International Journal of Engineering and Technology, 1 (3) (2012) 271-280
©Science Publishing Corporation
www.sciencepubco.com/index.php/IJET

Improvement in Parameters of Patch Antenna By Using "Hybrid Shaped" Metamaterial Structure

Bimal Garg, Himanshu Shrivastava, Prem Kumar

Department of Electronics Engineering, Madhav Institute of Technology and Science, Gwalior-474005, India
E-mail: bimalgarg@yahoo.com, shrivastavahimanshu@gmail.com, premakrati@gmail.com

Abstract

In this work, a Rectangular microstrip patch antenna loaded with "Hybrid shaped" metamaterial structure is designed at a height 3.2 mm from the ground plane by using CST-MWS software. The resonance frequency of the designed antenna is 2.1GHz.The 10 dB impedance bandwidth of proposed antenna is 31.10 MHz. The Return loss of the proposed antenna is reduced by 35 dB .This antenna is small size, cheap, compact and easy to fabricate, and achieve good radiation characteristics with higher return loss. This antenna can have wide application in a great variety of wireless communication.Double-Negative properties of the proposed metamaterial structure have also been verified by using Nicolson-Ross-Weir Method (NRW).

Keywords: *Rectangular Microstrip Patch Antenna, Metamaterials, Bandwidth, Return Loss, NRW.*

1 Introduction

In high-performance aircraft, spacecraft, satellite and missile applications, where size, weight, cost, performance, ease of installation, low profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications. To meet these requirements microstrip antenna can be used. These antennas are low profile, conformal to planar and non-planar Surfaces, simple and inexpensive to manufacturer using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with Monolithic Microwave Integrated Circuit (MMIC) designs.

The introduction of the so-called metamaterials [1] (MTMs), artificial materials which have engineered electromagnetic responses that are not readily available in nature, has provided an alternate design approach to obtain efficient electrically-small antenna (EESA)systems.

2 Design and Simulated Results of Rmpa and Proposed Antenna.

The Rectangular microstrip patch antenna parameters are calculated from the formulas given below [2-3].

Calculation of Width (W):

$$\mathrm{w} = \frac{1}{2\mathrm{f_r}\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{\mathrm{C}}{2\mathrm{f_r}}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

Where,

c = free space velocity of light

ε_r = Dielectric constant of substrate

Effective dielectric constant is calculated from**:**

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

The actual length of the Patch (L)

$$\mathrm{L} = \mathrm{L_{eff}} - 2\Delta\mathrm{L} \tag{3}$$

Where

$$\mathrm{Leff} = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}}$$

Calculation of Length Extension

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

The parameters of rectangular microstrip patch antenna are specified in the Table1 and dimensional view is shown in figure 1.

Table 1: rectangular microstrippatch antenna specifications

	Dimensions	Unit
Dielectric Constant (ϵr)	4.3	-
Loss Tangent (tan ∂)	0.02	-
Thickness (h)	1.6	Mm
Operating Frequency	2.1	GHz
Length (L)	34.11386	Mm
Width (W)	43.87822	Mm
Cut Width	7.4	Mm
Cut Depth	10	Mm
Path Length	38.99604	Mm
Width Of Feed	6.00	Mm

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

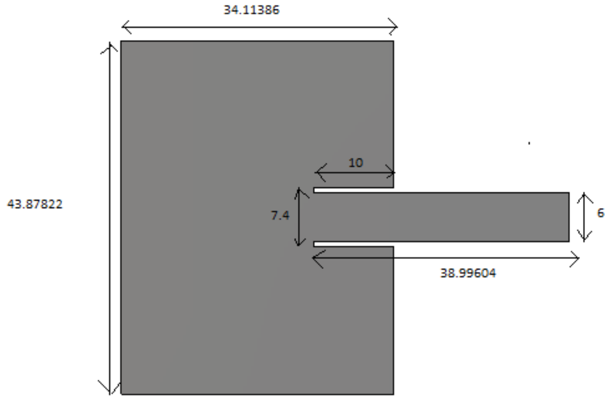


Figure 1: Rectangular patch antenna designed at 2.1GHz (All dimensions in mm).

