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A Novel Modified SSRR Metamaterial Antenna for 5GHz WLAN Band Applications

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Abstract

Objectives: In this paper design and analysis of novel metamaterial antenna for WLAN band applications is presented. **Methods/Statistical Analysis:** Proposed antenna operates at WLAN 802.11 band between 5 to 6 GHz range. The proposed antenna uses novel modified Square Split Ring Resonator (SSRR) shaped patch resulting in electrically smaller size and improved antenna performance in terms of gain and bandwidth. **Findings:** The overall size of antenna is 22.5 mm × 17.5 mm × 1 mm making it useful for small wireless devices. Simulated and measured results are presented and compared. Both the results are in good match with each other. **Applications:** Proposed antenna is suitable for its use in small and compact wireless devices such as USB dongles.

Keywords: ISM, Metamaterial, SSRR, WLAN

1. Introduction

Metamaterials are artificially manufactured electromagnetic materials that consists periodically arranged objects. Size of these objects and spacing between them are much smaller than operating wavelength. These special materials were proposed theoretically.[1] Veselago proposed electromagnetic wave propagation in artificial material having simultaneous negative permittivity and negative permeability. Almost thirty years later in 1996, J. B. Pendry suggested the plasmonic type negative (ε) structures using array of conducting thin wires at suitably chosen spacing and diameter.[2,3] In Pendry proposed an array of conducting Split Ring Resonator (SRR) showing negative permeability for a certain range of frequencies.[2]

Today's wireless and mobile communication system need multi-band device functionality. Antenna system used in defense, space, and medical imaging should have high gain, small size, and high directivity. The technological potential of Metamaterials for developing novel components and subsystems offers a very promising alternative that could overcome the limitations of current technology.[4] Metamaterial are capable to guide and control electromagnetic waves in a very efficient manner.

To improve the limitations of microstrip patch antenna various techniques have been suggested and investigated e.g., use of high permittivity dielectric substrate, slotted patch antenna, stacked configuration. These are the ways to improve the performance of microstrip patch antenna but it may not be possible to entirely eliminate above limitation of patch antennas. Further reduction in size of patch antenna deteriorates its gain and bandwidth. Because size, bandwidth and efficiency of an antenna has a fundamental relation with each other. the solution for miniaturization of the antenna, enhancement of gain and bandwidth is the use of artificial structures called metamaterial.[5-7] Use of metamaterial in antenna design improves the performance of electrically small antennas. Many structures have been proposed which enhances antenna parameters.[8-11]

A Metamaterial antenna for ISM band applications is presented in this paper operating at 5 GHz band. The SSRR structure is modified by introducing umbrella shaped elements on opposite sides of outer square. This

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modified unit cell is also optimized to support 5 GHz band. The designed antenna is having defected ground structure to further enhance bandwidth coverage.

Next section discussed the evolution of proposed antenna. Section III presents the simulations and measured results of the proposed antenna. Section IV concludes the paper.

2. Evolution of Antenna Structure

In this section the evolution of proposed metamaterial antenna is presented which is developed from antenna with conventional SSRR patch. The antenna consists of ground plane, dielectric substrate and conventional Square Split Ring Resonator (SSRR) shaped patch with stripline feed. The main objective of using metamaterial based patch is to reduce the size. The overall size of antenna is 22.5 × 17.5 × 1 mm^3. Figure 1 shows the top view and the bottom side view of the conventional antenna with its detailed dimensions.

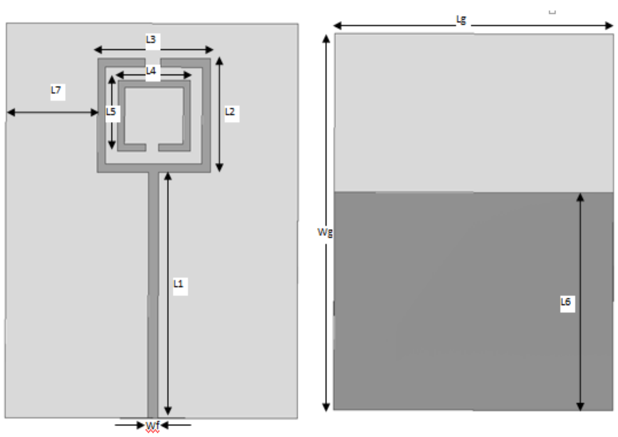

Figure 1. Top and Bottom views of Conventional Metamaterial antenna.

