International Journal of Research in Electronics
and Communication Technology (IJRECT 2014)
Vol. 1 Issue 1 Jan-March 2014
ISSN : 2348-9065 (Online)
ISSN : 2349-3143 (Print)

Performance Improvement of Microstrip Patch Antenna using Left-Handed Metamaterial

[I]Varsha Gupta, [II]Pooja Sahoo
[I,II]Dept. of Electronics, Madhav Institute of Technology & Science, Gwalior, India
[I]varshag472@gmail.com, [II]sahu.pooja2009@gmail.com

Abstract

In this paper, the design of a microstrip patch antenna with a metamaterial structure at 2GHz is proposed. The proposed antenna design is fabricated on FR4 substrate and the experimental results obtained are in good agreement with the simulated results.The influence of metamaterial designed on another layer characteristics of the conventional patch antenna along with a comparison of characteristics of the conventional patch antenna and the patch antenna with metamaterial is shown. By using the metamaterial the return loss of conventional patch antenna is increased from -12.0dB to -22.02dB. The antenna is simulated by using MOM based IE3D software. The simulated and experimental results are in good agreement.

Keywords

Left Handed Metamaterial (LHMTM), Negative permittivity, Negative permeability

I. Introduction

The microstrip antenna has attracted several academic as well as industry experts due to its several advantages like low profile, light weight, low cost antennas etc. But due to its disadvantages of narrow bandwidth, low gain, high loss etc it is not finding its applications in broadband applications. Several methods of improving the various antenna characteristics like bandwidth, gain, efficiency etc are available in the literature. Several patch antennas having wide bandwidth are also reported in the literature but their large size limited their applications.

The theoretical concept of metamaterials to increase the transmitting power was given by Victor Veselago (1968), Engheta and Ziolkowski (2006), Pendry (2000) Garg et al. An array of metallic wires can be used to obtain negative permittivity and split ring resonators for negative permeability (Pendry et al., (1999). By using the available information a structure composed of split ring resonator and thin wire fabricated by Smith et al. (2001) possessed the negative permittivity and permeability simultaneously. This structure was named as LHM (Wu et al., 2005) (Burokur et al., 2005).

Metamaterial is an artificial material that exhibits unique properties in electromagnetic spectrum unlike those of conventional materials available in nature [1]-[3]. The conventional material available in nature have positive magnetic permeability and almost positive dielectric permittivity, whereasmetamaterialexhibits negative permeability,µ and/or negative permittivity, ε. Due to these significant features metamaterial is also referred to as single negative(SNG) or double negative(DNG) material [1]-[4]. In metamaterial, the refractive index is negative i.e. the group and phase velocity of the electromagnetic wave appears in opposite direction. The reversed direction of propagation with respect to direction of energy flow leads to reversed Doppler shift. These materials are also referred to as negative index material (NIM) because the refractive index is negative hence both refracted and incident wave remains on same side [1-6].

The potential applications of metamaterials at microwave frequencies include (a) substrate materials for antenna and microwave component designs and fabrications, and (b) absorbers for engineering and radar applications. Split ring resonators (SRRs) [11] and some other planar structures [11-12] were applied to enhance the return loss.

II. Design Considerations

Initially a conventional patch antenna was designed at a resonance frequency of 2GHz on FR4 substrate with a dielectric constant of 4.4 and thickness 1.6mm by using the design equations(Balanis, 1997; Stutzman and Thiele, 1998) given as follows:

Calculation of Width (W)

$$W = \frac{1}{2f_r\sqrt{\epsilon_0\mu_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

Calculation of the effective dielectric constant(ϵ_{eff}) of the rectangular microstrip patch antenna

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\sqrt{\frac{1}{1+\frac{12h}{W}}}$$

Calculation of Length Extension(ΔL)

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

The effective length of the patch (L_{eff})

$$L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{eff}}}$$

The actual length of the Patch (L)

$$L = L_{eff} - 2\Delta L$$

The dimensions of conventional patch antenna obtained by using the above equations are listed in Table 1. The conventional patch antenna with the parameters obtained above is shown in Fig. 1.

