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Metamaterial Loaded Rectangular Patch Antenna for Wireless Communication Application

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ABSTRACT

In this paper, a metamaterial based compact multiband rectangular microstrip patch antenna is proposed. The return loss of metamaterial loaded microstrip patch antenna obtained at the resonant frequency 2.4GHz. The metamaterial structure printed on FR4 substrate at hight of 1.6mm from the ground plane. The FR4 substrate has 4.4 dielectric constant.These metamterial structures are periodic in nature and possesses negative permittivity and negative permeability. The greatest advantage of metamaterial loading will be miniaturization. This metamterial loaded rectangular patch antenna is simulated and tested using HFSS Simulator, where an electromagnetic analysis tool is used. The fabricated antennas results are measured using Vector Network Analyzer (VNA).

Key words : Complimentary Split Ring Resonators (CSRR), Double Positive(DPS), Double Negative(DNG), Metamaterial(MTM).

1. INTRODUCTION

Microstrip patch antenna is most widely used in various wireless communication applications like in mobile, satellite communication. Rectangular microstrip patch antenna is most popular because of its small size, low profile, and ease fabrication and feed [1].Microstrip patch antenna with low dielectric constant and thick substarte provides large bandwidth and better efficiency [5]. But it requires large dimensions. On the other hand if substrate with high dielectric constant is used then it affects the gain and bandwidth [2].So to overcome the above drawback metamaterials can be used. Metamaterials are used for further miniaturization of antenna. Metamaterials (MTM) are artificial structures which use different periodic structures to get the properties which are found in nature [6]. Conventional materials which are available in nature possesses basic properties a positive permittivity and permeability. Such materials are known as Double Positive (DPS) materials. Whereas metamterials are termed as Double negative (DNG) materials because of negative permittivity and permeability [4].

2. ANTENNA DESIGN

The metamaterial loaded rectangular patch antenna has been designed for 2.4GHz. The FR4 substrate with 4.4 relative permittivity and 1.6mm thickness is used. The inset fed microstrip patch antenna designed for 50Ω impedance.
The Figure 1 shows the geometry of proposed antenna.

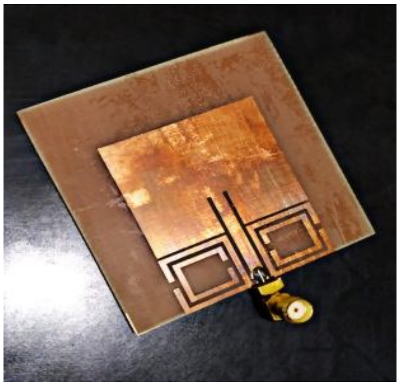

Figure 1: Rectangular Patch Antenna with Metamaterial Substrate (FR4 fabricated antenna)

Following equations are used to design the length and width of the patch [2];

$$W=\frac{c}{2fr}\sqrt{\frac{2}{\in_r+1}}$$

$$\in_{reff}=\frac{\in_r+1}{2}+\frac{\in_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

$$\frac{\Delta L}{h}=0.412\frac{(\in_{reff}+0.3)(\frac{W}{h}+0.264)}{(\in_{reff}-0.258)(\frac{W}{h}+0.8)}$$

$$L = \frac{c}{2 f_r \sqrt{\epsilon_{reff}}} - 2\Delta L$$

Thus the conventional patch has been designed by using above mentioned formulas.

Among various feeding techniques, microstrip feed line is the easiest to construct. In microstrip feed line the conducting strip can be directly connected to the edge of the patch. The width of the feed line strip is very small as compared to the patch width. Furthermore, if inset cut is implemented into patch, impedance matching obtained very easily. In order to implement inset cut, the proper inset position has been find out with the help of online mictrostrip line calculator as shown in figure 2.we have to find out proper inset position.