The detailed dimensions of conventional Metamaterial antenna are given in Table 1.

Table 1. Dimensions of Conventional Metamaterial Antenna

Parameter	Value (mm)	Parameter	Value (mm)
L_g	22.5	L1	15
W_g	17.5	L2	6.5
L3	6.75	L7	5.375
L4	4.25	Wf	0.6
L5	4	L6	15

The material parameters such as epsilon (ε) and mu (μ), a Figure 2 shows the metamaterial unit cell is considered. To simulate the Metamaterial cell assignment of excitations & boundary conditions is done to different surface so that the *S* parameters can be extracted.

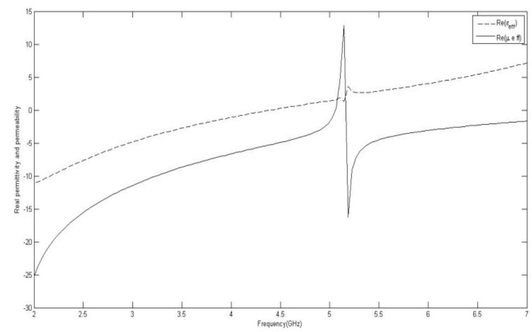

Figure 2. Metamaterial Unit Cell Analysis showing mu and epsilon plot vs Frequency.

After obtaining the metamaterial properties at desired frequency band the unit cell is used as an antenna fed by microstrip feed line. Due to its use as an antenna element the unit cell structure needed to be scaled up by almost 20%. But the size of antenna with modified SSRR is smaller compared to antenna with conventional SSRR. This is due to the fact that conventional SSRR antenna resonates at higher frequency i.e 6.19 GHz and to resonate it in 5 GHz its size should be increased to achieve that. Therefore overall size of conventional SSRR based antenna is larger than antenna with modified SSRR shown as Figure 3 and 4.

With the help of following equations value of epsilon and mu is calculated by using return loss parameter from HFSS.

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

$$\epsilon = \frac{n}{z} \quad (2)$$

$$\mu = nz \quad (3)$$

where n = refractive index

ε = permittivity

μ= permeability

The detailed dimensions of final proposed antenna are given in Table 2.

By introducing the extra elements electrical length of the antenna gets increased. So the size of proposed antenna is reduced for the operating frequency because the electrical length of antenna is inversely proportional to the size of antenna. The dimensions of umbrella shaped elements are optimized to achieve maximum operating bandwidth at resonant frequency. This antenna supports the ISM 5GHz band. The main objective of research work is to propose a small size antenna.

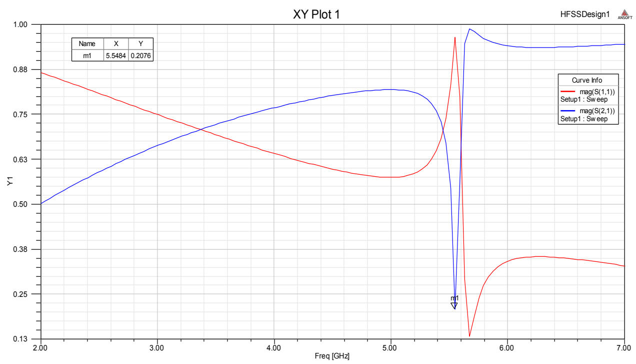

Figure 3. Simulated S Parameters of modified SSRR.

