Design and Analysis of Rectangular Microstrip Patch Antenna using Metamaterial for Wimax Application at 3.5GHz

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Abstract—This present paper show Design and analysis of patch antenna using metamaterial (MTM) structure is proposed for WIMAX application at 3.5 GHz. The proposed antenna is designed by SRR with thin wire loaded with Rectangular microstrip patch antenna on FR-4(lossy) substrate at 50 Ω matching impedance and at 3.2 mm height from the ground plane by using CST MWS Software at operating frequency 3.5 GHz. This paper show comparison between Rectangular microstrip patch antenna alone and Rectangular microstrip patch loaded with meta-material with enhancement in bandwidth, Directivity and Return loss at same resonant frequency. The Bandwidth increase 393.1MHz as compare to 79.1MHz of Rectangular microstrip patch antenna and Return loss reduce to -33.943189 dB compare to RMPA alone.

Keywords— Rectangular Microstrip Patch Antenna (RMPA), Left Handed Metematerials, Return Loss, Directivity, Impedance Bandwidth.

I. INTRODUCTION

In modern wireless communication systems, the microstrip patch antennas are commonly used in the wireless devices. Therefore, the miniaturization of the patch antenna has become an important issue in reducing the volume of entire communication system. The common method for reducing the microstrip patch antenna size is to utilize a high permittivity dielectric substrate. But, the antennas are more expensive, less radiation efficiency, and have narrow bandwidth. To overcome the above drawbacks, many design techniques of the patch antenna have already been proposed. WIMAX has more efficient application at 3.5GHz. In this application it has low cost, wider bandwidth and lower size. Application of a conventional antenna always limited since they are governed by the 'right hand rule' which determine how electromagnetic wave should behave. However, a metamaterial substrate offers an alternative solution to wider antenna applications using the 'left hand rule' [3]. Metamaterials are composite materials with unique electromagnetic properties due to the interaction of electromagnetic waves with the finest scale periodicity of conventional materials [4]. The important parameters of any type antenna are impedance bandwidth and return loss. The impedance bandwidth depends on parameters related to the patch antenna element itself and feed used.

II. DESIGN SPECIFICATIONS

The RMPA parameters are calculated from the following formulas. Desired Parametric Analysis "[9-10]"

2.1 Calculation of Width (W)-

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

Where

C = free space velocity of light

ε_r = Dielectric constant of substrate

2.2 The effective dielectric constant of the rectangular microstrip patch antenna

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

2.3 Actual length of the patch

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

2.4 Calculation of length extension

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

III. Analysis of Patch Antenna and Metamaterial Structure with Simulated Results

The Rectangular Microstrip Patch Antenna is designed on FR-4(lossy) substrate at 50 Ω matching impedance, dielectric constant=4.3 and height from the ground plane d=1.6mm.The parameter of rectangular microstrip patch antenna are L= 21.9mm, W= 41.9mm, Cut Width= 5mm, Cut Depth= 10mm, length of transmission line feed= 26.3mm, with width of the feed= 3.009mm shown in figure1. The simple RMPA is inspired by metamaterial structure at 3.5GHz.

Table-1 Rectangular Microstrip Patch Antenna parameter

Parameter	Value	Unit
thickness of substrate h	1.6	Mm
Fi	10	Mm
Gpf	1	Mm
Lf	20.58	Mm
length of substrate	21.9	Mm
Mt	0.1	Mm
W	41.9	Mm
Wf	3.009	Mm

