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

Adamu Y. Iliyasu, Mohamad Rijal Bin Hamid, Mohamad Kamal A Rahim, Mohd Fairus Bin Mohd Yusoff
Advance RF & Microwave Research Group, School of Electrical Engineering, University Technology Malaysia (UTM), Malaysia

Article Info

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 Wireless Area Network (WLAN) Application. The design is based on reconfiguring wideband metamaterial antenna by applying frequency reconfiguration technique. This was achieved by employing SRR and CSRR for bandwidth enhancement and two PIN Diode switches at different position for reconfiguration. The antenna has electrical dimension of $0.18\lambda_0 \times 0.11\lambda_0$ 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.

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

Corresponding Author:
Adamu Y Iliyasu,
Department of Communication Engineering,
University Technology Malaysia (UTM)
Johor Bahru, 81310 Malaysia.
Email: alhaji080@kustwudil.edu.ng

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 $\lambda_g$ ($p < \frac{\lambda_g}{4}$) [3]. Classification of metamaterial depends on the positive or negative sign of permeability $\mu$ and permittivity $\varepsilon$ 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 $\mu$ and $\varepsilon$ can be obtain by using Nicolson-Rose-Weir (NRW) numerical method with generated S-parameters as presented in (1), (2), (3) and (4) [6].

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Wideband frequency reconfigurable metamaterial antenna employing SRR... (Adamu Y. Iliyasu)
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](image)

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](image)

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.
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.

Figure 4. Schematic Diagram of Proposed Antenna

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 and SW2

| SW1  | SW2  | Status       | Bandwidth/Operating 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 3.94 dBi 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.

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

The main objective of this work was to show 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 reconfiguration 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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BIOGRAPHIES OF AUTHORS

Adamu Yau Iliyasu
Date of birth 10/10/1980
Place of birth Kano, Nigeria, received B.SC in Electrical Engineering Kano. University of science &Technology, Wudil. Faculty of Electrical Engineering. M.SC in Electrical & Computer Engineering at Meliksah/Erciyes University Turkey. Currently a PhD Student under RF and Microwave Research Group University Technology Malaysia. School of Electrical Engineering. Malaysia. Johor.

Mohammad Rijal Hamid
received the M.Sc. degrees in communication engineering from the Universiti Teknologi Malaysia, Johor Bahru, Malaysia, in 2001 and the Ph.D Degree at the University of Birmingham, Birmingham, U.K. in 2011. He has been with Universiti Teknologi Malaysia (UTM) at the School of Electrical Engineering, Faculty Of Engineering, UTM, since 1999. Currently his position is a Senior Lecturer. His major research interest is reconfigurable antenna design for multimode wireless applications

Mohamad Kamal A. Rahim
is a Professor at School of Electrical Engineering, UTM Skudai Johor. Graduated with a Bachelor of Electrical Engineering from the University of Strathclyde, UK (1987), a Master of Electrical Engineering (Communication) degree from the University of New South Wales, Australia (1992) and a Doctor of Philosophy (Electrical Engineering) from the University of Birmingham, UK (2003). His research interest includes the areas of design of Dielectric resonator antennas, microstrip antennas, small antennas, microwave sensors, RFID antennas for readers and tags, Multi-function antennas, microwave circuits, EBG, artificial magnetic conductors, metamaterials, array antennas, wearable antennas, textile antenna, smart antennas, computer aided design for antennas and design of millimeter frequency antennas for 5G. He has published over 400 articles. He has supervised more than 20 Phd, 50 Master which includes thesis, project report, dissertation and more than 100 undergraduate students. 10 Phd and 50 Master students have been graduated through his supervision

Mohd Fairus Mohd Yusoff
is a graduate faculty member of the School of Electrical Engineering, University Technology Malaysia. He received his Bachelor in Engineering (Electrical-Telecommunication) in 2002 and Master of Electrical Engineering (Electrical - Electronics and Telecommunications) in 2005 from University Technology Malaysia. He obtained his PhD in 2012 from University of Rennes 1, France. His main research interests and areas are antenna design, millimetre waves and microwave devices.