The Simulated Results of Rectangular microstrip patch antenna is shown in figure 2 and 3.The CST-MWS (computer simulation Technology) was chosen to simulate the structures shown in the figures below.

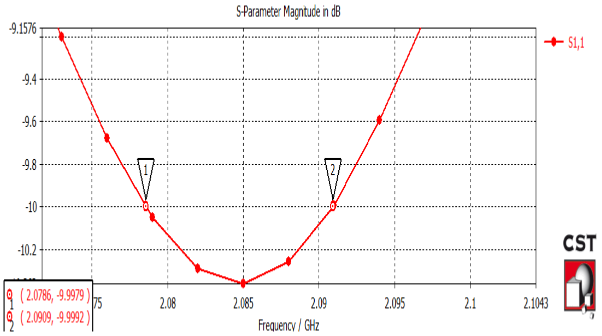
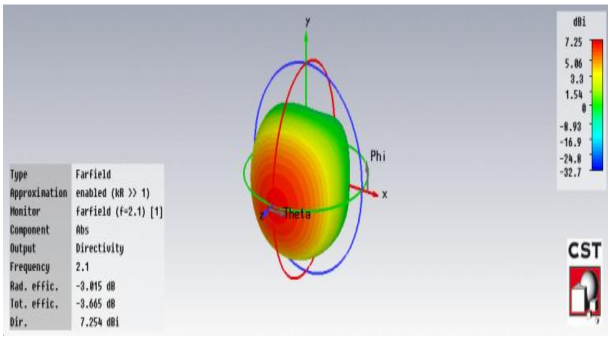


Figure 2: Simulated Result of Rectangular microstrip patch antenna showing return loss of -10.5 dB and 12.3 MHz Bandwidth.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2.1) [1]
Component	Abs
Output	Directivity
Frequency	2.1
Rad. effic.	-3.015 dB
Tot. effic.	-3.665 dB
Dir.	7.254 dBi

Figure 3: Radiation Pattern of Rectangular microstrip patch antenna.

Nicolson-Ross-Weir Method (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 modeling 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 [11][13-14] at thetop & bottom of Y-Axis (shown in figure 8) in order to calculate the S11 and S21 parameters so as to prove that the proposed structure possesses Double Negative metamaterial properties. In figure 4, X-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 Y-axis (Port 1) towards the positive Y-axis (Port 2).

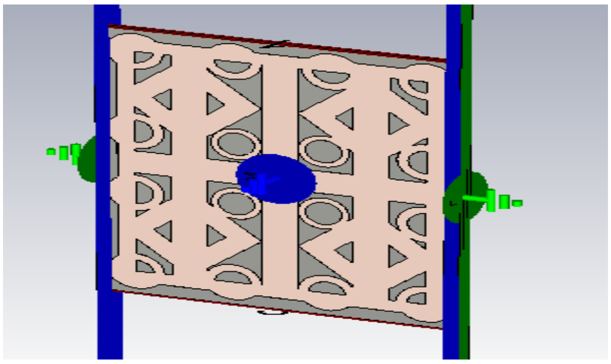


Figure 4: Proposed metamaterial Structure placed between the two Waveguide Ports at the top & bottom of Y axis.

NRW Method:

Equations used for calculating permittivity & permeability using NRW approach[9][10][13]:-

$$\mu_r = \frac{2.c(1-v2)}{\omega.d.i(1+v2)} \tag{5}$$

$$\varepsilon_r = \mu_r + \frac{2.S11.c.i}{\omega.d} \tag{6}$$

Where,

$$v2 = \text{S21 - S11} \tag{7}$$

ω = Frequency in Radian,
d = Thickness of the Substrate,
c = Speed of Light,
$v2$ = Voltage Minima

Figure 5 & 6 shows the negative value of permittivity and permeability [4-5] [15-16] obtained from the equation 5 & 6 at the designed frequency.