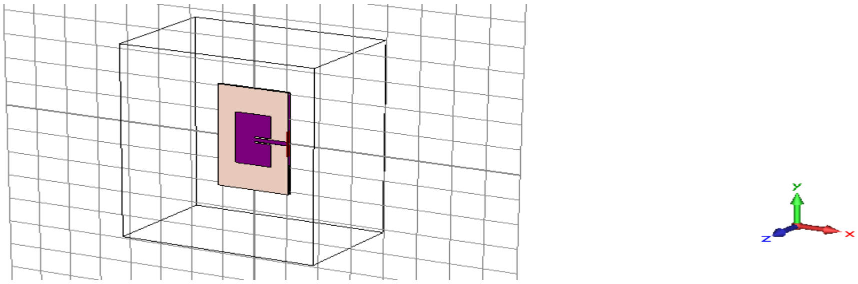


Figure 1. Design of Rectangular microstrip patch antenna

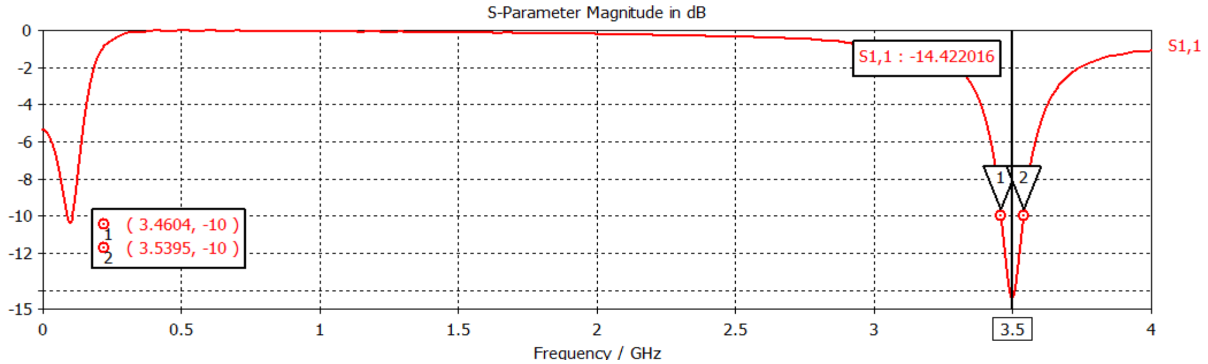


Figure 2. S-Parameter Magnitude of Rectangular microstrip patch antenna at 3.5GHz.

The bandwidth of simple RMPA is 79.1MHz and Returnloss is -14.422016dB.

Table-2 Metamaterial specification

Parameter	Value	Unit
thickness of substrate	1.6	Mm
length of ring1	36	Mm
length of ring3	32	Mm
length of ring4	28	Mm
length of substrate	19.66	Mm
length of wire	5	Mm
gap1	30	Mm
length of ring2	34	Mm
split wid	1	Mm
width of ring	3	Mm
width of ring4	18	Mm
gap2	6	Mm
gap3	6	Mm

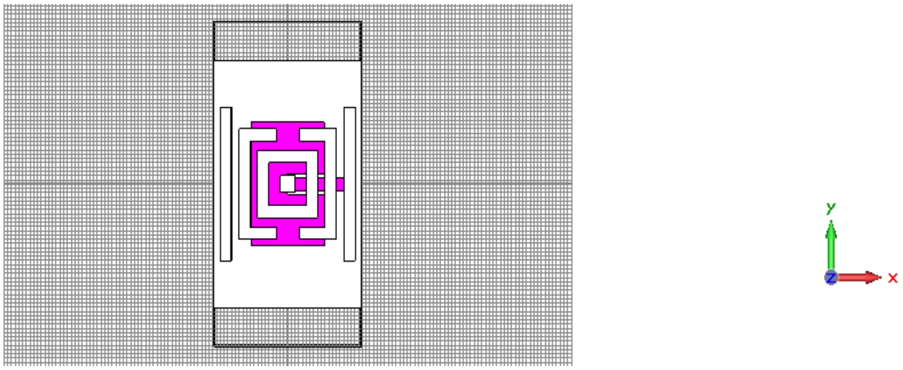


Figure 3. Design of proposed Metamaterial structure at the height of 1.6 mm from ground plane.

In this metamaterial design, a split RMPA is design on substrate with 3 mm width. This design gives the better improvement in impedance bandwidth and reduction in return loss.

