ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

# Design and Performance Analysis of Patch Antennausing Metamaterial

**Sachin Chalisgaonkar*1, Santosh Sharma2**

*1Department of Electronics and Communication, Student, MPCT Gwalior, India

2Department of Electronics and Communication, Assistant Professor, MPCT Gwalior, India

sachin.chalisgaonkar83@gmail.com

## Abstract

In this paper, a Symmetrical Rectangular Structure has been chosen to construct the metamaterial substrate due to the ability of constructing this shape, this structure produces a better performance compared to the other shapes. The implementation of the metamaterial as the substrate in a rectangular microstrip patch antenna produces high value of return loss. This high value of return loss indicates that only small amount of reflection waves were returned back to the source and most of the power will be radiated from the patch.CST MICROWAVE STUDIO isused to design the metamaterial based rectangular microstrip patch antenna.

**Keywords**: Rectangular microstrip patch antenna (RMPA), Metamaterial (MTM) Impedance Bandwidth, Return loss.

## Introduction

The concept of such antennas though introduced in early1950‟s in US by Deschamps& in France by Gutton&Baissinot,it was in 1970‟s only that with advent of Printed Circuittechnology, some serious advancement in this research area had begun [2]. A Microstrip device literally means asandwich of two parallel conducting layers separated bysingle thin dielectric substrate. The lower conductor is called

Ground Plane & the upper conductor is a simple resonantCircular/ rectangular Patch. The metallic patch (usually Cu orAu) may take many geometrics viz. rectangular, circular,triangular, elliptical, helical, ring etc.The IEEE definition of Antenna [IEEE std. 145-1983] says:Antenna is a means “for radiating or receiving radio waves”[1]. In addition to receiving or transmitting energy, an antennain an advanced wireless system is usually required tooptimize or accentuate the radiation energy in some directions and suppress it in others. Thus antenna is a directionaldevice as well as probing device.

The field of Antennas isvigorous and dynamic and planar oriented antennas such asMicrostrip Patch has attracted significant attention primarily for space borne applications. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gainand radiation patterns. The microstrip antenna consists ofconducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations.The early work of Munson on micro strip antennas for use as a low profile flush mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems. Various mathematical models were developed for this antenna and its applications were extended to many other fields. The number of papers, articles published in the journals for the last ten years, on these antennas shows the Importance gained by them.

The micro strip antennas are the present day antenna designer’s choice. Low dielectric constant substrates are generally preferred for maximum radiation. The conducting patch can take any shape but rectangular and circular configurations are the most length of the antenna is nearly half wavelength in the dielectric; it is a very critical parameter, which governs the resonant frequency of the antenna. There are no hard and fast rules to find the width of the patch. There are many kinds of materials used to improve the gain of microstrip patch antenna. Among them, Metamaterial [4-6] are found most suitable. Metamaterials have opened an exciting field to realize unexpected physical properties and applications, which are not possible from naturally occurring materials. Conductive or dielectric inclusions in metamaterials can be tailored in shape and size, periodicity, and defects to produce unusual yet exciting properties.

Unusual properties such as, negative permittivity and permeability, negative refraction at the interface of two (RH and LH) media [7]. Metamaterial are artificial structure that can be design to exhibit specific electromagnetic proper-ties that doesn't found in the nature. In Greek “Meta‟ means “beyond‟[1]. These

ISSN: 2277-9655
Impact Factor: 1.852

features in the field of communication, microwave, biomedical and in antenna brings Metamaterial in the lead role, due to it provide change in Electromagnetic properties[2].

### Design Specifications

The RMPA parameters are calculated from the following formulas. Desired Parametric Analysis [1][7].