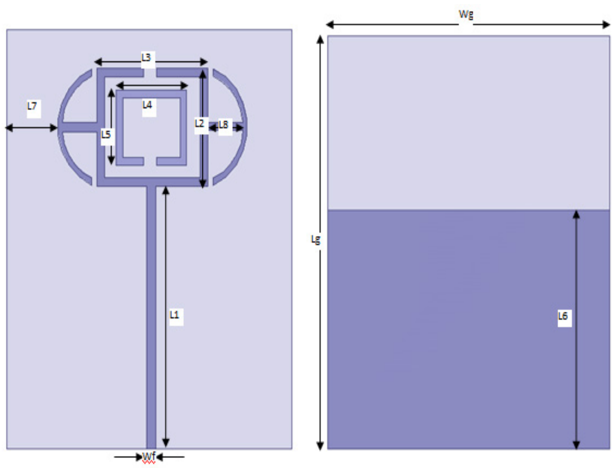

Figure 4. Top and Bottom views of Proposed Metamaterial antenna.

3. Results and Validation

The simulation software, HFSS, produced all the simulation results presented in this section. The proposed antenna was simulated and optimized several times until satisfactory results were obtained. In this section, the accomplished results such as return loss plot (S11) & VSWR plot are discussed. Proposed antenna covers wideband and this is achieved by using a modified ground plane.

3.1 Simulated Return Loss

Figure 5 shows the return loss (S11) of the conventional metamaterial antenna.

Table 2. Dimensions of Final Proposed Antenna

Parameter	Value (mm)	Parameter	Value (mm)
L_g	22.5	L1	14.2
W_g	17.5	L2	6.5
L3	6.75	L7	3.1
L4	4.25	L8	2.8
L5	4	Wf	0.6
L6	13.3		

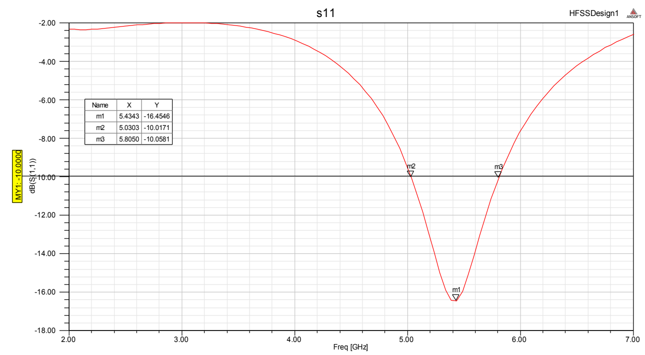

Figure 5. Simulated S11 Plot of Conventional Metamaterial Antenna.

The conventional SSRR antenna resonates at 6.19 GHz. The return loss is -22.05 dB. Bandwidth covered is 1.47 GHz which covers only upper portion of WLAN 5 GHz band.

Figure 6 and 8 shows the return loss (S11 parameters) for the final proposed antenna. It is the plot between return loss in dB and frequency.

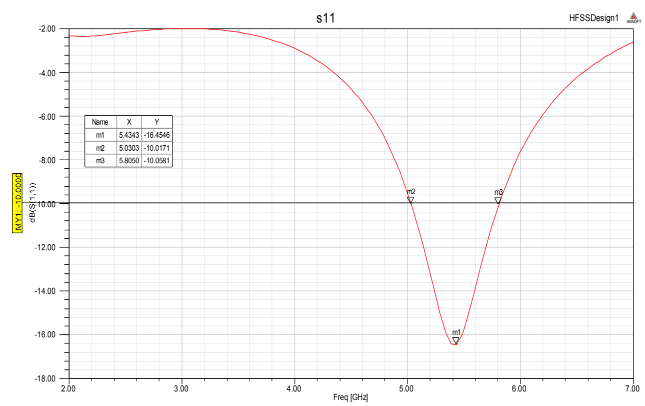

Figure 6. Simulated Return Loss of Proposed Antenna.

The proposed modified SSRR antenna resonates at 5.43 GHz. The return loss is -16.45 dB and bandwidth covered is 770 MHz which covers almost entire WLAN 5 GHz band.

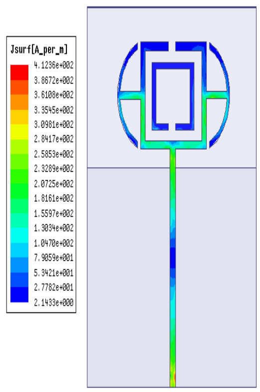

Figure 7. Current Distribution of Modified SSRR Antenna.