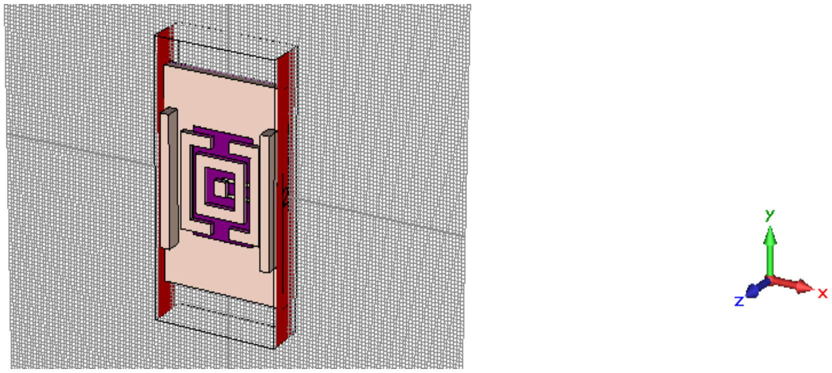


Figure 4. Rectangular microstrip patch antenna with proposed Metamaterial structure between two waveguide plane**.**

Simulation result of Return loss and bandwidth of Rectangular microstrip patch antenna loaded with metamaterial structure is shown in Fig 5. The proposed meta-material structure reduces the return loss by -33.943189dB and increases the bandwidth up to 393.1MHz.

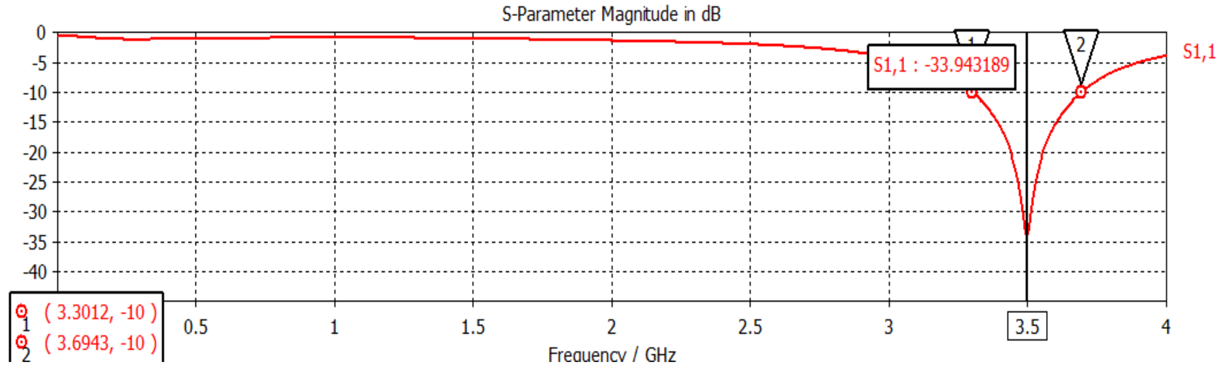


Figure5. Simulation of Return loss and impedance band width of RMPA with proposed Metematerial structure at operating frequency .

The maximum power deliver to rectangular microstrip patch antenna is 0 .96387579watt . As compared to RMPA alone, maximum power deliver to proposed antenna is increased up to 0.99959665watt.

