METAMATERIAL BASED MICROSTRIP PATCH ANTENNA FOR HIGH FREQUENCY APPLICATION

Swapnil P. Chilap[1], Pralhad P. Narwade[2]

[1]PG Scholar, [2]Assistant Professor, Department of Electronics and Telecommunication, MGMCET, Kamothe, Navi-Mumbai, (India)

ABSTRACT

This paper presents the design of metamaterial based microstrip patch antenna for high frequency application. Work is mainly focused on improving the characteristics of microstrip patch antenna. Metamaterials have been intensively researched due to their particular features such as negative permittivity and/or permeability and ultra-refraction phenomenon. To satisfy the demand of commonly used wireless communication systems, an antenna which can operate at higher frequencies and enhanced characteristics are desirable. The arrangement of all elements is done that they provide an improvement into return loss by which we can notice other factors of antenna. The frequency response of a metamaterial can be tailored by varying its characteristics. A new metamaterial structure using square and ring split ring resonator is proposed. Using this metamaterial structure, a microstrip patch antenna is designed with enhanced characteristics such as reduction in return loss from -20 dB to -36 dB with tunability is achieved.

Keywords: Left-Handed Materials, Metamaterial, Microstrip Patch Antenna, Return Loss, Split Ring Resonator.

I. INTRODUCTION

A microstrip antenna is one of the most commonly ultilized printed antenna. It consist of radiating patch on one side of dielectric substrate and ground plane on the other side microstrip patch antenna on its most basic form, benefits from its low profile, low cost, simplicity and ominidirection radiation patterens. Narrow bandwidth is one of the main disadvantages of a microstrip patch antenna. The antenna has to operate over a wide bandwidth in case of multichannel applications. But at a given time it has to operate over only a small bandwidth to cover a single channel. In this case a tunable microstrip patch antenna can be used, where the resonant frequency of the antenna can be tuned [1].

The common method to increasing band width is by increasing the height of the dielectric substrate while the other is to decrease the substrate dielectric constant. Over the years, indeed, several techniques have been proposed in order to enhance the gain of the antenna as well as other parameter such as return loss. The conventional approach to miniaturizing an antenna is to set the radiator on a high dielectric substrate. Obviously, there are two drawbacks to this [2]. One of the problems is the electromagnetic field remains highly concentrated around the high permittivity region, and another one is the Characteristic impedance in a high permittivity medium is rather low, which creates difficulties in the impedance matching.

We proposed a microstrip patch design antenna using metamaterial. Metamaterials are artificial materials synthesized by embedding specific inclusions in host media and they exhibit the properties of either negative permittivity or permeability. If both negative permittivity and negative permeability happen at the same time, then the composite exhibits an effective negative index of refraction and is referred to as left handed metamaterials (LHMs). The "meta" refers to the resulting effective properties whose electromagnetic responses are "be-yond" those of their constituent materials. The idea of metamaterial was first proposed theoretically by Veselago in 1968 [3]. The negative permittivity was demonstrated and theorized with an array of metallic wires in 1996 by Pendry [4]. The structure had plasma frequency and thereby negative permittivity in the microwave regime. The structure of negative permeability was demonstrated and theorized in 1999 with Split Ring Resonator (SRR) structure [5]. The negative index of refraction existed in the region where both the real parts of the electric permittivity and magnetic permeability were simultaneously negative, typically in a structure composed of SRRs and metallic wires [6].

Metamaterial exhibits exceptional properties not readily observed in nature. The inclusion of metamaterial in the design improves the characteristics of a microstrip patch antenna due to these exceptional properties. Metamaterials and its utilization for antenna's techniques were identified [7], [8], [9].

II. DESIGN SPECIFICATION

Microstrip patch antenna parameters are calculated from formula given below.