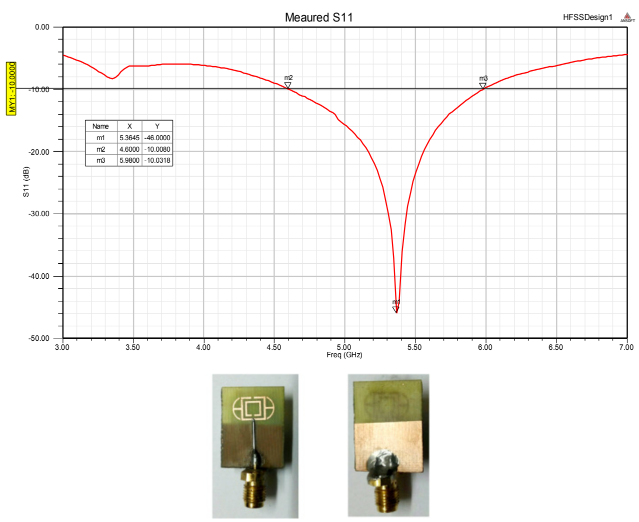

Figure 8. Measured Return Loss of Proposed Antenna.

3.2 Surface Current Distribution

It can be observed from Figure 7 that the antenna radiation is mainly due to strip line, lower portion of outer square & connecting strip to umbrella shaped elements.

3.3 Measured Return Loss

The proposed modified SSRR antenna resonates at 5.36 GHz. The return loss is -46 dB and bandwidth covered is 1380 MHz which covers the entire WLAN 5 GHz band.

Comparison between simulated and measured results is shown in Figure 9.

The shift in the resonant frequency is observed in simulated and fabricated antennas and this is due to fabrication process, available material properties and connector properties.

As shown in above Table 3. That there is slight change in resonance and bandwidth characteristics of the proposed antenna. The reason for this is connector and cable losses, variation in practical substrate material characteristics etc. As compared to a design available in literature the proposed antenna showed better gain, resonance and reduced size.

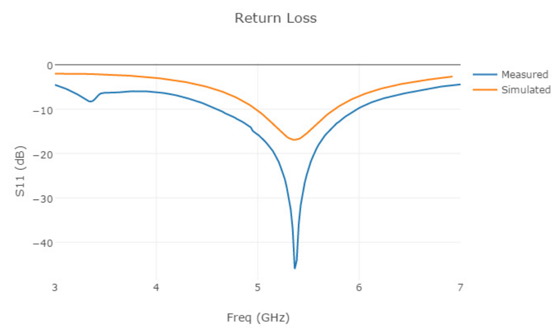

Figure 9. Comparison between Simulated and Measured Results.

Table 3. Comparison between Simulated & Measured Results of Proposed Antenna

Parameters	Simulated Results	Measured Results	Design in[14]
Resonant Frequencies	5.43 GHz	5.36 GHz	5.5 GHz
Size	22.5 mm x 17.5 mm		20 mm x 20 mm
Return Loss	-16.45 dB	-46 dB	Simulated: -34 dB Measured: -21 dB
Overall Impedance BW	770 MHz	1380 MHz	1600 MHz
Peak Gain	3.08 dB	---	2.8 dB

4. Conclusion

A Metamaterial based antenna for ISM band applications is presented. The SSRR structure is modified by introducing umbrella shaped elements on opposite sides of outer square. This modified unit cell is also optimized to support 5 GHz band. The designed antenna is having defected ground structure to further enhance bandwidth coverage The overall size of antenna is 22.50 × 17.5 × 1 mm^3.

After simulation the resonant frequency, Return loss and bandwidth are -16.45 dB at 5.43 GHz and 770 MHz (5.03 GHz-5.8 GHz) respectively while during measurement the resonant frequency, Return loss and bandwidth are -46 dB at 5.36 GHz, 1380 MHz (4.60 GHz - 5.98 GHz).

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