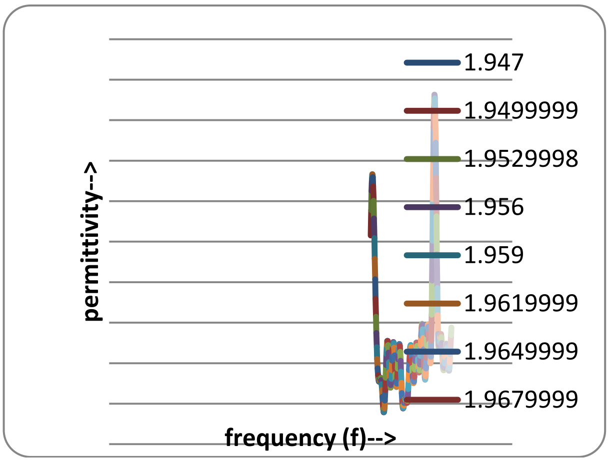


Figure 5: Permittivity versus Frequency Graph obtained from Microsoft Excel Software.

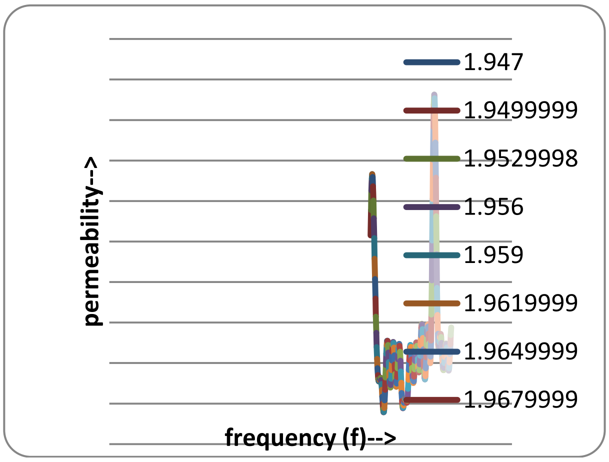


Figure 6: Permeability versus Frequency Graph obtained from Microsoft Excel Software.

Then, the “Hybrid Shaped” metamaterial structure is placed above the patch antenna at a height of 3.2 mm from ground plane in order to study its influence, and the results are compared with those of the Patch antenna alone. The required specifications of this design are shown in the figure7.

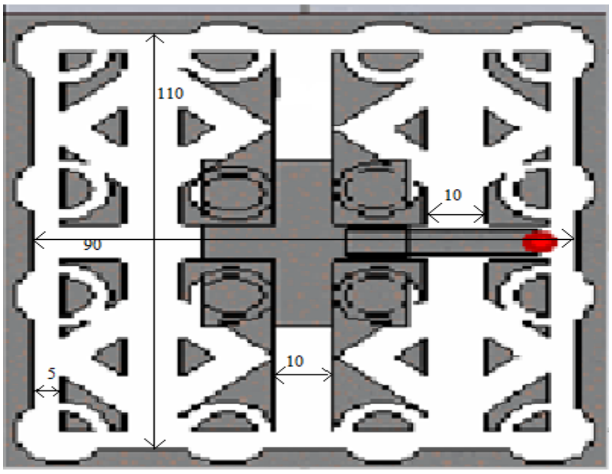


Figure 7:Rectangular microstrip patch antenna loaded with “Hybrid Shaped” metamaterial Structure (All dimensions in mm).

3 Result

A Research on [7-8]metamaterial was carried out to understand the fundamentals of the newly discovered substance. The simulated result of rectangular microstrip patch antenna with “Hybrid Shaped” structure is shown in figure 8. At 2.1 GHz frequency the simulated rectangularmicrostrip patch antenna results in Return Loss of -10.5dB& 12.1MHz Bandwidthwhilewhen it is designed with “Hybrid Shaped” metamaterial structure at 3.2mm from the ground plane, it shows Return Loss of -45 dB& 31.10MHzBandwidth which shows significant improvement of bandwidth [17] and reduction in return loss.The Return Loss of the proposed metamaterial structure is reduced by 35dB [9-10] [12] in comparison to the RMPA alone.The response of the proposed metamaterial when tested with the help of spectrum analyzer shows the return loss of -42db &29.5 Mhz band width which is slightly less than the simulated response due to the practical conditions & limitations