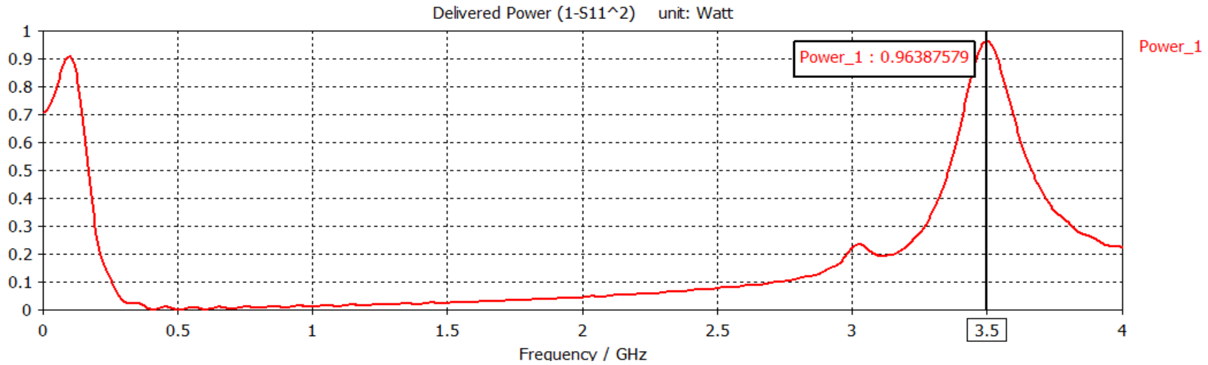


Figure6. Delivered power to reduced size RMPA is showing above 0.96387579 watt.

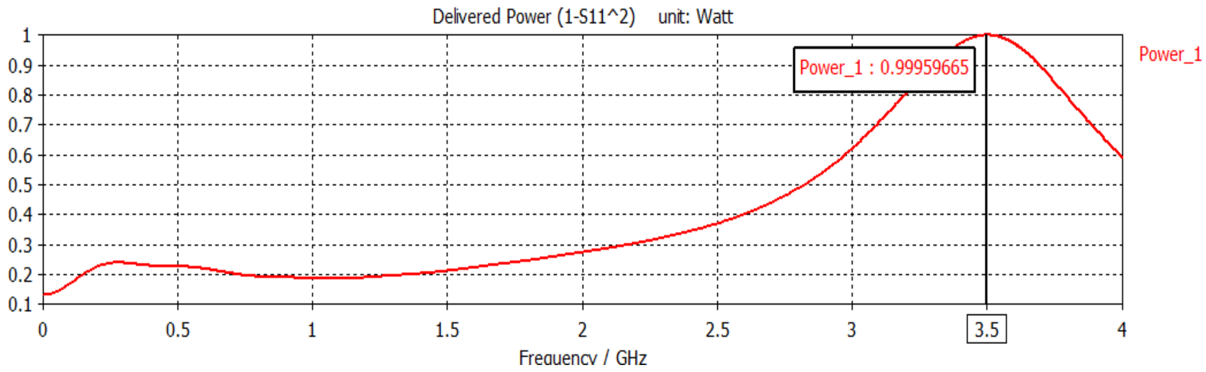
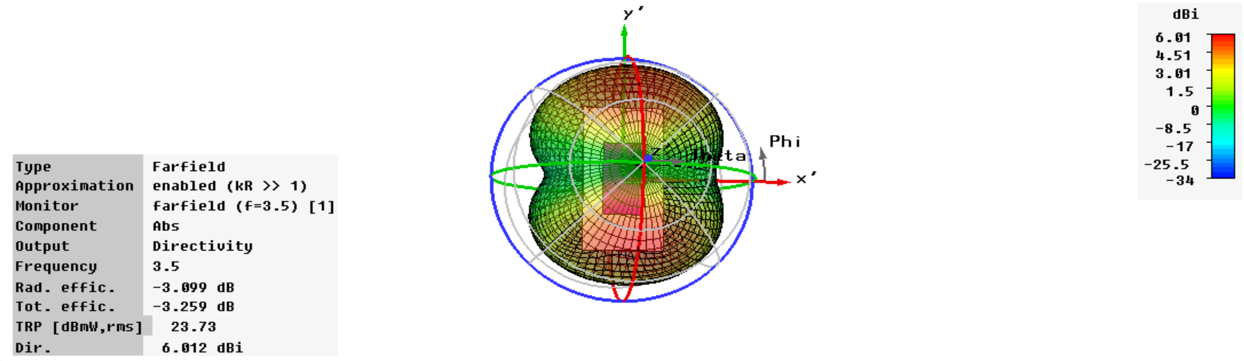
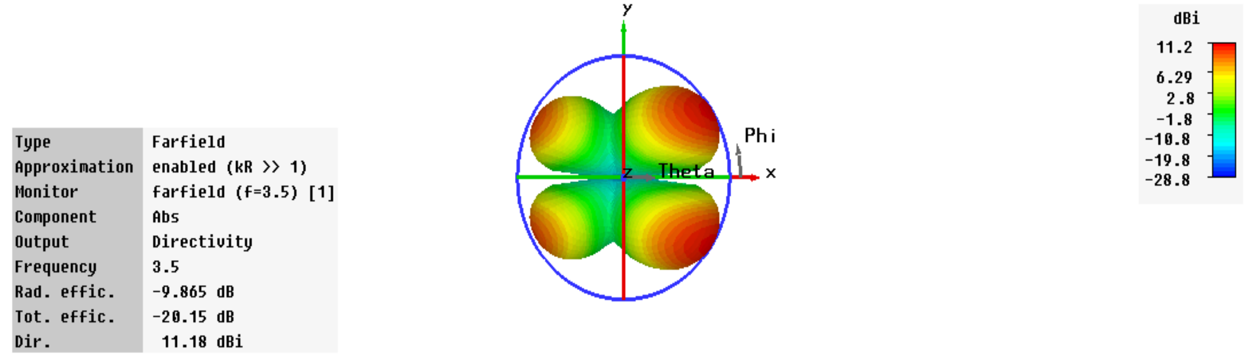