A. Desired parameter analysis [10] [11]

Calculation of Width (W):

$$W = \frac{1}{2f\sqrt{\mu_o \varepsilon_o}}\sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad [1]$$

Where,

c = Speed of light

ε_r = dielectric constant of substrate

Effective dielectric constant of a microstrip patch antenna:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\frac{1}{\sqrt{1 + \frac{12h}{w}}} \quad [2]$$

Lengths of metallic patch (L):

$$L = L_{eff} - 2\Delta L \quad [3]$$

Where,

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}}$$

Calculation of length of extension:

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

Calculation of VSWR:

$$\text{VSWR} = S = \frac{1+\Gamma}{1-\Gamma} \quad [5]$$

Where,

Γ = Reflection Coefficient

Calculation of Return Loss:

$$\text{Return Loss} = 20\log|\Gamma| \quad [6]$$

Table I: Design Parameter of microstrip patch antenna

	Dimension	Unit
Dielectric Constant of FR-4 (Lossy) (ϵ_r)	4.4	-
Loss Tangent (tan ∂)	0.02	-
Thickness of FR-4 (Lossy) (h)	1.6	mm
Operating Frequency	6.130	GHz
Length (L)	10.38	mm
Width (W)	14.08	mm
Path Length	6	mm
Width of Feed	1.6	mm

Dimensional view of microstrip patch antenna as shown in Fig.1 and simulated results of microstrip patch antenna without metamaterial as shown in Fig.2.

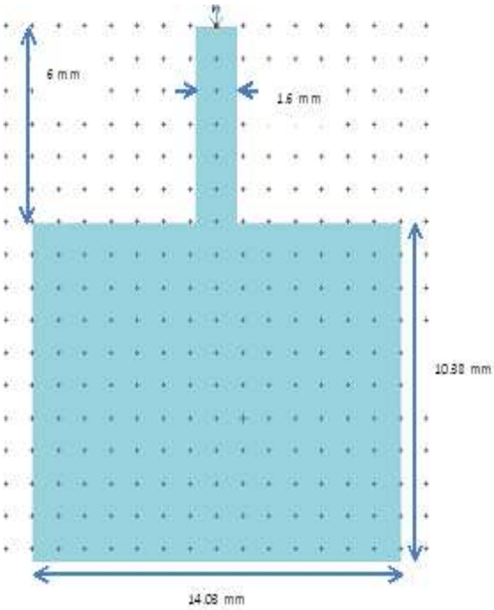

Fig. 1: Microstrip Patch Antenna Without Metamaterial

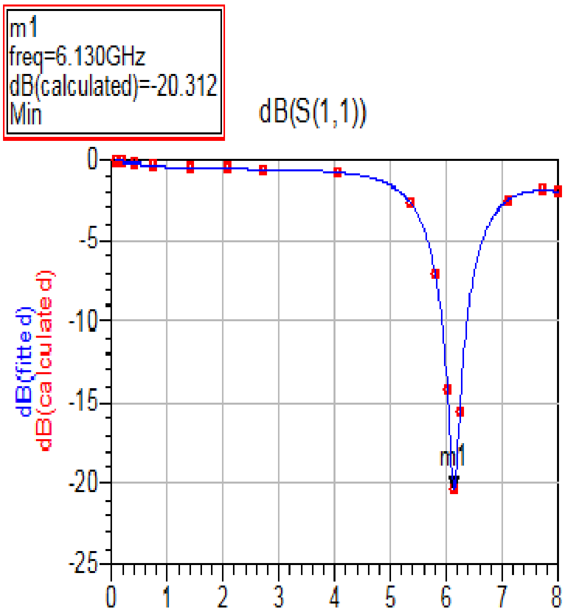

Fig.2: Simulation Of Return Loss S_{11} Of Microstrip Patch Antenna Without Metamaterial

In this paper a Split Ring Resonator (SRR) by combination of Square and Ring shaped metamaterial structure (Square-Ring SRR) has been introduced. Two dimensional views are shown in Fig.4. The structure gives negative refraction index.

