Academic Science

International Journal of Electronics, Electrical and Computational System
IJEECS
ISSN 2348-117X
Volume 6, Issue 7
July 2017

2x2 MIMO Antenna Design To Improve Gain And Bandwidth With Reduced Mutual Coupling Using Discrete Mushrooms.

[1]**Prashant Kumar** (M.E Scholar)
[2]**Garima Saini** (Assistant Professor)
[1,2] Department of Electronics and Communications, National Institute of Technical Teacher, Training and Research, Chandigarh, India

ABSTRACT.

In this paper, we present the gain and bandwidth enhancement of a microstrip MIMO antenna with low mutual coupling using discrete mushrooms. A technique of using three discrete mushrooms as a loading to reduce the mutual coupling between the closely placed 2x2 MIMO elements presented in this paper. The antenna system consists of 2x2 radiating elements of same dimensions printed on a substrate. Superstrate layer has been designed to load the microstrip MIMO antenna. The superstrate layer has designed to reduce the loading effect on the antenna, so that the mutual coupling between the antenna elements can be greatly reduced, also improve the gain and bandwidth of the antenna. The loaded 2x2 MIMO antenna system with an overall size of 40.57mm x 118.16mm x 8.17mm realize the gain improve 5.46dB, bandwidth increase of 144MHz and mutual coupling reduction of 17.62dB between the antenna elements over the band of 4.19-4.5 GHz. The proposed antenna resonates at the frequency band of 4.19-4.5 GHz and 2.25-2.51 GHz. This antenna can be used for Wi-MAX and Wi-Fi. This structure is simulated and analysis using High Frequency Structure Simulator (HFSS) software.

Keyword- MIMO, Gain, Bandwidth, Mutual coupling, Superstrate layer, HFSS.

1. INTRODUCTION

MIMO (Multiple Input Multiple Output) is one of the advanced forms of microstrip patch antenna, whereas they use more than one radiating element in order to enhance the antenna performance. MIMO is a part of the modern wireless communications system such as 3G, 4G, WLAN/Wi-Fi, LTE, Wi-Max. It covers both the Wi-MAX and Wi-Fi and can be used in other MIMO antenna applications. 4x4 and 8x8 MIMO techniques have been integrated into the IEEE 802.11n [1] and IEEE 802.11ac [2] standard respectively. There has been a large requirement of an antenna to transfer voice, data and multimedia information at a very high data rate in RF communication systems. MIMO technique plays an important role to achieve the improve rates [3].

The microstrip patch antenna is preferable due to its easy fabrications; it is studied extensively from past many years because of its light weight, low cost, small size and capability with the standard manufacturing process. [4,5,6,7]. However, in the MIMO antenna exists the mutual coupling between the elements of the MIMO due to the existence of surface wave, which degrades the performance of MIMO systems in term of diversity, channel capacity, an efficiency of transmission, a sensitivity of receiver etc [8,9]. Therefore, it is a difficult task to suppress the mutual coupling between the antenna elements for MIMO systems. Various techniques have been developed to enhance the gain of the MIMO antenna. Some of the most common methods are U-shaped slotted patch antenna, the different type of MIMO antenna and superstrate layer loaded antenna. [10,11]. The superstrate layer is one of the technique to enhance the performance of the microstrip MIMO antenna in the form of the gain and bandwidth. This method is known as the resonance gain methods and it utilized a superstrate with the parameter of relative permitivity $\varepsilon >>1$ and relative permeability $\mu>>1$. This gain varies proportionately to either μ or ε depending on the configurations. However, it was seen that gain is inversely proportionate to the bandwidth. [12].

Single discrete mushroom-like loading is designed to reduce the mutual coupling between closely spaced SICBS (substrate integrated cavity backed slot) antenna [13], and five discrete mushrooms-like loading is also proposed for suppressing the mutual coupling in SICBS antennas recently [8]. Three discrete mushrooms-like

loading are proposed to reduce the mutual coupling of closely spaced 2x2 MIMO antenna systems to achieve very low mutual coupling of -46.69dB.