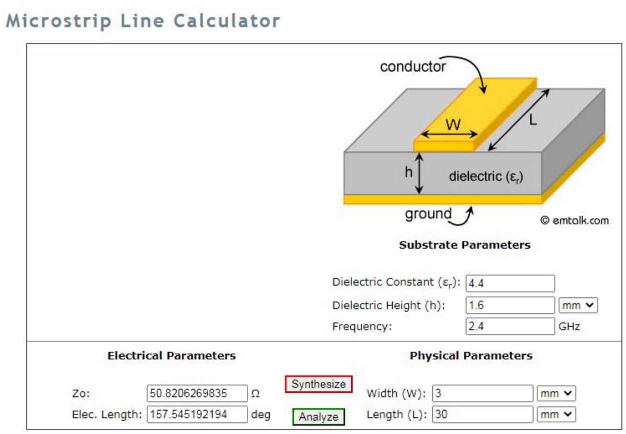

Figure 2: Microstrip Line Calculator [9]

By using inset feed, the impedance of the transmission line can be matched closer to the impedance of the centre of the patch as the transmission line is cut closer to it. This results in increment in current distribution as well as voltage in the patch [2].

The complementary split ring resonator has been placed at both the sides of feed line.

3. METAMATERIAL GEOMETRY

After obtaining the dimensions conventional patch, a complementary split ring resonator as a metamaterial structure is incorporated into the antenna design. Such a metamterial design printed on FR4 substrate which is having thickness 1.6mm. A rectangular complementary split ring resonator (CSRR) loaded microstrip patch antenna with an inset fed is designed.

The unit cell of proposed rectangular CSRR structure is shown in figure 3.

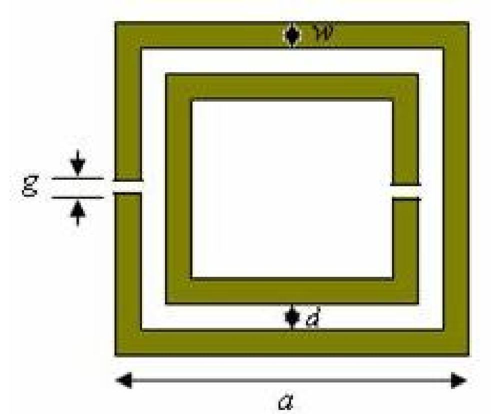

Figure 3: Unit cell of proposed rectangular CSRR Structure [3][7]

4. DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA WITH METAMATERIAL

Initially microstrip antenna, which is a rectangular patch, has been designed with a resonant frequency of 2.4GHz. Then it is loaded with a metamaterial Complementary Split Ring Resonator structure near feed line. The ground plane and the patch with metamaterial structure are placed on opposite sides of FR4 substrate. The inclusion of the metamaterial results in miniaturization but reduces the gain which is the trade off with gain [5].

The figure 1 shows the fabricated antenna whereas figure 4 shows the designed antenna on simulation software.

Whenever there is metamaterial loading then the patch antenna's resonance frequency depends on metamaterial constitutive parameters. That means designed antenna resonates when metamaterial constitutive parameters becomes negative. Therefore resonance frequency of the antenna shifts to the metamaterial resonance frequency. So even though the patch antennas dimensions are as per the resonant frequency 2.4GHz but in results it shifts to 1.4GHz practically [8].

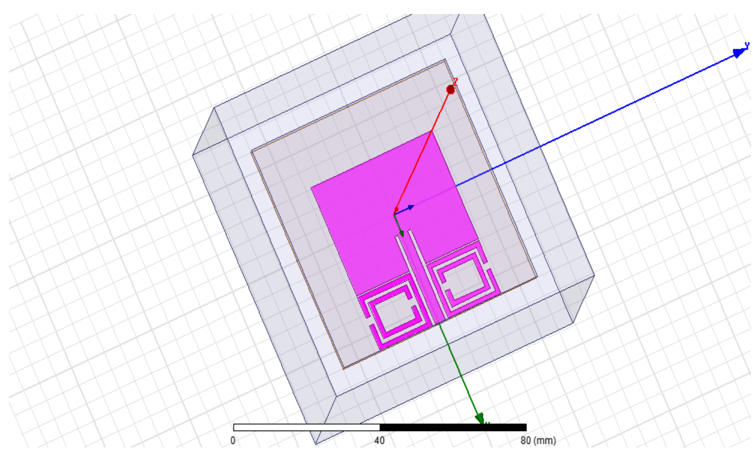

Figure 4: Inset Fed Metamaterial Loaded Microstrip Patch Antenna designed using Simulation Software

5. SIMULATION AND PRACTICAL RESULTS

5.1 Return Loss:

The return loss of designed antenna and fabricated antenna is shown in figure 5. It has been noted that the antenna with metamaterial achieves the low return losses. The simulated and measured return loss bandwidth extends from 1.4340-1.4580 GHz and 1.5-1.6 GHz respectively. It is measured using Rhode and Schwarz ZVL 135 Microwave Vector Network Analyzer of 13.6 GHz.

