

# Potential Parameters Enhancement of Compact Microstrip Antenna by Using “SLOTTED SRR” Shaped Metamaterial Structure

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**Abstract** — This work demonstrates integration of an artificial material onto a Rectangular Microstrip Patch Antenna to improve its performance. Such antennas are gaining a high interest as system designer require more complex function to be implemented in reduced area. The artificial material used is commonly called “Metamaterial” or “Left-Handed-Metamaterial (LHM)” and it exhibit some peculiar electromagnetic properties that don’t exist in nature. So, when a microstrip patch antenna is integrated using Left-Handed-Metamaterial, potential parameters like return loss, bandwidth, directivity, gain & efficiency etc. shows improvement. These antennas are cost-effective, more powerful and highly efficient in comparison to the basic microstrip antenna and have their applications in various commercial and military equipments. Proposed Antenna along with RMPA is designed to simulate at 2.4GHz. The designing and analysis has been done using the Computer Simulation Technology (CST-2010) software. The various parameters are compared and the results were deduced.

**Keywords** - Rectangular Microstrip Patch Antenna, Left-Handed Metamaterial, Split Ring.

## 1. INTRODUCTION

To design the patch antenna first step is to calculate the required parameters which are involved in designing. After getting these required values, the simulated results are obtained by using computer simulation technology microwave studio (CST-MWS) simulation software. Antennas play a very important role in the field of wireless communications. Some of them are Parabolic Reflectors, Patch Antennas, Slot Antennas, and Folded Dipole Antennas. We can say antennas are the backbone and almost everything in the wireless communication without which the world could have not reached at this age of technology. To design a microstrip patch antennas for a specific resonating frequency, accurate dimensions of patch is required. Therefore, it becomes necessary to use simulation programs to test the performance of the patch before fabrication.

In year 1967, Victor Vesalago, a Russian Physicist made a theoretical speculation on the existence of substances with simultaneously negative  $\epsilon$  and  $\mu$ , which serves as the origin of all research on LH MTMs [1] [8]. However, there was not much progress until year 1999 when Prof J.B Pendry [4] [6] proposed his design of Thin-Wire (TW) structure that exhibits the negative value of permittivity,  $\epsilon$  and the Split Ring Resonator (SRR) with a negative permeability,  $\mu$  value. Following this interesting discovery, Dr. Smith from Duke University combined the two structures and became the first to fabricate the LHM in his lab. It is also desired to integrate this material into the current existing antennas developed by previous scholars to enhance the characteristics of the antenna – especially the Return Loss and also the Gain and Directivity.

## 2. METHODOLOGY AND SIMULATED RESULTS

The Rectangular Resonant Microstrip Patch Antenna is etched on FR4 (Lossy) substrate of thickness  $h = 1.6\text{mm}$ , and dielectric constant  $\epsilon_r = 4.3$  by using PEC (Perfect Electric conductor) as the conducting plane. The proposed design is based on “SLOTTED SRR” Shaped metamaterial structure. The Rectangular microstrip patch antenna (RMPA) parameters are calculated from the formulas given below.

**Desired Parametric Analysis [2, 3]:**

Calculation of Width (W)

$$W = \frac{1}{2f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where,

$c$  = free space velocity of light,  
 $\epsilon_r$  = Dielectric constant of substrate.

Effective dielectric constant is calculated from:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( \frac{1}{\sqrt{1 + \frac{12h}{w}}} \right) \quad (2)$$

The actual length of the Patch (L)

$$L = L_{eff} - 2\Delta L \quad (3)$$

Where,

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{eff}}} \quad (4)$$

Calculation of Length Extension

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{eff} + 0.3) \left( \frac{w}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left( \frac{w}{h} + 0.8 \right)} \quad (5)$$

The RMPA is designed using the calculated parameters shown below in Table 1.

**Table 1: RMPA Specifications**

	Dimensions	Unit
Dielectric Constant ( $\epsilon_r$ )	4.3	-
Loss Tangent ( $\tan \delta$ )	0.02	-
Thickness (h)	1.6	mm
Operating Frequency	1.9275	GHz
Length (L)	29.77	mm
Width (W)	38.39	mm
Cut Width	5.0	mm
Cut Depth	10.0	mm
Width Of Feed	3.009	mm

### Designing and Simulation of RMPA at 2.4GHz

A rectangular microstrip patch antenna (RMPA), with a recessed microstrip feedline, backed by a perfect electrical conductor (PEC) ground plane is shown in Figure 1. The antenna was designed to resonate at 2.4GHz.