III. NICOLSON-ROSS-WEIR (NRW) APPROACH

In this work Nicolson-Ross-Weir (NRW) technique [12], [13] has been used to obtain value of permittivity and permeability. To convert S-parameter this provides easy as well as effective formulation and calculation. The simulated *S*-parameter are then exported to Microsoft excel program for verifying the double- negative properties of proposed metamaterial structure. Equation used for calculating Permittivity and Permeability using NRW approach [14].

$$\mu_r = \frac{2.c(1-v_2)}{\omega.d.i(1+v_2)} \quad [7]$$

$$\varepsilon_r = \frac{2.c(1-v_1)}{\omega.d.i(1+v_1)} \quad [8]$$

$$V_1 = S_{11} + S_{21} \quad [9]$$

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

Where,

μ_r = Permeability

ε_r = Permittivity

c = Speed of light

ω = Frequency in radian

d = Thickness of substrate

i = imaginary coefficient

V_1 = Voltage maxima

V_2 = Voltage minima

Frequency (GHz)	Re [μ_r]	Re [ε_r]
5.6	-22.6485	-0.545
5.655	-22.2522	-0.6117
5.716	-18.6286	-0.638
5.821	-15.8826	-1.1634
5.942	-11.2682	-0.5694
6	-9.1677	-0.4919

Table II: Negative Value Permeability and Permittivity

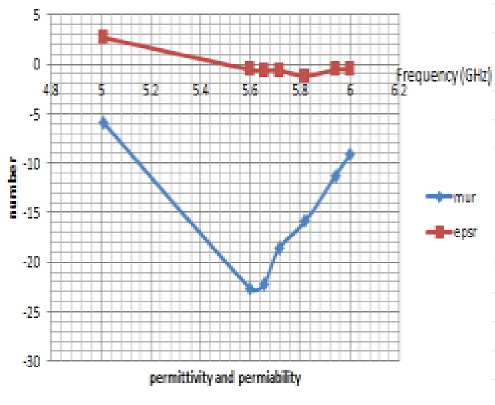

Fig.3: Permeability and Permittivity Versus Frequency

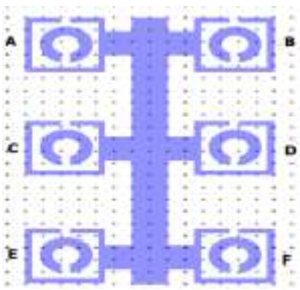

Fig.4 (a)

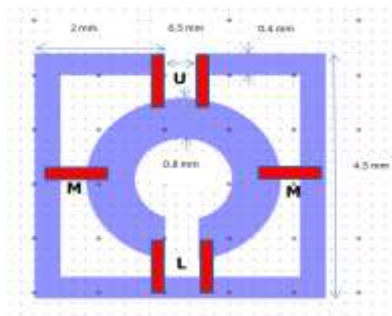

Fig.4 (b)

Fig.4 (A): Design Of Proposed Square-Ring Metamaterial Structure, (B) One Cell Metamaterial Structure

IV. ANALYSIS OF MICROSTRIP PATCH ANTENNA WITH METAMATERIAL STRUCTURE

Microstrip patch antenna with proposed metamaterial structure is given in Fig.5 and Return loss S_{11} of microstrip patch antenna with proposed square-ring metamaterial structure is as shown in Fig.6.

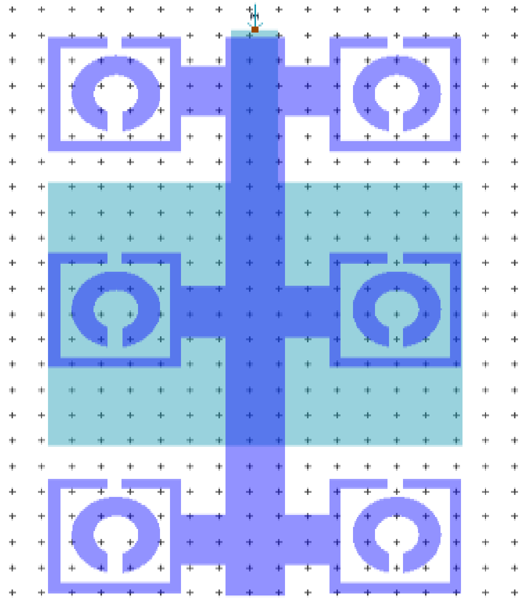

Fig. 5: Microstrip Patch Antenna With Proposed Square- Ring SRR Metamaterial Structure

