Gain Enhancement of Microstrip Patch Antenna Using Metamaterial Superstrate

H. R. Vani [1], M. A. Goutham [1], and Paramesha [2]

[1] Department of Electronics and Communication Engineering
Adichunchanagiri Institute of Technology (AIT), Chikkamagaluru, Karnataka
Vani4ait@gmail.com

[2] Department of Electronics and Communication Engineering
Government Engineering College, Hassan, Karnataka

Abstract **─** In this work, a gain enhancement of conventional microstrip patch antenna has been treated for WLAN applications. About 1.3dB gain enhancement, compared to a conventional patch, has been achieved by loading the microstrip patch with a metamaterial superstrate composed of 2x3 array of Square Split Ring Resonator. Simulations have been carried out using Ansys HFSS. Measured results have been taken to validate the simulation result.

Index Terms **─** Metamaterials, microstrip patch antenna.

I. INTRODUCTION

Modern wireless communication system requires high data rate that depends on the gain of the antenna. Towards this, metamaterial starts playing a very important role in the design of an antenna [1]-[3]. In [4], gain enhancement of microstrip patch antenna (MPA) is achieved by using graded index dielectric superstrate. In [5], a planar two-layer superstrate over a printed patch antenna to enhance the broadside gain is considered. The problem of enhancing the directivity of an aperture coupled microstrip patch antenna using one dimensional electromagnetic bandgap (EBG) structure is treated in [6]. It was found that the directivity level, beamwidth as well as reflection coefficient and gain could be enhanced by using superstrate with two layers. In [7], study of performance parameters of patch antennas with different feeding methods is presented and compared with that of patch antennas without dielectric superstrate. It was found that the directivity level, beam width as well as reflection coefficient and VSWR could be further enhanced by using superstrate with two layers rather than one, regardless of the feeding method. In [8], a meandered line-double split ring resonator (DSRR) superstrate loaded high gain circular patch antenna is presented for X-band and showed that the superstrate loading has minor effect on the return loss characteristics but a major effect on the gain characteristics of the circular patch. Scope for miniaturization and compactness of an antenna leads to the design of novel antenna structure loaded with metamaterial. Hence, in the proposed work, a metamaterial superstrate loaded microstrip patch antenna is designed on low cost, FR4 epoxy substrate for WLAN application.

II. ANTENNA DESIGN

A. Microstrip patch antenna without superstrate

The microstrip patch antenna with co-axial feeding is designed using ANSYS HFSS on a less expensive, widely available FR4 epoxy substrate with relative permittivity of 4.4 and dielectric loss tangent of 0.02 for 5.5 GHz WLAN application. Figure 1 shows simulated top view of MPA. The dimension of the patch and the substrate is 12mm x 16mm x 0.1mm and 26mm x 30mm x 1.6mm respectively. The equations to calculate the dimension of patch antenna are given in [9].

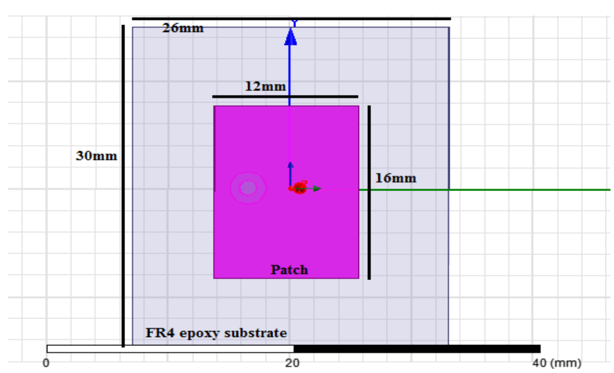
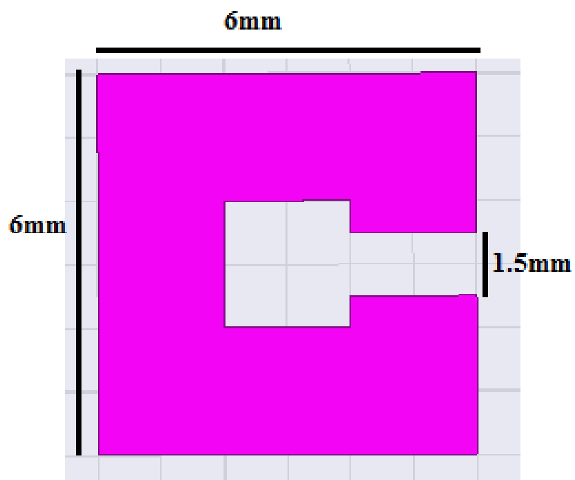


Fig. 1. Simulated top view of rectangular MPA.