Table 1: Dimensions of the Conventional Patch Antenna

Parameter	Value
Length of patch(L)	45.6mm
Width of patch(W)	35.44mm
Substrate Thickness(h)	1.6mm
Dielectric Constant(εr)	4.4
Cut Depth	5.5mm

After obtaining the results for conventional patch,a metamaterial structure is incorporated into the antenna design on another layer of FR4 substrate of thickness 1.6mm and at a height of 3.2mm from the ground.The basic structure of metamaterial used in the proposed antenna design is shown in Fig. 3.The geometry of the proposed antenna is shown Fig. 4. The simulation of the conventional patch antenna and proposed antenna design, MOM based IE3D software is used.

III. Results And Discussion

On simulating the conventional patch antenna a return loss of -12dB is obtained as shown in Fig. 2, whereas for the proposed antenna design is -22.02dB, shown in Fig. 5. The various characteristics like magnitude and phase of S11, Smith Chart,VSWRand Radiation Pattern obtained for proposed antenna design are shown in Fig. 8,9,10 and11 respectively.The comparison of simulated and experimental results is shown in Fig. 6.

IV. Conclusion

From the above analysis it can be concluded that the antenna characteristics can be improved by using the Metamaterial structure. This Design presents an planar metamaterial antenna structure. This antenna provides combination of metamaterial and normal patch antennaperformance with high return loss .The return loss of the structure can be increased up to - 5dB. The resonant frequency of the antenna structure is obtained by equivalent circuit which is in good agreement with obtained simulated results. This antenna can be operated as metamaterial or normalpatch antenna to get reconfigurability using micro-electromechanical switches.

References

[1] G. Veselago, *"The electrodynamics of substances with simultaneously negative electrical and magnetic properties", Sov. Physics USPEKHI, Vol.10, pp 509-517, 1968.*

[2] *J.B.Pendry, A.J.Holden, D.J.Robbins and W.J.Stewart, "Magnetism from conductors and enhanced nonlinear phenomenon", IEEE Transaction on Microwave Theory technology, Vol.47, pp. 2075-2084, Nov.1999.*

[3] *R. W. Ziokowiski, "Design, fabricationand testing of double negative metamaterials", IEEE Transactions on antennas and propagation, Vol, 51, No.7, pp 1516-1528, July 2003.*

[4] *D.R.Smith, D.C.Vier, Th.Koschny and C. M. Soakoulis, "Electromagnetic parameter retrieval from inhomogeneous metamaterial", Physical review, pp. 1-10, 2005.*

[5] *R.W.Ziolkowski and A. Erentok, "Metamaterial based efficient electrically small antenna", IEEE Transactions on antennas and propogation, Vol.54, No.7, pp.2113-2130, July2006.*

[6] *L. L. Wei and Y. H. W. Q, C. Zhining, "Broad-bandwith and low loss metamaterials: theory desing and realization", Journal of Zheijiang University Science A, 7(1), pp.5-23, 2006.*

[7] *Li,B.,Wu,B. and Liang C.H.(2006) study on high gain cicular Waveguide Array Antenna with metamaterial structure. Progress in Electromagnetics Research,PIER60207-219.*

[8] *J.B.Pendry,Negative refraction makes a perfectlens,Phys Rev Lett, (2000)3966-3969.*

[9] *Y.T.Lo.Theory and experiment on micro stripantennas, IEEE Trans Antennas Propag27 (1979); 137-145.*

[10] C.A.BALANIS *"Antenna Theory" analysis and design 2ndedition.*

[11] *D. M. Pozer and D.H. Schaubert, "Microstrip Antennas," Proc. IEEE, Vol. 80, pp.79-91.*

[12] *Huda A. Majid, Mohamad Kamal A. Rahim and ThelahaMasri, "Left Handed Metamaterial Design ForMicrostrip Antenna Application", IEEE InternationalRf and Microwave Conference Proceedings 2008.*