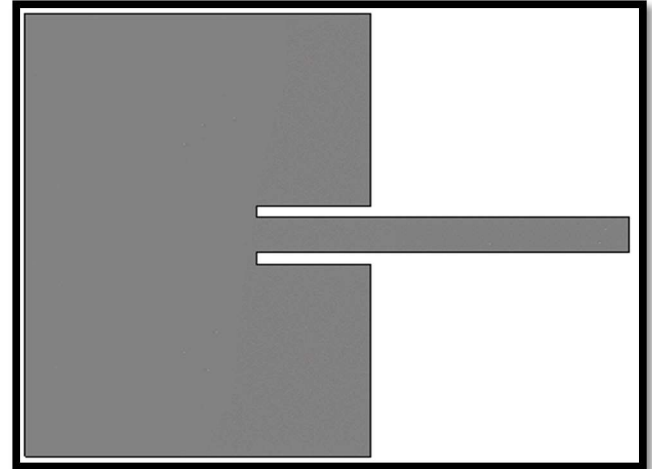


Figure 1: Dimensional view of Rectangular Microstrip Patch Antenna at 2.4 GHz

The return loss is a main parameter in almost all antenna analysis. It is also known as the S11 parameter in the two port network. It measures the antenna's absorption of the fed power over the total power fed. A good antenna should indicate a return loss of less than -10 dB, which indicates that the antenna absorbs more than 90% of the fed power.

Initially, the Return Loss of the Rectangular Patch Antenna is -16.65dB as shown in Figure 2.

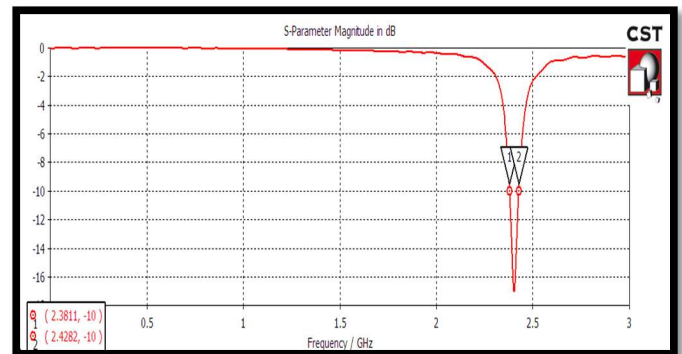


Figure 2: Simulated Result of Rectangular microstrip patch antenna showing Return Loss of -16.65 dB

Figure 3 shows a 3D radiation pattern together with the azimuth and elevation plane definition. Three dimensional plots reveal a much better insight into the behavior of the antenna's radiation. This is demonstrated for the far field plot at 2.4 GHz in Figure 3; the tilt of the pattern can be easily observed. The radiation pattern in figure 3 shows directivity of 7.238dBi.

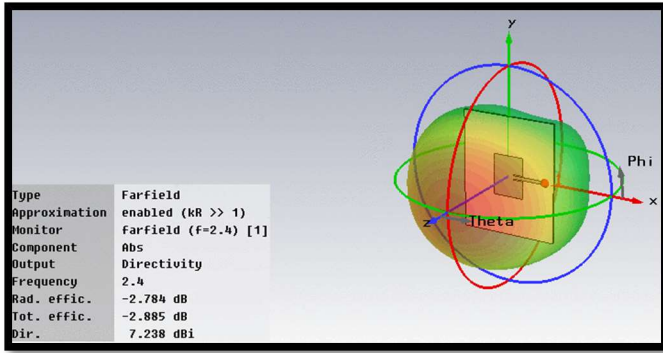


Figure 3: Radiation Pattern of Rectangular microstrip patch antenna showing 7.238dBi directivity

After designing & simulating the RMPA in Transient Mode at the operating frequency, the proposed “SLOTTED SRR” shaped metamaterial structure is taken into account.

