International Journal Of Advance Research, Ideas And Innovations In Technology

ISSN: 2454-132X
Impact factor: 4.295
(Volume 5, Issue 1)
Available online at: www.ijariit.com

Design and analysis of low profile meta-material based MSPA

Prashant Sharma
prashant_0927@yahoo.com
Rustamji Institute of Technology, Gwalior, Madhya Pradesh

Devendra Kumar
dkraghav9@yahoo.co.in
Rustamji Institute of Technology, Gwalior, Madhya Pradesh

ABSTRACT

This paper proposes a new generation of antenna that applies metamaterial properties for enhancement of bandwidth. The performance of Microstrip Patch Antenna with and without using the Metamaterial structure has been analyzed. The hexagonal shaped, interconnected, symmetrical meta-material structure between horizontal lines is proposed for enhancement of bandwidth and reduction in the return loss at the operating frequency of 1.70 GHz. The bandwidth and return loss has been improved drastically by using meta-material structure.

Keywords— *Rectangular microstrip patch antenna (RMPA), Metamaterial (MTM) Impedance bandwidth, Return loss*

1. INTRODUCTION

In Microstrip patch antenna when the source signal is applied at the patch, the EM waves will be radiated. The dielectric constant of substrate usually varies in the range of 2.2 to 12. Metamaterials (MTMs) denote artificially constructed materials having electromagnetic properties not generally found in nature. Examples include photonic band gap structures [1,2] and double negative (DNG) media [3,4,5] i.e. MTMs having a negative permittivity and negative permeability. Pendry [4] has proposed the possibility that a DNG medium with a negative index of refraction might overcome known problems with common lenses to achieve a “perfect” lens, which would focus the entire spectrum, both the propagating as well as the evanescent spectra. Pendry’s analysis followed much of the original work of Veselago [3]. The substrate height & the dielectric constant of the substrate are a very important factor that influences the variation of various parameters of the antenna. The metamaterial structure reduces return loss and increases bandwidth [6,7].

2. ANTENNA DESIGN

In this paper, we propose a rectangular microstrip patch antenna with an FR4 substrate of height 1.6 mm and a dielectric constant of 4.3. The dimensions are calculated for 1.7 GHz frequency and shown in table1. Metamaterial structure with the double negative property as shown in figure 3 is placed at a height of 3.2 mm with the ground plane. The complete antenna with a meta-material structure is shown in figure 4.

Formula used for designing of RMPA: [8]

Calculation of Width (W)

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

Where,
c = free space velocity of light
ε_r = Dielectric constant of the substrate

The effective dielectric constant of the RMPA

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

The actual length of the Patch (L)

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

Where,

$$\mathrm{Leff} = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4)$$

Calculation of Length Extension

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

Table 1: RMPA Specification

Parameter	Dimension	Unit
Dielectric Constant	4.3	-
Loss Tangent	0.02	-
Thickness	1.6	mm
Operating Frequency	1.70	GHz
Length	39.88	mm
Width	51.18	mm
Cut Width	6	mm
Cut Depth	8	mm
Path Length	37.25	mm
Feed Width	4	mm

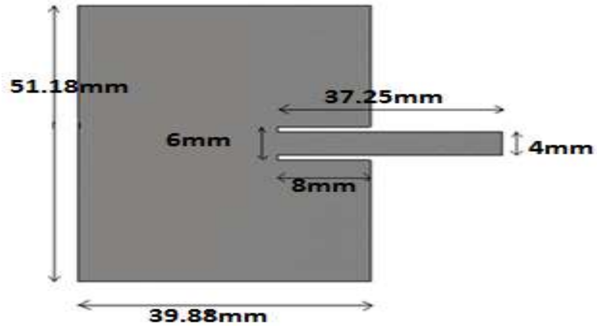

Fig. 1: Top view of RMPA at 1.70 GHz

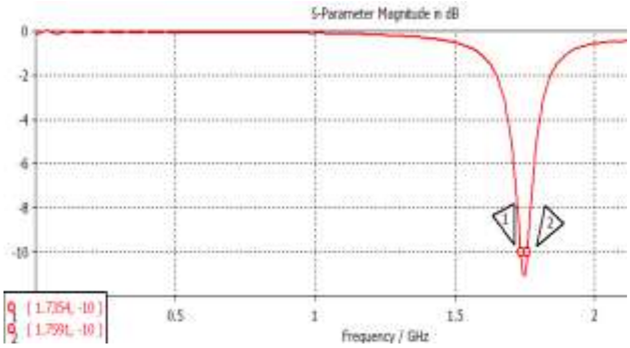

Fig. 2: Graph of return loss vs. frequency

3. DESIGN OF METAMATERIALS

In this Metamaterial design, symmetrical hexagonal shapes are interconnected with each other. The outer hexagonal shapes are having a cut horizontally with 2 mm width. This design gives a better improvement in impedance bandwidth and reduction in return loss.