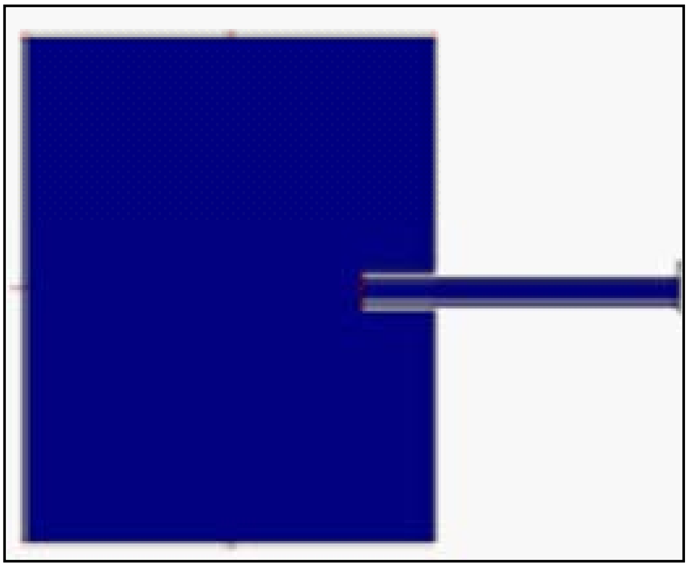


Fig.1: Conventional Patch Antenna

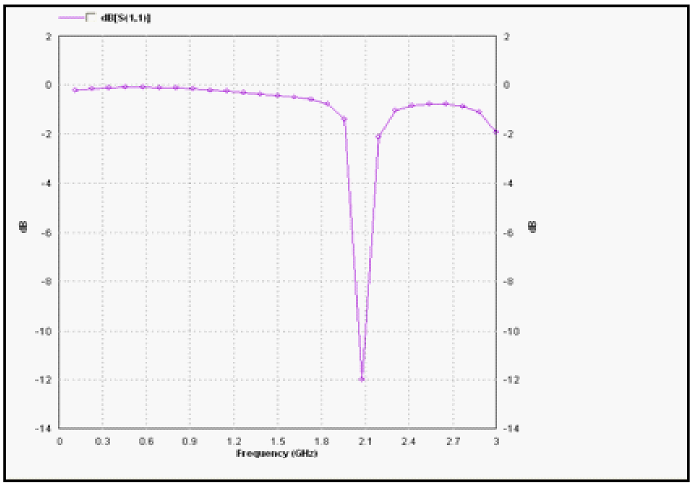


Fig. 2: Return loss versus frequency plot for conventional patch antenna

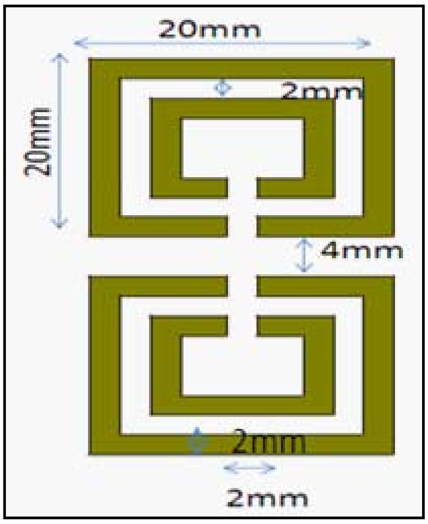


Fig.3: Basic structure of the rectangular SRR

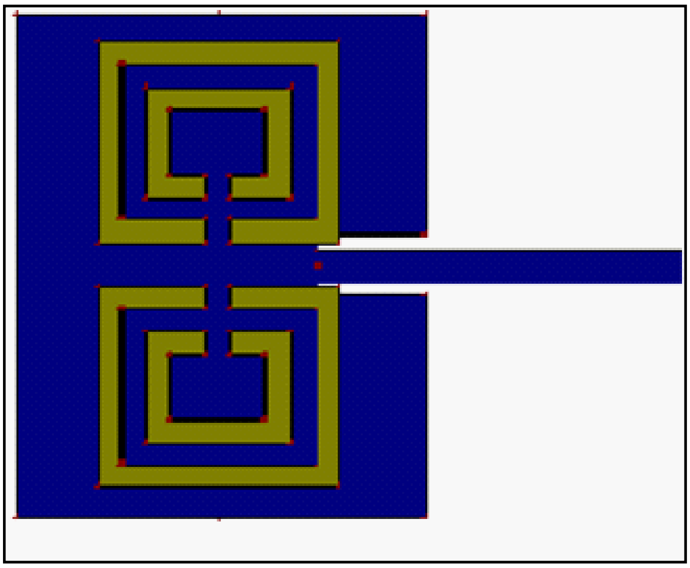