**Calculation of Width (W):**

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where
**C** = free space velocity of light,
**Ɛr** =Dielectric constant of substrate

**The effective dielectric constant of the rectangularmicrostrip patch antenna:**

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right)$$

(2)

**Actual length of the patch (L):**

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

**Calculation of length extension**:

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (4)$$

### Analysis of Rectangular Microstrip Patch Antenna and Metamaterial Structurewith Simulated Results

A microstrip patch antenna using metamaterials (fig 1) is designed for the resonant frequency 1.836 GHz. The length of the patch is 35 mm and its width is 46mm. The length of the microstrip line is 33mm which is used for the feeding purpose. For the designing of this antenna we took a both sided copper PCB. On the lower side of PCB copper field acts as the ground for this antenna and the on the upper side of the PCB we designed the patch of giving dimensions. On the other PCB we designed metamaterial structure and the lower portion of this PCB, which acts as a ground plane is removed. After etching we connected both PCB with the help of screw in such a manner so that the both design could overlap on each other. The whole geometry is simulated and realized practically using a dielectric substrate of height 1.6mm and having a dielectric constant 4.4mm. Loss tangent of the material is 0.02. microstrip feeding technique is used for providing the feed to the antenna.

**Table1.Rectangular Microstrip Patch Antenna Specifications**

| parameters | Dimension | Unit |
|---|---|---|
| Dielectric constant | 4.3 | - |
| Loss tangent (tan ) | .02 | - |
| Thickness (h) | 1.6 | Mm |
| Operating frequency | 1.836 | GHz |
| Length L | 35 | Mm |
| Width W | 46 | Mm |
| Cut width | 6 | Mm |
| Cut depth | 10 | Mm |
| Path length | 33 | Mm |

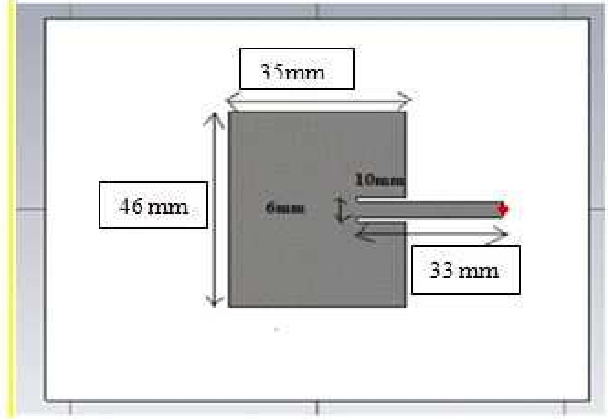


**Figure1. Rectangular microstrip patch antenna at 1.836 GHz.**

Rectangular microstrip patch antenna (RMPA) is oprating at frequency 1.836 GHz.

This design gives the better improvement in impedance bandwidth and reduction in return loss.An antenna's bandwidth specifies the range of frequencies over which its performance does not suffer due to a poor impedance match.

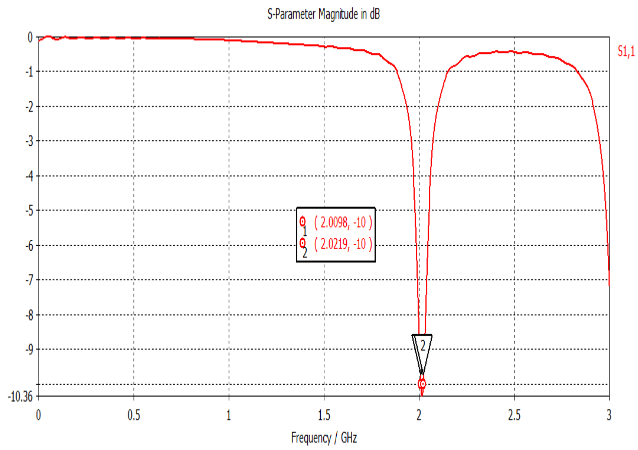


**Figure2.Simulation of return loss and bandwidth of RMPA.**

The bandwidth of simple RMPA is 12.1MHz and Return loss is -10.36 dB.

The Rectangular microstrip patch antenna has 3D Radiation pattern at 1.836 GHz as shown in figure3.