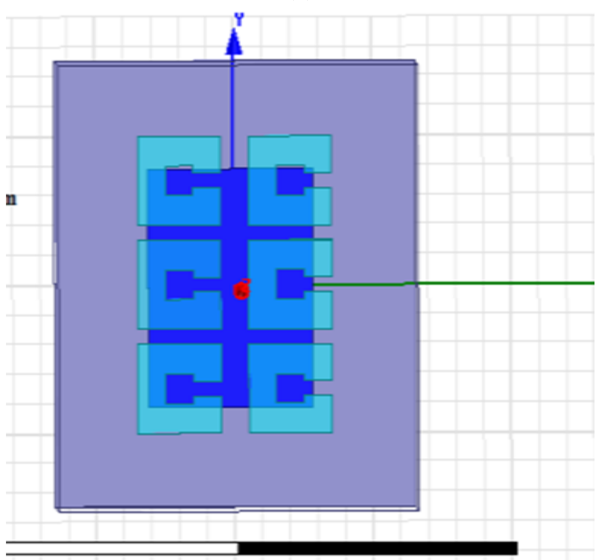
Submitted On: August 6, 2018
Accepted On: March 18, 2019

B. Proposed MPA with metamaterial superstrate

The proposed design consists of metamaterial superstrate loaded microstrip patch antenna. Figure 2 (a) shows the geometry of square split ring resonator metamaterial. The dimension of the ring is 6mm x 6mm. The gap width is 1.5mm. Figure 2 (b) shows the simulated metamaterial superstrate loaded microstrip patch antenna. The metamaterial superstrate is composed of 2x3 array of Square Split Ring Resonator on a FR4 epoxy material. The superstrate dimension is 26mm x 30mm x 1.6mm and is placed at a height of 5mm from the substrate. The fabricated metamaterial superstrate loaded MPA prototype is shown in Fig. 2 (c).



(a)



(b)

(c)

Fig. 2. (a) Metamaterial unit cell, (b) simulated metamaterial superstrate loaded MPA, and (c) fabricated metamaterial superstrate loaded MPA.

III. SIMULATED AND MEASURED RESULTS

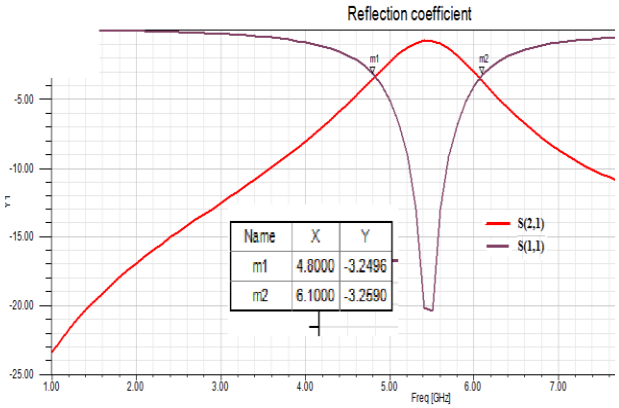
The S-parameters for metamaterial unit cell is shown in Fig. 3 (a). S11 and S21 parameters crosses at 4.8GHz and 6.1 GHz. Hence, the unit cell structure reflects the electromagnetic waves in this band [10]. The measurements are taken on Vector Network Analyzer (Rohde and Schwarz, German make ZVK Model No. 1127.8651). The simulated and measured return loss of microstrip patch antenna with and without superstrate loading is shown in Fig. 3 (b). The summary of simulation and tested results is shown in Table 1.

From Fig. 4 it is clearly seen from simulation that the antenna gain is increased by 1.2dB when metamaterial superstrate is included in the system.