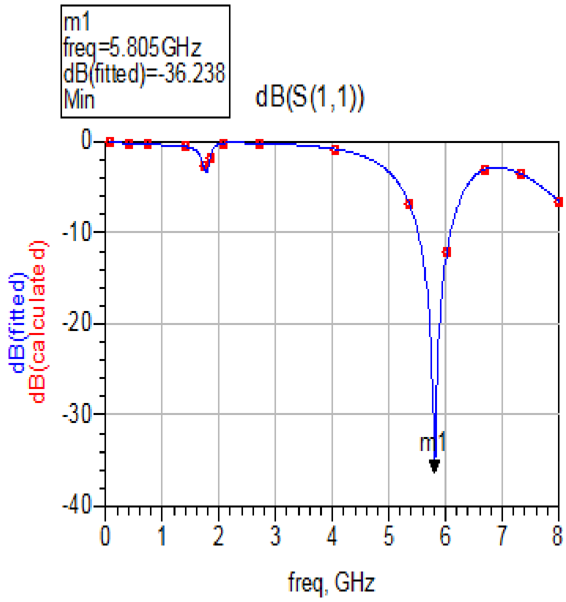

Fig. 6: Simulation Of Return Loss S_{11} of Microstrip Patch Antenna With Proposed Square-Ring SRR Metamaterial Structure

If we made connection as per below Table III then tuning is observed. Fig.7 show that only one frequency is observed when we load metamaterial patch, Fig.8 show that two frequency is observed when we load metamaterial patch, Fig.9 show that three frequency is observed when we load metamaterial patch.

Table Iii: Result of Different Cell Loading with Metamaterial Patch

No. of Frequency obtain	Cell Loading	ON SWITCH	Frequency (GHz)
ONE	C	S_{CU}	5.910
	C	S_{CL}	6.076
	C	S_{CM}	5.751
	C	S_{CULM}	5.971
TWO			
	ABCDEF	S_M	6.093 & 6.863
	ABCDEF	S_U	5.980 & 8.000
THREE			
	ABCDEF	S_L	4.752 & 5.819 &6.270