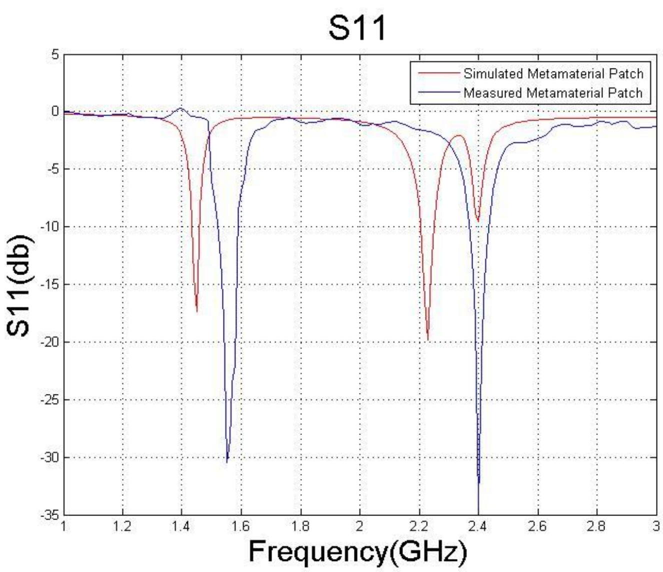

Figure 5: Simulated and measured return loss of inset fed metamaterial loaded microstrip patch antenna

5.2 Radiation Pattern:

The radiation pattern is a graphical depiction of the relative field strength transmitted from or received from by the antenna [8].

Figure 6 is the simulated radiation pattern in XZ plane at 1.4GHz.

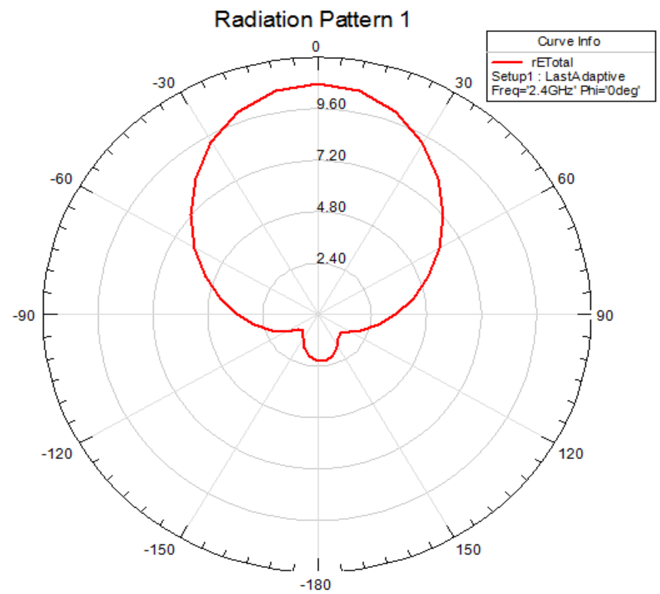

Figure 6: Simulated radiation pattern in the XZ plane at 1.4GHz.

Figure 7 is the simulated radiation pattern in YZ plane at 1.4GHz.