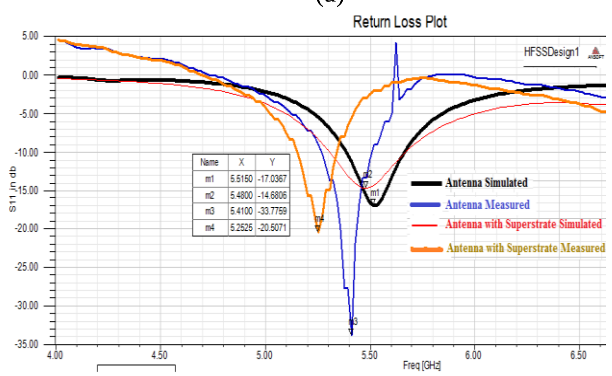
The experimental setup for the gain measurement is shown in Fig. 5. Two steps were used for the estimation of antenna gain. In the first step estimation of gain without metamaterial superstrate is made followed by estimation of gain with metamaterial superstrate. For gain calculation equation in [7] is used:

$$G(dB) = 10\log\left(\frac{P_r}{P_t}\right) - G_t(dB) - 20\log\left(\frac{\lambda_0}{4\pi R}\right)(dB). \quad (1)$$

Where P_t and P_r are transmitted and received powers respectively. G_t is the gain of the pyramidal horn antenna equal to 17dB. *R* is the distance between transmitting antenna and antenna under test. The gains obtained from measurements are 3.7dB and 5dB for patch antenna without and with metamaterial superstrate loading respectively. The enhancement in gain is better with less number of rings on the FR4 epoxy superstrate than that obtained in [10].



(a)



(b)

Fig. 3. (a) S-parameters for the metamaterial unit cell. (b) Simulated and measured |S11| responses of the microstrip patch antenna with and without superstrate loading.

Table 1: Summary of simulation and tested results

Parameters	MPA without Superstrate		MPA with Superstrate	
	Simulated	Fabricated	Simulated	Fabricated
Resonant Frequency (in GHz)	5.51	5.41	5.48	5.25
Return Loss (in dB)	−17.03	−33.77	-14	-20

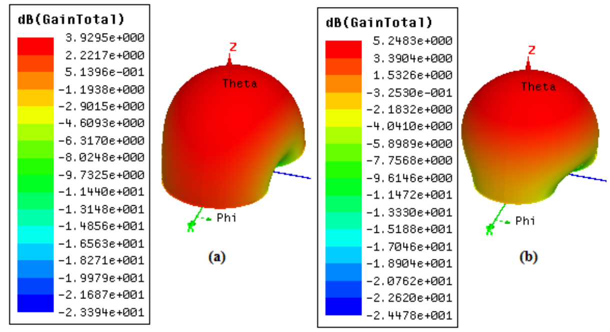


Fig. 4. (a) and (b) simulated 3D gain plot for microstrip patch antenna without and with superstrate loading.

Fig. 5. Experimental setup for the estimation of antenna gain.

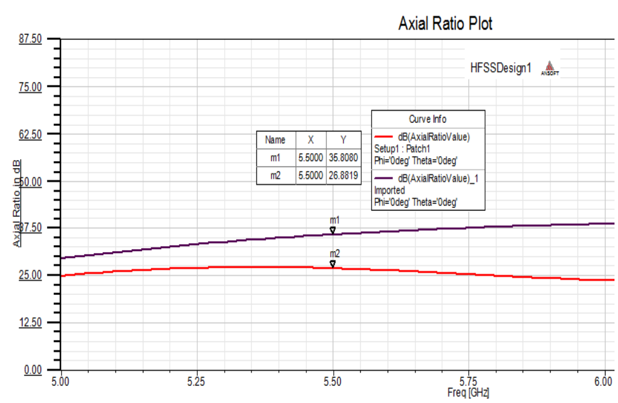


Fig. 6. Variation of axial ratio with frequency.

HFSS simulation of variation of axial ratio with frequency is shown in Fig. 6. At 5.5GHz, the axial ratio is 26.8dB and 35dB for MPA with and without superstrate respectively. This indicates that the antennas are linearly polarized.

IV. CONCLUSION

A Square Split Ring Resonator metamaterial superstrate loaded microstrip patch antenna for gain enhancement has been presented in this paper for WLAN applications. A comparison of the characteristics of the proposed antenna with a conventional patch antenna shows that the superstrate loading has minor effect on the return loss characteristics but a major effect on the gain characteristics of the patch. The superstrate loading has enhanced the gain by about 1.3 dB as compared to a conventional patch.