Fig.4 : Geometry of the proposed antenna design

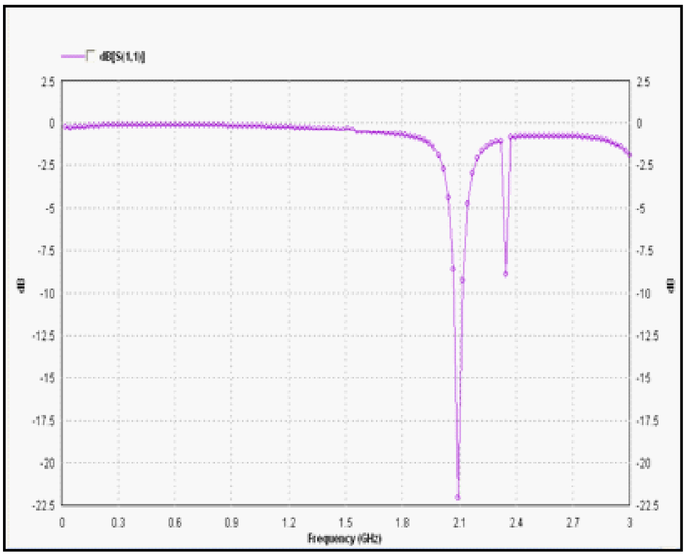


Fig.5 : Return loss versus frequency plot for proposed antenna

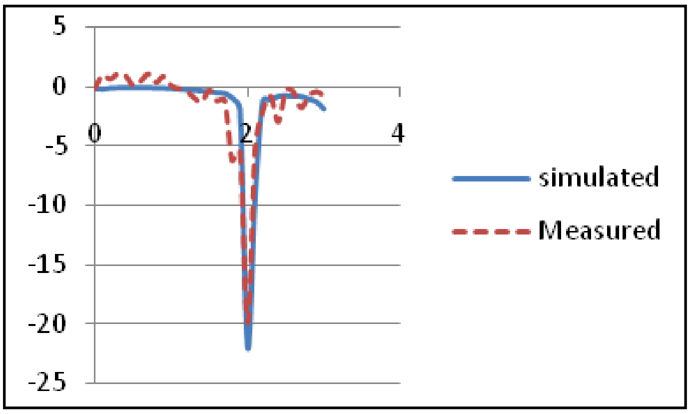
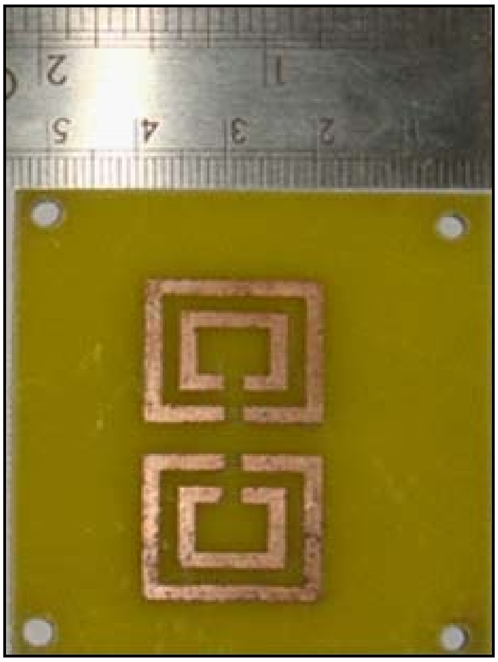
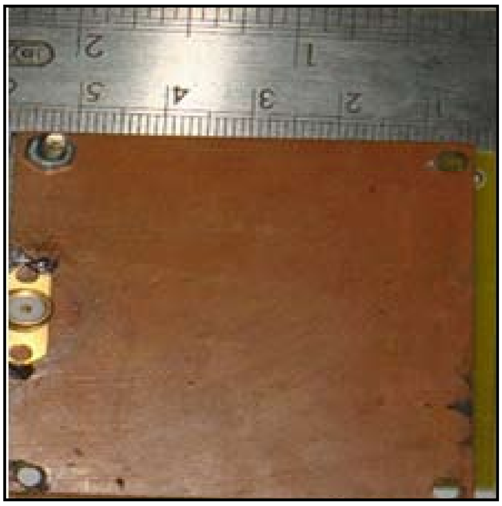


Fig.6 : Comparison of the simulated and experimental results for proposed antenna