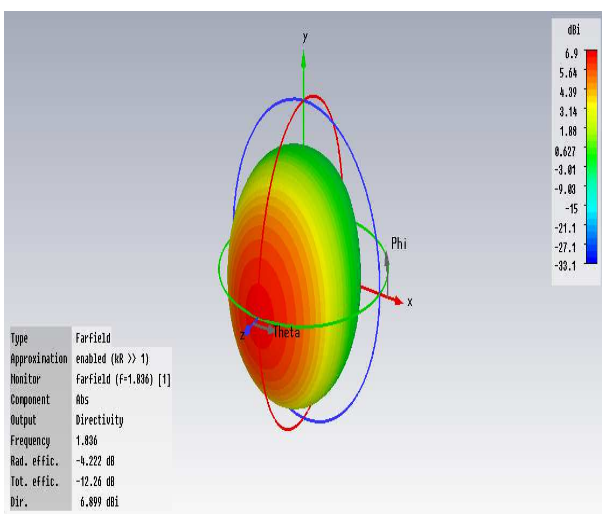


**Figure 3.Directivity of simple RMPA is 6.899dBi**

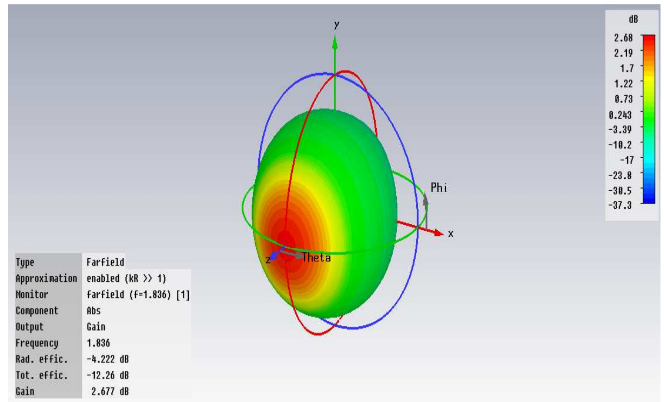


**Figure 4.Gain of simple RMPA is 2.677 dB**

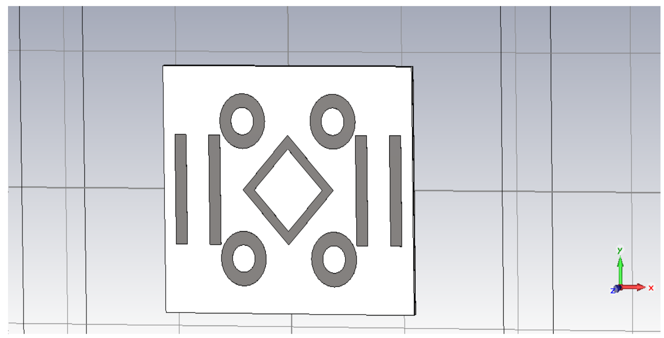

**Figure 5.Design of proposed metamaterial structure at the height of 3.2 mm from ground plane.**

In this metamaterial design, symmetrically strips and circle are loaded on the patch antenna.These are distributed equally with each other. This design gives the better improvement in impedance bandwidth and reduction in return loss.

**Equation used for calculating permittivity and permeability**
**Using NRW approach**

$$\mu_r = 2.c\,(1-V_2)/\omega.d.i(1+V_2)$$

$$\varepsilon_r = 2.c\,(1-V_1)/\omega.d.i(1+V_1)$$

$$V_1 = S_{11}+S_{21}$$

$$V_2 = S_{21} - S_{11}$$

**Where**
**$\varepsilon_r$ =Permittivity**
**$\mu_r$=Permeability**
**C=Speed of light**
**ω=Frequency in Radian**
**d= thickness of the substrate**
**i= imaginary coefficient**
**$V_1$=Voltage Maxima**

ISSN: 2277-9655
Impact Factor: 1.852

| Frequency[GHz] | Permeability[$\mu_r$] | Re[$\mu_r$] |
|---|---|---|
| **1.824** | -1013.16528397713-2251.3107585928i | -1013.16528 |
| **1.827** | -1361.47244713851-2041.65660015068i | -1361.47245 |
| **1.829** | -1600.25010068953-1751.95506249197i | -1600.2501 |
| **1.833** | -1723.84425994146-1443.7048646286i | -1723.84426 |
| **1.836** | -1755.6228007935-1159.70768799892i | -1755.6228 |
| **1.839** | -1726.59804065196-919.269761871643i | -1726.59804 |
| **1.842** | -1662.92047812992-725.192499367031i | -1662.92048 |
| **1.845** | -1582.50382960134-572.480709105443i | -1582.50383 |
| **1.847** | -1496.34810151785-453.854987618998i | -1496.3481 |