This paper elaborates the design of superstrate layer modified 2x2 MIMO antenna using discrete mushrooms, which operate in the resonating frequency 4.5GHz and 2.4 GHz. This antenna has been designed for Wi-Max and Wi-Fi applications.

2. ANTENNA DESIGN AND PERFORMANCE

Figure.1 (a) demonstrates the geometry of a 2x2 MIMO antenna whereas; Figure.1 (b) demonstrates the side view of 2x2 MIMO antennas. The presented 2x2 MIMO antenna, resonating at the frequency of 5.8GHz, is designed of FR-4 substrate of thickness = 1.48mm, dielectric constant (ε_r) =2.5 and loss tangent =0.02. The width (W) and length (L) of the patch, as computed utilizing the equations (1) to (4) are 19.54mm and 15.57mm, respectively. FR-4 substrate is also used for superstrate layers with the dielectric constant of 4.5, loss tangent 0.02 and thickness of the layers is 1.48mm. In Figure.1 (b) sub2 represent the superstrate layers upper and bottom of the sub1. The 50Ω SMA coaxial connector is utilized to feed the MIMO antenna. Table 1 demonstrates the different dimensions of the proposed MIMO antenna. The resonant input resistance of the rectangular patch antenna is 157.5Ω. The corporate feed technique is used to feed the MIMO antenna. This feeding network provides power splitting using quarter wave impedance transformer [14]. A quarter wave transformer of 88.74Ω is utilized for matching the 50Ω rectangular patch line. The width w of the quarter wave transformer and a 50Ω line is calculated from [14], are 1.55mm and 4.25mm. The length of the quarter wave transformer is calculated is 5mm. the dimensions of the substrate are 40.57mm x 118.16mm. The length of feeding strip is 5mm.

$$W = \frac{C_o}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \tag{1}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{-1}{2}}, \frac{W}{h} > 1 \tag{2}$$

$$L = \frac{C_o}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{3}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \tag{4}$$