Figure7. Delivered power to reduced size RMPA loaded with Metamaterial structure.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=3.5) [1]
Component	Abs
Output	Directivity
Frequency	3.5
Rad. effic.	-3.099 dB
Tot. effic.	-3.259 dB
TRP [dBmW,rms]	23.73
Dir.	6.012 dBi

Figure 8. Radiation pattern of RMPA at 3.5 GHz showing directivity of 6.012dBi.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=3.5) [1]
Component	Abs
Output	Directivity
Frequency	3.5
Rad. effic.	-9.865 dB
Tot. effic.	-20.15 dB
Dir.	11.18 dBi

Figure9. Radiation pattern of proposed antenna showing Directivity.

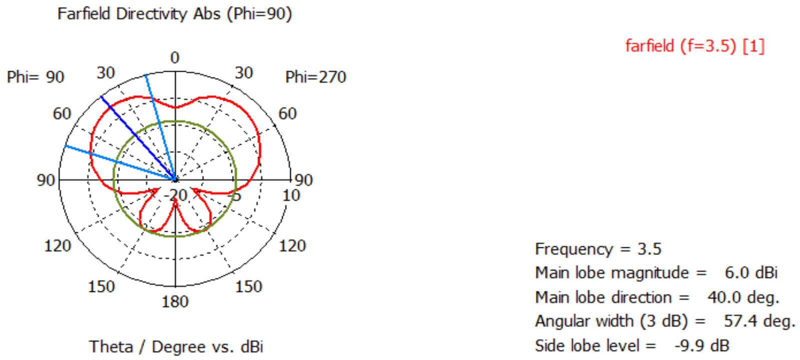


Figure 10. Directivity of RMPA alone (polar view).

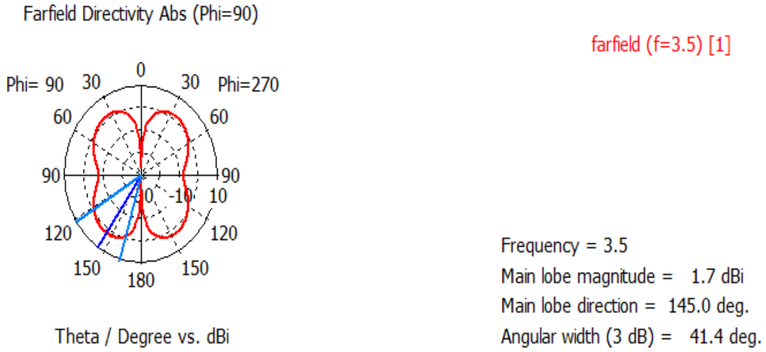


Figure11. Directivity of RMPA loaded with Metamaterial (polar view).