**Table 2**

**$V_2$=Voltage Minima**

For satisfying double negative property, the values of permeability and permittivity should be negative Within the operating frequency range. The obtained values of these two quantities from MS-Excel program are given in Table 2 & 3; Fig. 6 & Fig. 7 shows the graph between permeability & frequency and permittivity & frequency

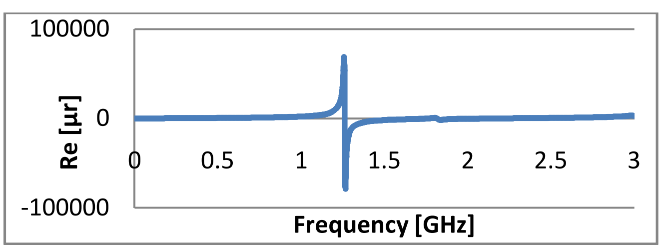


**Figure 6: Permeability versus frequency graph**

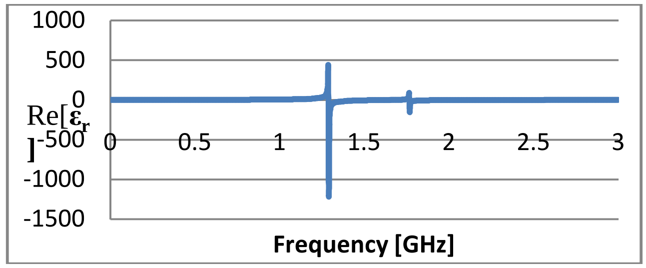


**Figure 7: Permittivity versus Frequency Graph**

**Table 3**

| Frequency[GHz] | Permittivity[$\varepsilon_r$] | Re[$\varepsilon_r$] |
|---|---|---|
| 1.824 | -8.61554829317584-2.31888510659417i | -8.615548293 |
| **1.827** | -8.57574354094187-2.12349757038769i | -8.575743541 |
| **1.829** | -8.52175400731373-1.89677104477037i | -8.521754007 |
| **1.833** | -8.44313909522449-1.64705045483765i | -8.443139095 |
| **1.836** | -8.33275637052589-1.38514979160947i | -8.332756371 |
| **1.839** | -8.18765627197724-1.12298079096466i | -8.187656272 |
| **1.842** | -8.00893845710753-0.872003622417211i | -8.008938457 |
| **1.845** | -7.80118584173573-0.641810608716234i | -7.801185842 |
| **1.847** | -7.57123059730726-0.439222747096188i | -7.571230597 |

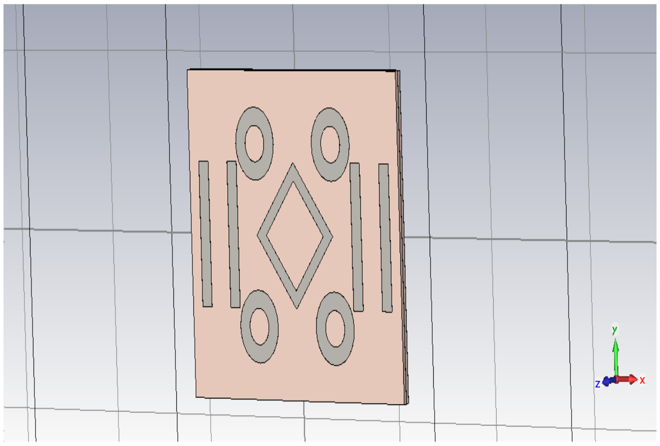


**Figure 8. Rectangular microstrip patch antenna with proposed metamaterial structure.**

The proposed metamaterial structure reduces the return loss by 17.257dB and increases the bandwidth up to 9MHz