(a) Top View



(b)Bottom View

Fig.7:Various views of the proposed antenna

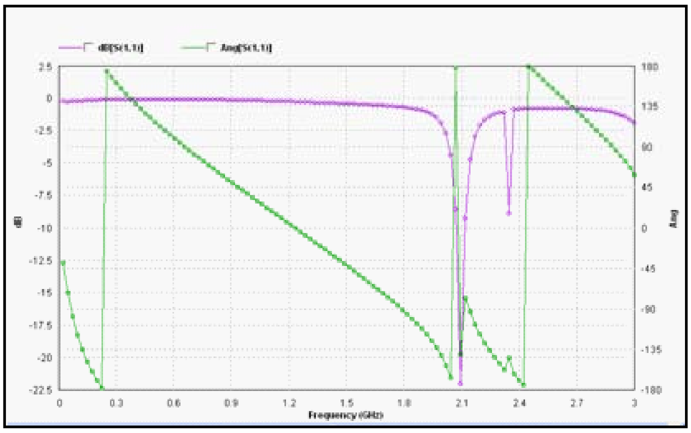


Fig. 8: Magnitude (dB) and phase of S11

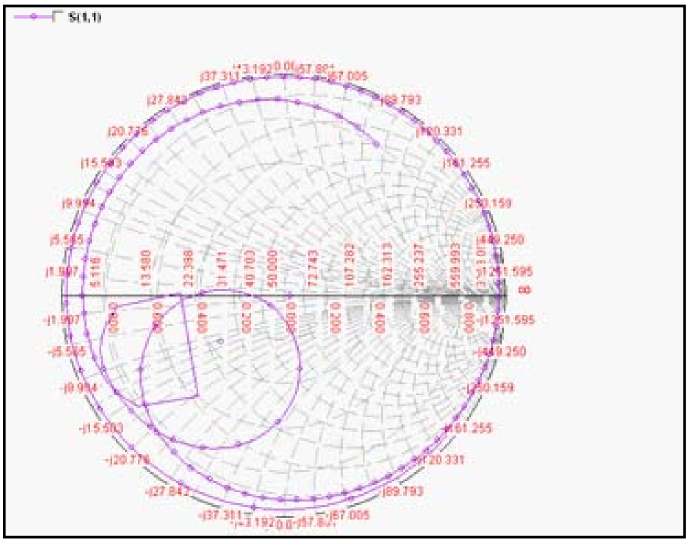


Fig.9 : Smith chart for the proposed antenna

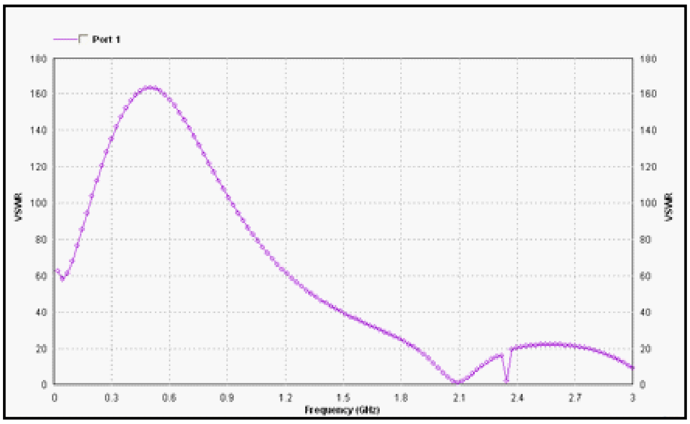


Fig.10 : VSWR versus frequency plot for proposed antenna

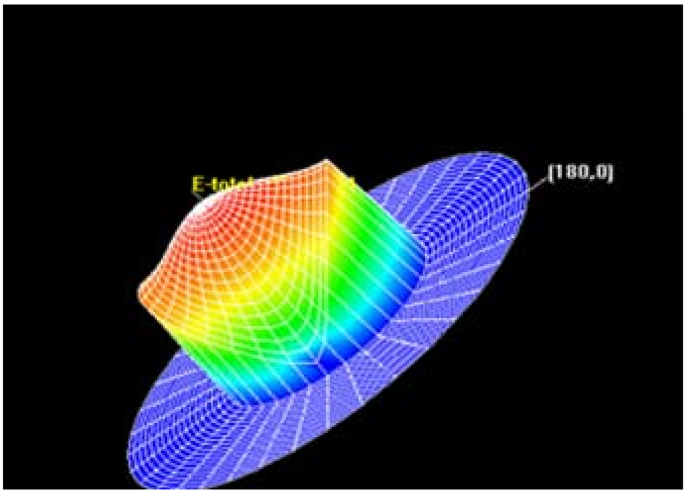


Fig.11 : Radiation Pattern for proposed antenna