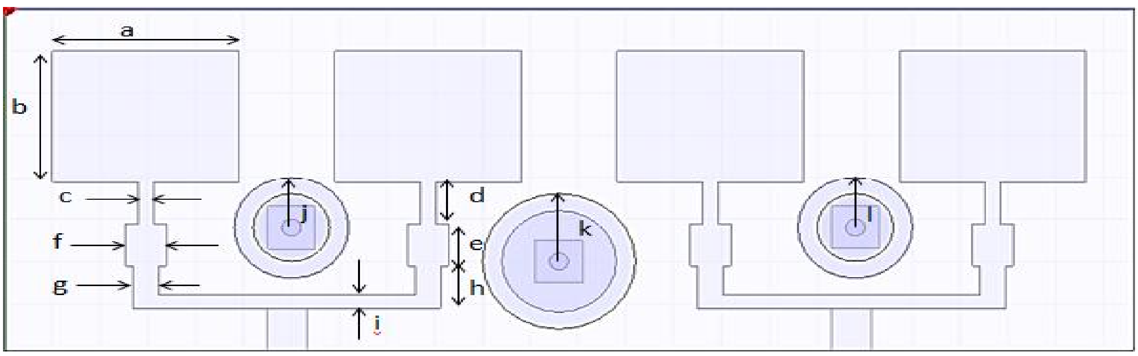


Figure 1(a). Geometry of 2x2 MIMO antenna

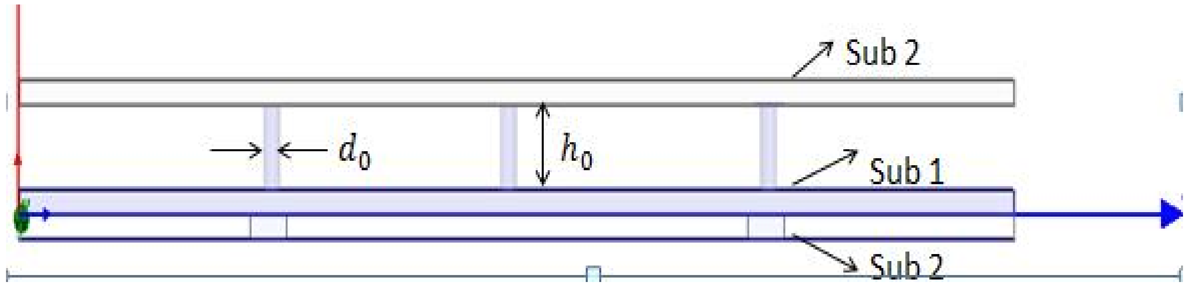


Figure 1(b). Side view of antenna

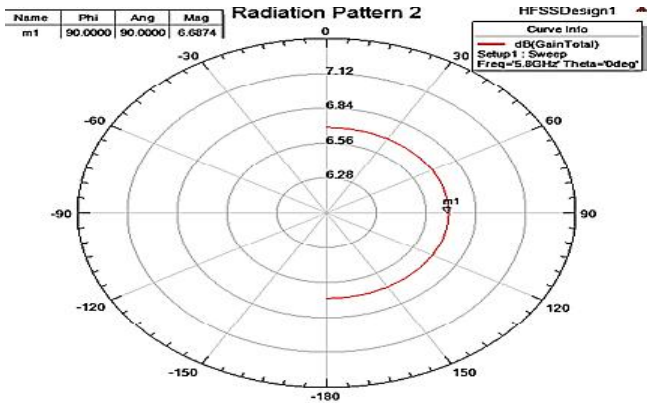
Table 1. Dimensions of proposed 2x2 MIMO antenna.

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
a	19.54	h	5
b	15.75	i	1.55
c	1.55	d_o	2
d	5	h_o	5.17
e	5	j	6
f	4.25	k	8
g	2.7	l	6

Figure.1(b) shows the side view of the 2x2 MIMO antennas, two superstrate layers are present in the design present by Sub2. The superstrate layers are designed by the FR-4 substrate of thickness 1.48mm, dielectric constant ε_r=4.5 and loss tangent=0.02. The upper layer of the superstrate is separated by the vias [15]. The height of via (h_0) is pre-set as about $0.1\lambda_0$ (λ_0 is the free space wavelength at resonating frequency 5.8 GHz) is 5.17mm. The diameter of via is denoted by the d_0 equal to 2 mm. The radiuses of the mushroom cells are presented by the j, k and l. The geometrical dimension of the superstrate layers is 40.57mm x 118.16mm. HFSS software is used to simulate this 2x2 MIMO antenna. The antenna measurements are done to validate the simulated results.