### Designing and Simulation of “SLOTTED SRR” double negative metamaterial structure.

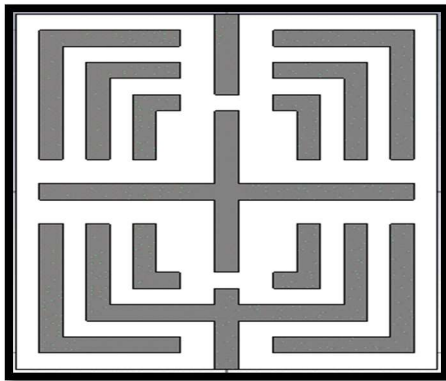


Figure 4: Rectangular Microstrip Patch Antenna loaded with “SLOTTED SRR” shaped metamaterial structure.

When the proposed structure is incorporated with the RMPA, it shows the Return Loss of -28 dB as shown in Figure 5.

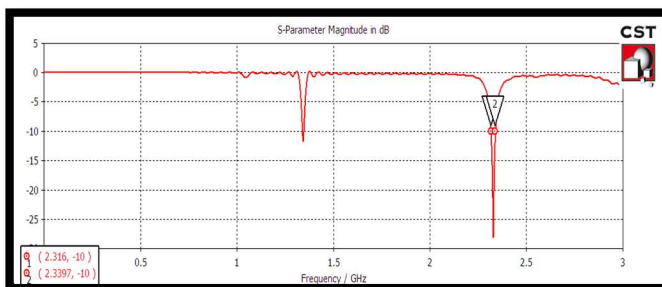


Figure 5: Simulated result of proposed metamaterial structure showing Return Loss of -28dB

In Figure 6, it shows the improved directivity [12-14] of 7.417dBi.

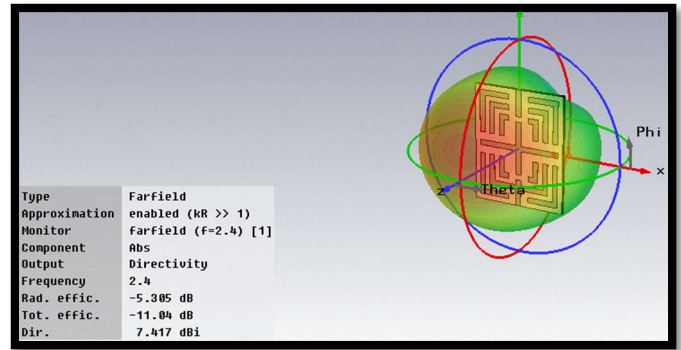


Figure 6: Radiation Pattern of proposed metamaterial structure showing 7.417dBi directivity

Smith Chart [7] in Figure 7 shows that the proposed “SLOTTED SRR” shaped metamaterial structure is matched at 2.4 GHz frequency.

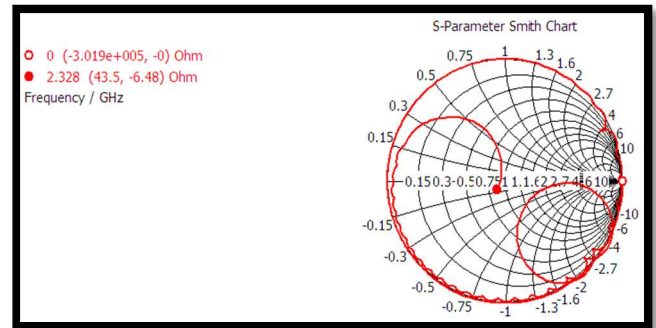


Figure 7: Smith chart of the proposed metamaterial structure at 2.4 GHz.

### 3. CONCLUSION

In this work, the behavior of a Rectangular Microstrip Patch Antenna loaded with “SLOTTED SRR” shaped double negative metamaterial structure at a height of 3.2mm from the ground plane is examined. It is revealed that integrating the proposed metamaterial structure [16] with the patch antenna at a height of 3.2mm from the ground plane, significantly improves the potential characteristics of the antenna. Return loss of the proposed Antenna improves up to -28dB and directivity improves by 0.179dBi significantly. Other Parameters like radiation efficiency and total efficiency also increases drastically as shown in Fig. 3 & Fig. 6. The proposed “SLOTTED SRR” metamaterial structure is electrically small and suitable to handle easily. The proposed antenna could be used in several microwave applications that requires improved bandwidth & reduced return loss at the operating frequency. The proposed

structure could be considered as a novel approach for improving antenna's potential characteristics. In case of single element it has been observed that the antenna gain, bandwidth, directivity and total efficiency is quite low. But, while deploying it with the Metamaterial structure, all the potential parameters increases significantly.

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