w

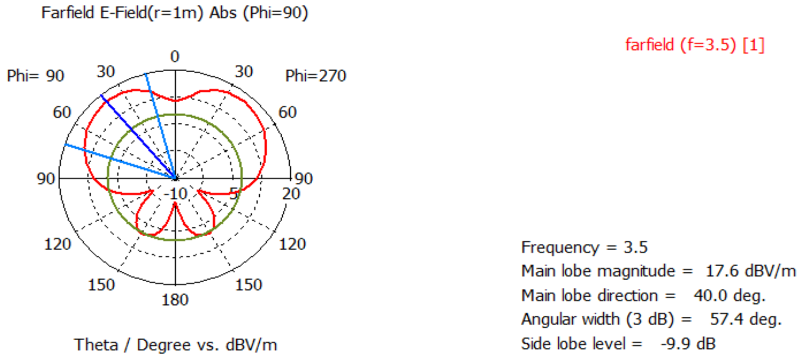


Figure12. E-Field pattern of RMPA alone.

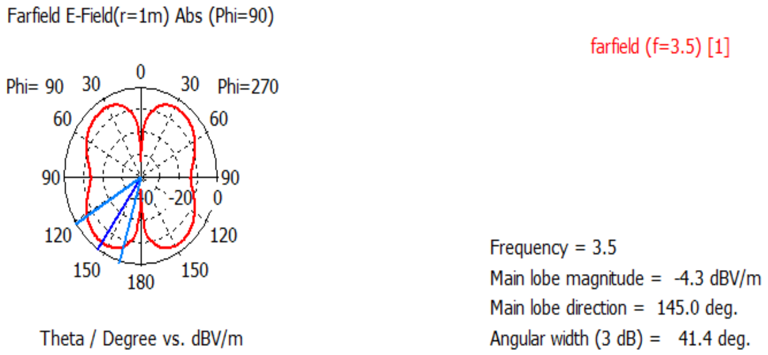


Figure13. E-Field pattern of RMPA loaded with Metamaterial.

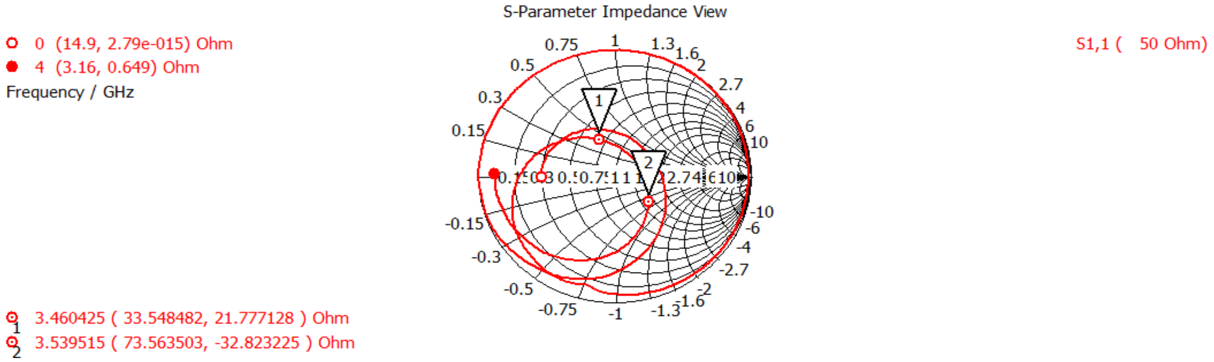


Figure 14. Smith chart of simple Rectangular microstrip patch Antenna.

