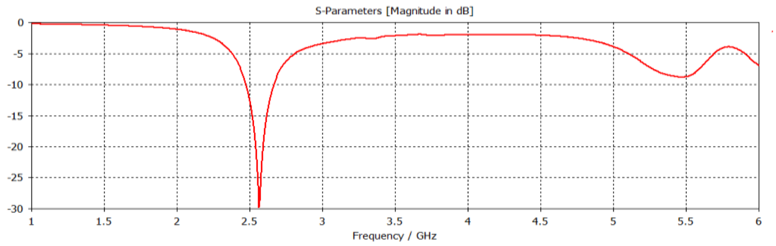
From the schematic diagram above with ON and OFF bottoms, the following results were obtained. When SW1 and SW2 are in OFF condition, we obtained wideband with bandwidth range of 2.3-5.6 GHz. For SW1 ON and SW2 OFF, single band was obtained at 3.1 GHz. Also, when SW1 is OFF and SW2 ON, another single band occurred at 2.5 GHz. Finally, for SW1 and SW2 in ON state, we obtained single band at 3.5 GHz. Table 1 contains the summary of the switch operation. Figure 5 (a), (b), (c) and (d) represent the results of the four-switch operation.



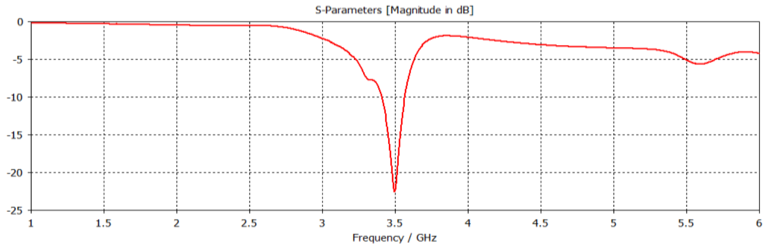
(a)



(b)



(c)



(d)

Figure 5. Results for (a) SW1 and SW2 off (b) SW1 ON and SW2 OFF (c) SW1 OFF and SW2 ON (d) SW1 and SW2 ON

Table 1. The Performance of

SW1	SW2	Status	Bandwidth/Operatind Bands (GHz)
OFF	OFF	Wideband	2.3-5.5
ON	OFF	Single Band	3.1
OFF	ON	Single Band	2.5
ON	ON	Single Band	3.5

Figure 6 shows the radiation pattern for E-Plane and H-Plane at 2.4 GHz and 5.2 GHz with realized peak gain of 2.24 dBi and 3.94dBi for 2.4 GHz and 5.2 GHz respectively. From the radiation pattern both E-Plane and H-Plane shows omnidirectional pattern.

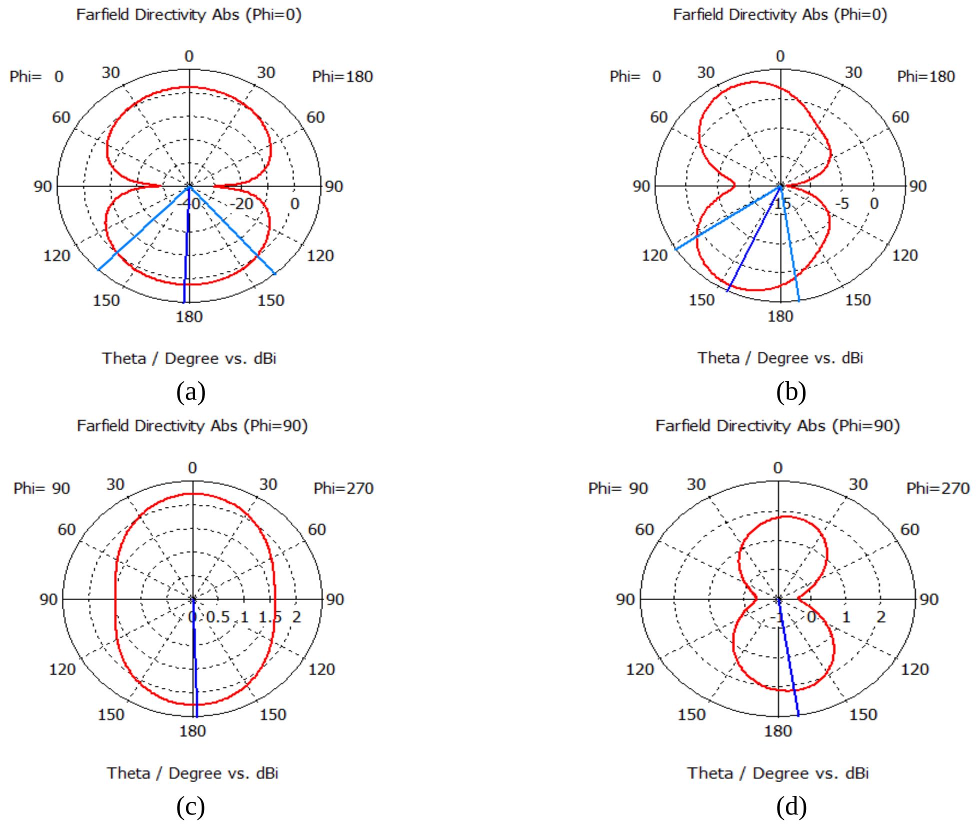


Figure 6. Radiation Pattern for E-Plane (a) at 2.4 GHz (b) at 5.2 GHz for H-Plane at (c) 2.4 GHz (d) 5.2 GHz

3.2. Result Comparison

Table 2 contain the comparison of the result obtained from this work with previous work based on bandwidth enhancement, compactness, gain and efficiency. Form the Table 1, bandwidth was presented in ration and dimension in free space wavelength by conserving lower operating frequency.

Table 2. Result Comparison

REF	Lower Operating Frequency (GHz)	Bandwidth Ratio	Electrical Size	Peak Gain (dBi)	Efficiency (%)
[45]	2.1	1.8:1	$0.16\lambda_0 \times 0.35\lambda_0$	1.5	73.3 and 74.5
[46]	2.16	1:1	$0.23\lambda_0 \times 0.14\lambda_0$	1.62	72
[47]	2.23	1.7:1	$0.36\lambda_0 \times 0.29\lambda_0$	2.12 and 3.62	95 and 97
[48]	2.48	1.7:1	$0.25\lambda_0 \times 0.14\lambda_0$	2.36	92.81
This Work	2.4	1:2	$0.18\lambda_0 \times 0.11\lambda_0$	2.24 and 3.9	96

4. CONCLUSION

The main objective of this work was to shows the effect of basic metamaterial structures SRR and CSRR in miniaturization and bandwidth enhancement, then reconfigure the wideband metamaterial antenna by using frequency reconfiguration technique. Investigation and simulation was shown that, the bandwidth was maintained by replacing two normal rings in the existing antenna with standard metamaterial SRR and CSRR. Three operating frequencies at 2.5 GHz, 3.0 GHz and 3.5 GHz were obtained by utilizing frequency reconfigfuration technique. From the bandwidth range and single bands obtained within the bandwidth, the antenna can be use for wireless communication application and cognitive radio application for frequency selectivity. The realized peak gain at 2.4 GHz and 5.2 GHz are 2.24 dBi and 3.9 dBi respectively with average efficiency of 96%. Finally, fabrication need to be done to compare between simulated and measured results.

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