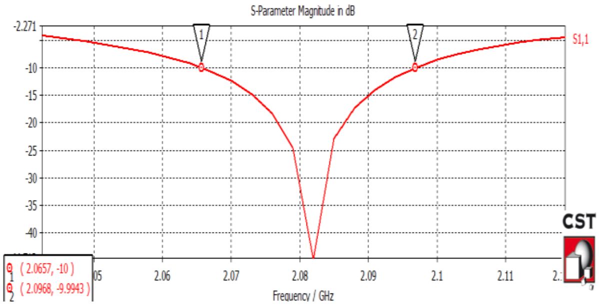
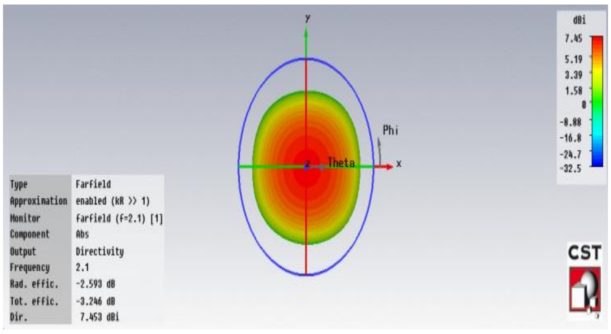


Figure 8: Simulated Return Loss of Rectangular microstrip patch antenna loaded With “Hybrid Shaped” metamaterial Structure.



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=2.1) [1]
Component	Abs
Output	Directivity
Frequency	2.1
Rad. effic.	-2.593 dB
Tot. effic.	-3.246 dB
Dir.	7.453 dBi

Figure 9: Radiation Pattern of Rectangular microstrip patch Antenna along With “Hybrid Shaped” metamaterial Structure.

Smith Charts[6] shown in figure 10 represents the impedance matching of antenna with coaxial cable of 50 ohm.

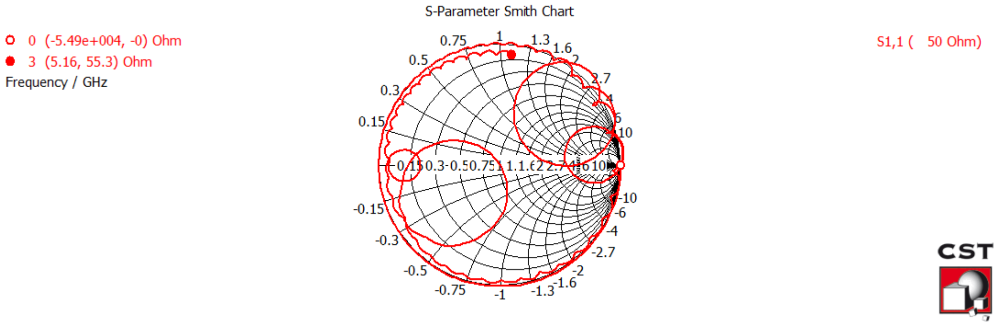


Figure 10: Smith Chart of Rectangular microstrip patch antenna loaded with "Hybrid Shaped" metamaterial Structure.

Testing With Spectrum Analyzer:

Testing of RMPA alone is shown in figure 12

Figure 11: Rectangular patch antenna designed at 2.1 GHz

Figure 12: Rectangular patch antenna designed at 2.1 GHztested with spectrum analyzer

Figure 13:Rectangular microstrip patch antenna loaded with “Hybrid Shaped” metamaterial Structure.

4 Conclusion

The “Hybrid Shapes” metamaterial structure with Rectangular antenna has been proposed in this paper. The simulated results provide high gain, wide bandwidth and directivity improvement, and increase total efficiency which encourages fabricating the structure. On making some variations in antenna parameter gain can be improved up to desired limit but some practical limitation should be taken care while fabricating the structure on CST-MWS software.