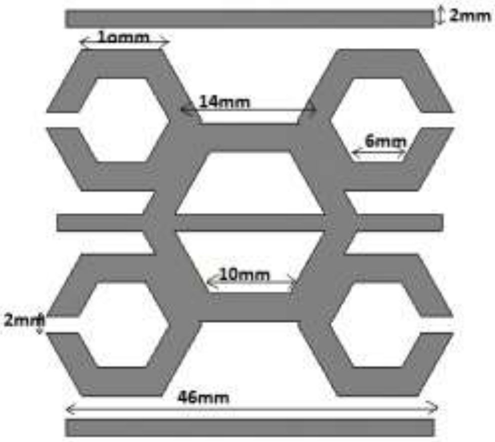

Fig. 3: Design of proposed meta-material structure at a height of 3.2 mm from a ground plane

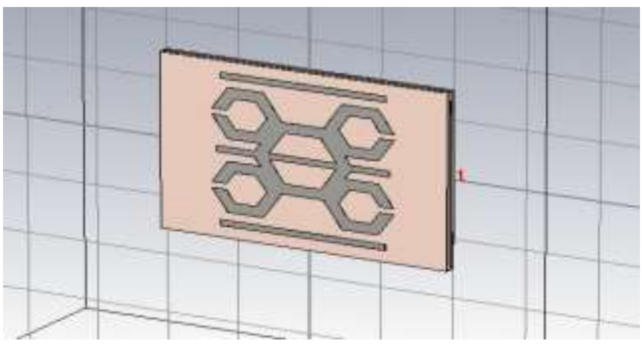

Fig. 4: Rectangular microstrip patch antenna with proposed metamaterial structure

4. RESULT AND ANALYSIS

Simulated result of return loss and bandwidth of rectangular Microstrip patch antenna without metamaterial is shown in figure 2. The return loss is -10 dB and bandwidth is 23.7 MHz. For the antenna loaded with metamaterial, the return loss and bandwidth are -26 dB and 69.6 MHz respectively.

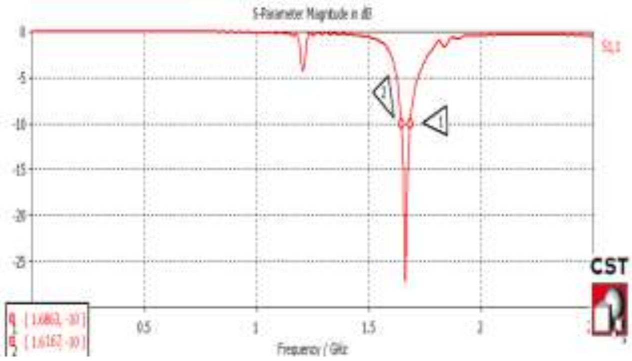

Fig. 5: Graph of return loss vs. frequency with Meta-material structure

Table 2: Comparison of designed antenna

Parameter	Without Metamaterial	With Metamaterial
Bandwidth	23.7 MHz	69.6 MHz
Return loss	-10 dB	-25 dB
Directivity	5.977 dB	6.918 dB
Gain	2.51 dB	4.651 dB
Frequency	1.70 GHz	1.70GHz

5. CONCLUSION

The purpose of the work is to design a small size, low profile and low-cost antenna, which can be used for wideband communication applications. The paper also analyzed the performance of Microstrip Patch Antenna with and without using the metamaterial structure. The efficiency and bandwidth of the antenna have been improved considerably. This antenna is suitable for the use in advanced wireless devices.

6. REFERENCES

[1] Nader Engheta, Richard W. Ziolkowski, “Metamaterial Physics & Engineering Explorations”, Wiley-IEEE Press, June 2006

[2] Nader Engheta, Richard W. Ziolkowski, “Metamaterial Physics & Engineering Explorations”, Wiley-IEEE Press, June 2006.

[3] Y. P. Zhang and J. J. Wang, "Theory and analysis of differentially- driven Microstrip antennas, "Antennas and Propagation, IEEE Transactions, vol. 54, pp. 1092-1099, 2006.

[4] H.A. Majid, M.K.A. Rahim and T. Marsi, ―Microstrip Antenna gain enhancement using left-handed Meta material structure‖, progress in Electromagnetic Research M. Vol.8, 235-247, 2009.

[5] R. W. Ziolkowski, “Superluminal transmission of information through an electromagnetic metamaterial,” Phys. Rev. E, Stat. Phys. Plasmas Fluids Relat. Interdiscip. Top, vol. 63, no. 046604, 2001.

[6] Ahmad A. Sulaiman, Ahmad S. Nasaruddin, “Bandwidth Enhancement in patch antenna by metamaterial substrate”, European Journal of scientific research, 2010.

[7] A. D. Yaghjian and S. R. Best, "Impedance, Bandwidth, and Q of Antennas," IEEE Trans. on Antennas and Propagation, Vol. 53, No. 4, pp. 1298 1324, 2005.

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