ACKNOWLEDGMENT

The author would like to thank the Department of Applied Science, Gulburga University, Karnataka for testing the antennas.

REFERENCES

[1] M. Gil, F. Aznar, A. Velez, et al., "Electrically small resonators for metamaterial and microwave circuit design," in *Passive Microwave Components and Antennas*, *V. Zhurbenko*, Ed., InTech, 2010.

[2] J. D. Baena, R. Marque's, and F. Medina, "Artificial magnetic metamaterial design by using spiral resonators," *Physical Review B*, 69, 014402, 2004.

[3] S. A. Tretyakov, C. R. Simovski, and M. Hudlicka, "Bianisotropic route to the realization and matching of backward-wave metamaterial slabs," *Physical Review B*, 75, 153104, 2007.

[4] Y. Li, K. Yoo, R. Mittra, G. Lu, D. Zeng, and Y. Guan, "Directivity enhancement of microstrip antennas using dielectric superstrates," *2010 International Conference on Applications of Electromagnetism and Student Innovation Competition Awards (AEM2C)*, Taipei, pp. 206-209, 2010.

[5] H. Errifi, A. Baghdad, A. Badri, and A. Sahel, "Directivity enhancement of aperture coupled microstrip patch antenna using two layers dielectric superstrate," *Proceedings of 2014 Mediterranean Microwave Symposium (MMS2014)*, Marrakech, pp. 1-4, 2014.

[6] J. C. Iriarte, *et al*., "EBG superstrate for gain enhancement of a circularly polarized patch antenna," *2006 IEEE Antennas and Propagation Society International Symposium*, Albuquerque, NM, pp. 2993-2996, 2006.

[7] H. Errifi, A. Baghdad, A. Badri, and A. Sahel, "Optimization and performance analysis of probe-edge-inset and aperture feed patch antenna covered by dielectric superstrate," *2015 International Conference on Wireless Networks and Mobile Communications (WINCOM)*, Marrakech, pp. 1-8, 2015.

[8] D. Gangwar, S. Das, and R. L. Yadava, "A meander line-DSRR double superstrate loaded high gain circular patch antenna," *2017 IEEE Applied Electromagnetics Conference (AEMC)*, Aurangabad, pp. 1-2, 2017.

[9] C. A. Balanis, *Antenna Theory: Analysis and Design*. Wiley-Interscience, New York, NY, USA, 2005.

[10] M. Saravanan, G. V. Beslin, and S. M. Umarani, "Gain enhancement of patch antenna integrated with metamaterial inspired superstrate," *Journal of Electrical Systems and Information Technology*, 2018.

Vani H. R. did her B.E. in Instrumentation Technology in 1991 from Mysore University, M.Tech in Industrial Electronics from NITK, Surathkal in 2003. She is working as Associate Professor in ECE at Adichunchanagiri Institute of Technology (AIT), Chikkamagaluru Karnataka. She is a Life Member of ISTE, New Delhi.

Goutham M. A., did his B.E. in Electronics and Communication. Engineering in 2001 from Kuvempu University, M.Tech in (Digital Electronics and Communication Systems) from Visveswaraiah Technological University (VTU) Belagavi, in 2005 and Ph.D. from Jadhavpur University, West Bengal, India in 2010. He is Professor in Electronics and Communication. Engineering Dept. with an experience of 15 years at Adichunchanagiri Institute of Technology (AIT), Chikkamagaluru, Karnataka. His current research interest includes MEMS, Wireless and Ad-hoc networks. He is a Life Member of ISTE, New Delhi.

Paramesha did his B.E. in Electronics and Communication. Engineering in 1989, M.Tech in Microwave Engineering from Banaras Hindu University, Varanasi, India in 1997 and Ph.D. from Indian Institute of Technology (IIT), Kharagpur, West Bengal, India in 2007. He is Professor and Head in Electronics and Communication Engineering Department at GEC, Hassan, Karnataka. His current research interest includes antennas for Satellite Communication, Microwave Antennas, and Millimeter systems. He is a Life Member of ISTE, New Delhi.