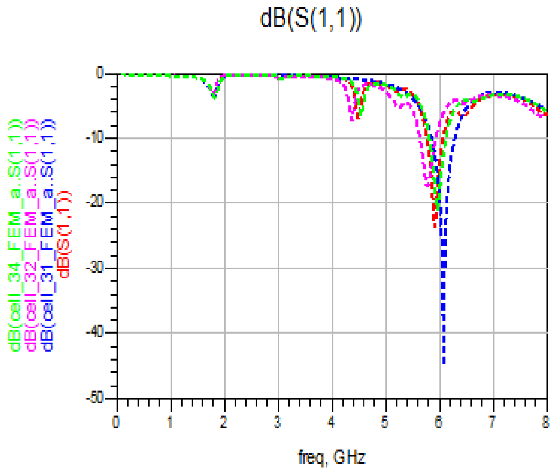

Fig.7: One Frequency is Observed After Loading Metamaterial Patch

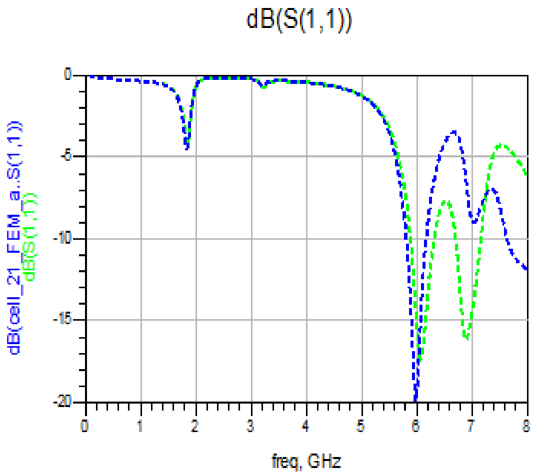

Fig.8: Two Frequency is Observed After Loading Metamaterial Patch

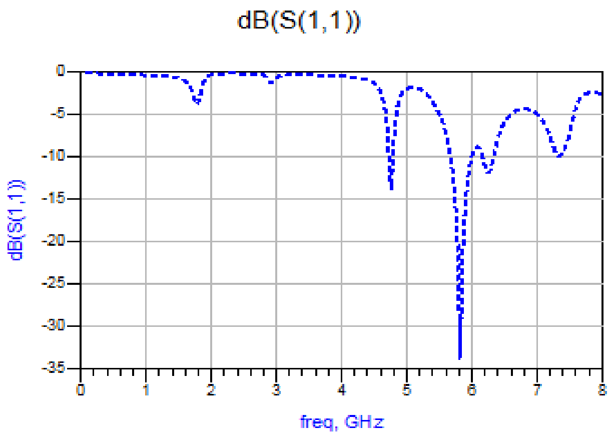

Fig.9: Three Frequency is Observed After Loading Metamaterial Patch

V. CONCLUSION

This paper presents the design of Square-Ring SRR based metamaterial structured microstrip patch antenna for high frequency application. The antenna was tested using ADS software (version 2011) for its return loss. The simulation result shows enhanced characteristics such as reduction in return loss from -20 dB to -36 dB with tunability is achieved.

REFERENCES

[1] G. Kumar, and K. P. Ray, "Broadband Microstrip Antennas," Artech House, Inc 2003.

[2] D. Psychoudakis, Y.H. Koh, J. L. Volakis, and J. H. Halloran, "Design method for aperture-coupled microstrip patch antennas on textured dielectric substrates," IEEE Trans. Antennas Propag., vol. 52, no. 10, pp. 2763 – 2766, Oct. 2004.

[3] V. G. Veselago, "The electrodynamics of substances with simultaneously negative values of ε and μ," Soy. Phys. Usp., 10,509–514, 1968.

[4] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Steward, “Low frequency plasmons in thin-wire structures,” J. Phys. Condens Matter,10,4785–4809, 1998.

[5] D.R. Smith, W. J. Padilla, D. C. Vier, S. C. N. Nasser, and S. Schultz, “Composite medium with simultaneously negative permeability and permittivity,” Phys. Rev Lett,84,4184–4187, May 2000.

[6] R. A. Shelby, D. R. Smith, and S. Schultz, “Experimental verification of a negative index of refraction,” J Science, 292, 77–79, Apr 2001.

[7] V. I. Slyusar, “Metamaterials on Antenna Solutions,” in Proc. International Conference on Antenna Theory and Techniques, 19-24, 6-9 Oct 2009.

[8] R. Ziolkowski, “Metamaterial-Based Antennas: Research and Developments,” IEICE Trans Electron, 89, 9, 1267-1275, Sep 2006.

[9] S. B. Jacob and U. P. Khot, “Frequency- Tunable Metamaterial For Microstrip Patch Antenna,” in proc. IEEE Conference on circuits, systems, communication and information technology application (CSCITA), 2014, DOI:10.1109/CSCITA.2014.6839258, pp. 195-200, 2014.

[10] C. A. Balanis, “Antenna Theory and Design,” John Wiley & Sons, Inc., 1997.

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

[12] Huda A. Mazid, Mohammad Kamal A. Rahim, Thelsa Masri, “Left-handed metamaterial design for microstrip patch antenna application”, IEEE International RF and Microwave Conference, pp. 218-221, 2008.

[13] R. Ziolkowski, “Design, fabrication and testing of double negative metamaterial,” IEEE Transaction on antenna and Propagation, vol. 51, No.7, pp. 1516-1529, july 2003.

[14] Bimal Garg, Aniket Smadhiya, Rahul Dev Verma, “design of Double-F Metamaerial structure of Enhancing Bandwidth of Patch Antenna With Negative μ and ε,” International Conference on C.S.N.T., pp. 35-39, 2012.