References

[1] V.G. Veselago “The electrodynamics of substances with simultaneously negative value ε and μ” Sov. Phys. Uspekekhy.10 (4), 509-514,1968.

[2] Constantine A.Balanis, Antenna Theory and Design.John Wiley & Sons, Inc., 1997.

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

[4] D.R. Smith, W.J. Padilla, D.C. Vier, et al, Composite medium with simultaneously negative permeability and permittivity, Phys Rev Lett 84, 4184–4187,May 2000.

[5] J.B. Pendry, Negative refraction males a prefect lens, Phys Rev Lett, 85 , 3966–396,2000.

[6] David M. Pozar, “Microwave Engineering”, 3rd Edition, John Wiley & Sons, 2004.

[7] NadarEngheta, Richard W. Ziolkowski, “Metamaterial Physics & Engineering Explorations”.

[8] Huda A. Mazid, Mohammad Kamal A. Rahim, ThelasaMasri, “Left-handed metamaterial design for microstrip antenna application”, IEEE International RF and Microwave conference, 2008.

[9] Wu, B-I, W. Wang, J. Pacheco, X. Chen, T. Grzegorczyk, and J.A. Kong, “A study of using metamaterials as antenna substrate to enhance gain,” Progress in Electromagnetic Research, PIER 51, 295-328, 2005.

[10] H.A. Majid, M.K.A. Rahim and T. Marsi, Microstrip Antenna gain enhancement using left-handed metamaterial structure, progress in Electromagnetic Research M. Vol.8, 235-247, 2009.
[11] BimalGarg, NitinAgrawal, Vijay Sharma, “Size Reduction of Rectangular Microstrip Patch Antenna Incorporated with “INTERCONNECTED FRAMED SHAPED” Metamaterial Structure for WLAN Applications”, International Conference on SCEECS 2012, MANIT Bhopal, 1-2 March 2012.
[12] BimalGarg, Vijay Sharma, NitinAgrawal, “Enhancement of Gain and Directivity of Rectangular Resonant Microstrip Patch Antenna Loaded with “SYMMETRIC W” shaped Double Negative Left-Handed inspired metamaterial”, National Conference on Recent Advances in Microwave Engineering, 2011.
[13] Silvio Hrabar, JurajBartolic, “Backward Wave Propagation in Waveguide Filled with Negative Permeability Meta Material”, 2003.
[14] Silvio Hrabar, GordanJankovic, BerislavZickovic, ZvonimirSipus, “Numerical and Experimental Investigation of Field Distribution in Waveguide Filled with Anisotropic Single Negative Metamaterial”, 2005.
[15] Richard R. Ziolkowski, Double Negative Metamaterial Design, Experiments and Applications, IEEE Transactions on Microwave Theory and Techniques, Vol.51, No. 7, July 2003.
[16] R. C. Hansen and M. Burke, "Antenna with magneto-dielectrics," Microwave Opt. Technol. Lett.,Vol. 26, No. 2, pp. 75-78, 2000.
[17] A. D. Yaghjian and S. R. Best, "Impedance, Bandwidth, and Q of Antennas," IEEE Trans. onAntennas and Propagati'on, Vol. 53, No. 4, pp. 1298 1324, 2005.
[18] M. E. Ermutlu, C. R. Simovski, M. K. Kdirkkdiinen, P. Ikonen, S. A. Tretyakov and A. A. Sochava,"Miniaturization of patch antennas with new artificial magnetic layers," 2005 IEEE Int. Workshop onAntenna Technology, Singapore, March 7-9, pp. 87 90, 2005.
[19] P. Ikonen, K. N. Rozanov, A. V. Osipov and S. A. Tretyakov "Magneto-Dielectric Substrates in Antenna Miniaturization: Potential and Limitations", IEEE Trans. on Antennas aridPropagation, Vol. 54,No. 11, pp. 3391 3399, 2006.