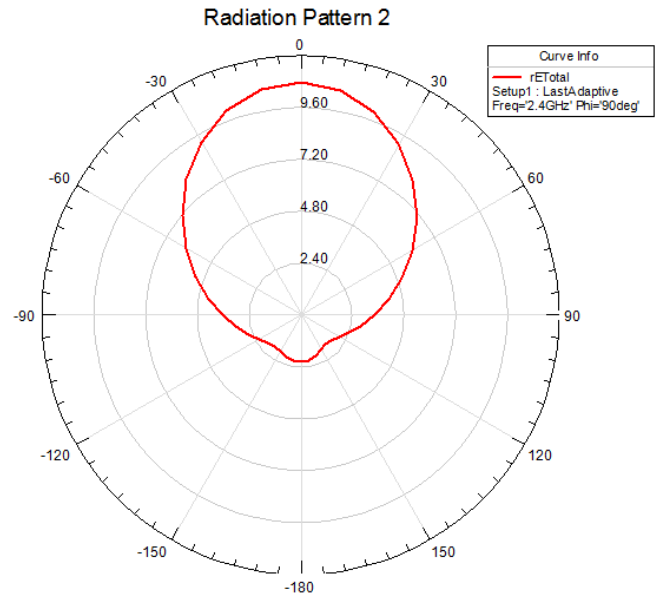

Figure 7: Simulated radiation pattern in the YZ plane at 1.4GHz.

Figure.8 shows the radiation patterns for proposed fabricated antenna configuration at the resonating frequency of 1.4 GHz.

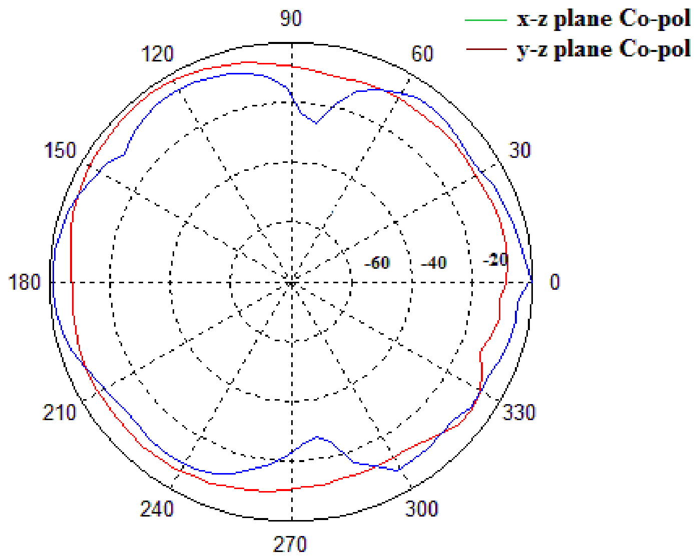

Figure 8: Measured radiation pattern

5.3 Experimental Setup:

Figure 9. a) : Snapshot of radiation pattern measurement set up

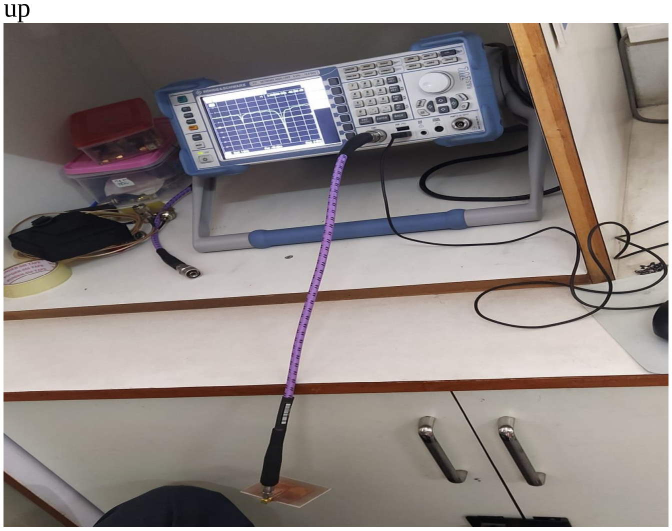

Figure 9. b) : Snapshot of S11 measurement set up by using VNA

6. CONCLUSION

In this paper a microstrip patch antenna using metamaterial has been presented. The designed antenna investigated by some parameters like return losses, radiation patterns for wireless applications. The metamaterial substrate provides miniaturization of the antenna. Hence antenna designed for 2.4GHz but shifts to metamaterial resonance frequency of 1.4GHz. The simulated return loss bandwidth designed FR4 substrate is obtained from 1.4340-1.4580 GHz. Rhode and Schwarz ZVL 135 Microwave Vector Network Analyzer of 13.6 GHz was used to measure the return loss bandwidth. The measured return loss bandwidth of inset fed proposed antenna fabricated on FR4 substrate is obtained from 1.5-1.6 GHz.So such a fabricated antenna can be used for various wireless communication application in the frequency range of 1.5-1.6 GHz.

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