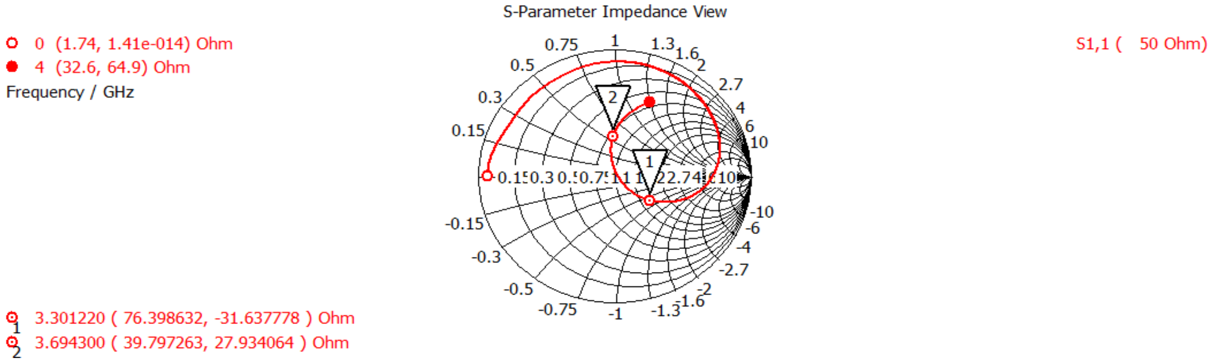


Figure15. Smirth chart of RMPA loaded with Metamaterial.

The Smith chart plot represents that how the antenna impedance varies with frequency which is normalized at 50 ohm for perfect matching.

2.5 Nicolson-Ross-Weir Metho (NRW)-

One methodology that makes use of the scattering parameters S11 and S21 to calculate the mentioned complex parameters of samples is named Nicolson-Ross-Weir (NRW) (Nicolson and Ross, 1970; Weir, 1974). The NRW modelling is the most common used method to perform the calculation of complex permittivity and permeability of materials. The obtained S- parameters are then exported to Microsoft Excel Software for calculating the value of the

Permittivity and permeability of the proposed design, using the Nicolson-Ross-Weir (NRW) approach. The proposed structure is placed between the two waveguide ports [12][13] at the left & right of the X-Axis in order to calculate the S11 and S21 parameters so as to prove that The proposed structure possesses Double Negative Metamaterial properties. In figure Y-Plane was defined as Perfect Electric Boundary (PEB) and Z-Plane was defined as the Perfect Magnetic Boundary (PMB). Subsequently, the wave was excited from the negative X-axis (Port 1) towards the positive X-axis (Port 2) Equations used for Calculating Permittivity & Permeability using Modified NRW Approach [6]-[8].

$$\mu_r = \frac{2.c(1 - v2)}{\omega.d.i(1 + v2)}$$

$$\varepsilon_r = \mu_r + \frac{2.s11.c.i}{\omega.d}$$

Where
V2 = S21 - S11
d = Thickness of the Substrate
ω= Freaquency in radian
i = imaginary coefficient
c = Speed of Light
V2 = Voltage Minima

IV. SIMULATION RESULTS

In this paper, Rectangular microstrip patch antenna loaded metamaterial structure is found that the potential Parameter of the proposed antenna is increased. This design is operated at 3.5GHz. At 3.5GHz, the bandwidths are increased up to 393.1MHz in comparison to 79.1MHz of RMPA alone. The Return loss of proposed antenna are reduced by -33.943189dB at dual band frequency as comparison to -14.422016dB of RMPA alone. The directivity of proposed antenna is 11.18dBi as comparison to directivity of RMPA alone is 6.012dBi. The maximum power deliver to proposed rectangular microstrip patch antenna is 0.99959665watt.

V. CONCLUSION

I have shown that left handed Metamaterial improves the bandwidth as well as reduces return loss of this Patch Antenna. The proposed antenna provide the better improvement in the impedance bandwidth and reduction in the return loss at 3.5GHz. The drawback of Patch Antenna was impedance bandwidth. For this purpose, Rectangular microstrip patch antenna loaded with metamaterial structure has been proposed for improving the bandwidth by using CST MICROWAVE STUDIO. in this paper Rectangular microstrip patch antenna loaded metamaterial structure is suitable for wimax application at 3.5GHz in wireless communication.

ACKNOWLEDGEMENT

The auther wish to thank their parents for their constant motivation without which this work would have never been completed. I express my gratitude towards Dr. Santosh Meena Asst. Professor, Gweca, Ajmer.

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