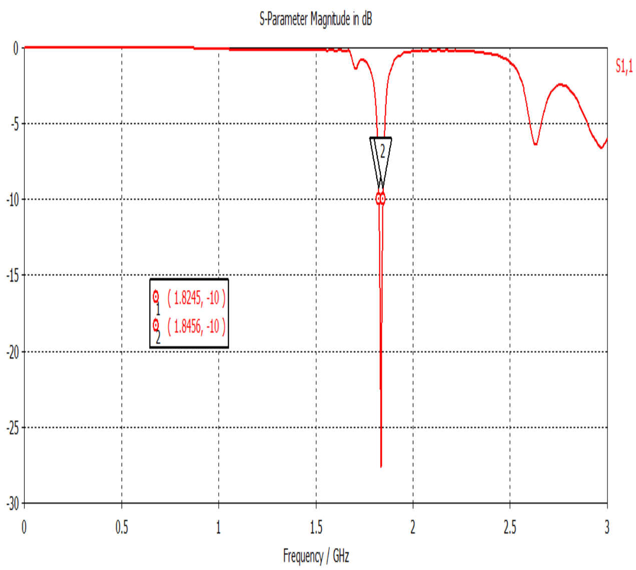


**Figure 9.Simulation ofResultof proposed structure at operating frequency 1.836GHz.**

The Simulated result of **proposed structure** is showing return loss of -27.617dB and Bandwidth of 21.1MHz.It is clear that the Directivity of proposed antenna is increasedin comparison to simple RMPA alone.

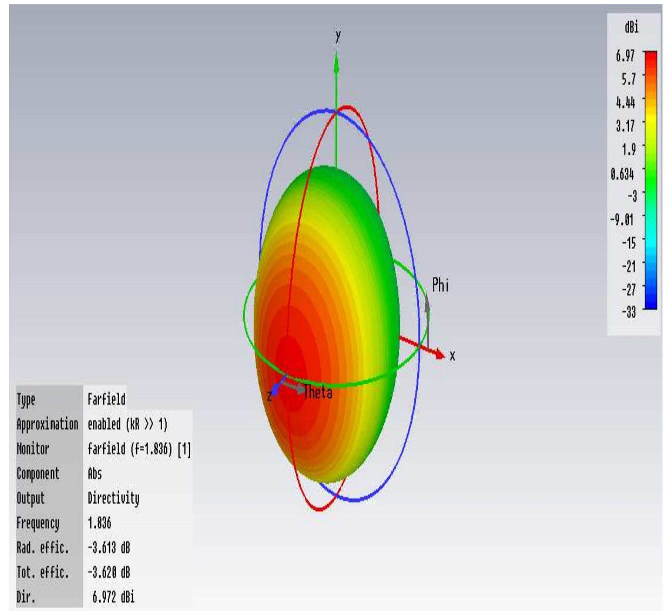


**Figure 10. Directivity of RMPA loaded with Metamaterial is 6.972 dBi**

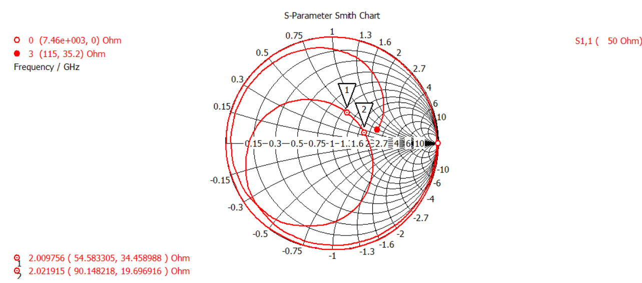


**Figure 11. Smith chart of simple Rectangular microstrip patch antenna.**

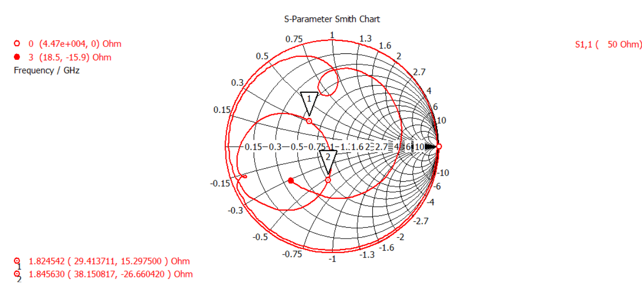


**Figure 12. Smith chart of RMPA loaded with metamaterial.**

Smith chart of RMPA loaded with metamaterial structure at 1.836GHz. Above Fig. shows the impedance variation in the simulated frequency range and received impedance matching for proposed antenna at characteristic impedance.

ISSN: 2277-9655
Impact Factor: 1.852

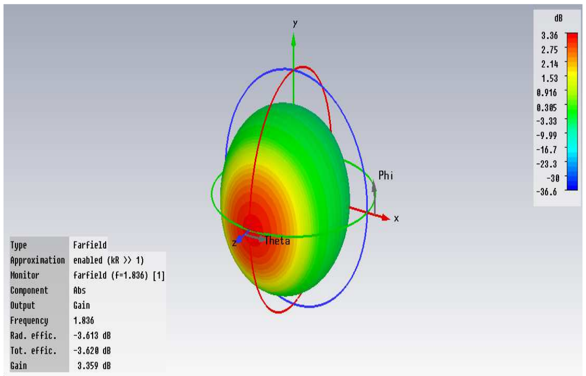


**Figure 13.Gain of proposed antenna at 1.836GHz is 3.359dB**

## Simulation Results

Patchantenna loaded with metamaterialstructure is simulated using CST-MWS software. The proposed design in comparison to RMPA alone, the potential parameters of the proposed antenna is increased. The return loss is reducedby 17.257dB and bandwidth is increased by 9MHz. From the Fig.10& 13 it is clear that the Directivity and Gain of proposed antenna design isincreased.

## Conclusion

The proposed antennastructure provides the better improvement in the impedance bandwidth and reduction in the return loss at operating frequency. The drawback of patch antenna was less impedance bandwidth. By using the properties of metamaterial, we can easily overcome the drawbacks of RMPA alone. This reduction of return loss indicates that only small amount of reflection waves were returned back to the source and most of the power will be radiated from the patch. The reduction of return loss ultimately improves gain of patch antenna which becomes patch antenna more directive.

## Acknowledgement

The authors wish to thank their parents for their constant motivation without which this work would have never been completed. The authors are grateful to the Dr. GhanshyamSingh,Director MPCT Gwalior for providing us lab facilities to complete this project work. We also express our gratitude towards Prof. PankajShrivastava HOD Dept. of Elex. & comm. MPCT and Prof.Pankaj Singh Tomar,Asst. Professor Dept. of Elex. & Comm., MPCT for their continued support and guidance.

## References

**Balanis**, “Antenna Theory, Analysis and De-sign,” John Wiley & Sons, New York, 1997.

**R. Garg**, P. Bhartia, I. Bahl, and A. Ittipi boon, “Mi-crostrip Antenna Design Hand book Antennas,” John Wiley & Sons, 1997.

**Pozar**, D.M. and D.H.Schaubert, MicrostripAnten-nas: The Analysis and Design of Microstrip Antennas and Arrays, New York: IEEE Press, 1995.

**W.L. Stutzman**, G.A. Thiele, Antenna Theory and design, John Wiley & Sons, 2nd Ed., New York, 1998.

**MerihPalandoke**n, Andre Grede, And Heino Henke, “Broadband Microstrip Antenna With Left-Handed Metama-terials,” IEEE Transactions on Antennas And Propagation, Vol. 57, No. 2, February 2009.

**S. Satthamsakul**, N. Anantrasirichai, C. Benjangka prasert and T. Wakabayashi, “Rectangular Patch An-tenna with Inset Feed and Modified Ground-Plane for Wideband Antenna,” SICE Annual Conference 2008 August 20-22, 2008, The University Electro-Communications, Japan.

**The** Basics of Patch Antennas By D. Orban and G.J.K. MoernautOrban Microwave Products 2009.