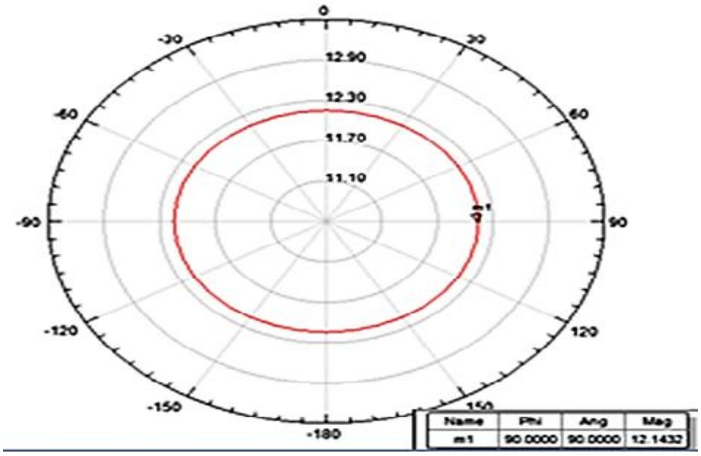
3. RESULT AND DISCUSSIONS

Figure.2 demonstrates the radiation pattern of the proposed MIMO antenna, a simulated result of proposed 2x2 MIMO antenna under loaded conditions is exhibited, the proposed antenna has been designed on the FR-4 substrate. It is shown that the unloaded 2x2 MIMO antenna resonate ate 5.8GHz with a gain of 6.687dB, whereas, when the proposed 2x2 MIMO antenna loaded with the superstrate layers or mushroom, then gain of proposed antenna improved to 12.143dBi, at the resonant frequency 4.5GHz, subsequently relating to the gain improvement of 81.58%. The length and width of the 2x2 MIMO antennas under both the conditions are same, but the height of the antenna is increased from 1.48mm to 8.13mm, due to separation between two layers using via. Figure 2 shows the radiation pattern of an unloaded or loaded antenna. The proposed antenna is suitable for Wi-MAX and Wi-Fi application. Figure 2 demonstrates the radiation plot, which is obtained from the HFSS software. The proposed microstrip 2x2 MIMO antenna has better gain.



Azimuth Plane Gain Display (dB)

Figure 2(a) Unloaded antenna



Azimuth Pattern Gain Display (dBi)

Figure 2 (b) Loaded antennas

Figure 2(a,b). Azimuth plane radiation patterns characteristics of unloaded and loaded MIMO antennas.

Figure.3. Demonstrates the return loss plot of proposed 2x2 MIMO antennas. It is observed that with superstrate layers or loading mushrooms, the S_{11} is less than -11.64dB from 4.19 to 4.5GHz and S_{11}=-19.07dB from 2.25 to 2.51GHz. It is observed that the bandwidth of the loaded 2x2 MIMO antenna is 310MHz at the resonating frequency 4.3GHz, subsequently relating to the bandwidth improvement of 86.74%.

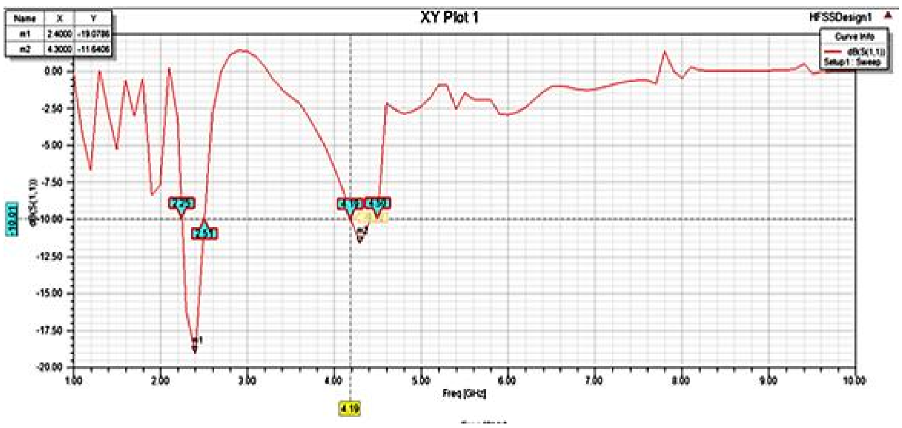


Figure 3. Return loss Vs frequency of 2x2 MIMO antennas

Freq =4.3GHz S_{11} = -11.64 dB, Freq =2.4GHz S_{11}=-19.07dB

Figure.4 shows the mutual coupling plot of the proposed 2x2 MIMO antenna with loaded mushroom or superstrate layers. It is observed that the S_{21} or S_{12} is less than -28.774dB, at the antenna resonating frequency 5.8GHz, without mushroom structure. With the occurrence of the mushroom structure, the S_{21} or S_{12} is less than -46.698dB, at the antenna resonating frequency 5.8GHz. Therefore, the mutual coupling of the closely spaced elements MIMO antenna system can be reduced, by 17.92dB using three discrete mushroom loading. Figure.5(a) and 5(b)" are the simulated electric field distribution when port 1 and port 2 are excited, respectively; it shows the surface current distribution along the proposed 2x2 MIMO antenna. The current is uniformly distributed along the feed of the antenna. The electric field intensity is maximum at 8.71(V/m) and 8.26(V/m) respectively, which is presemnvnnt in x-y plane.

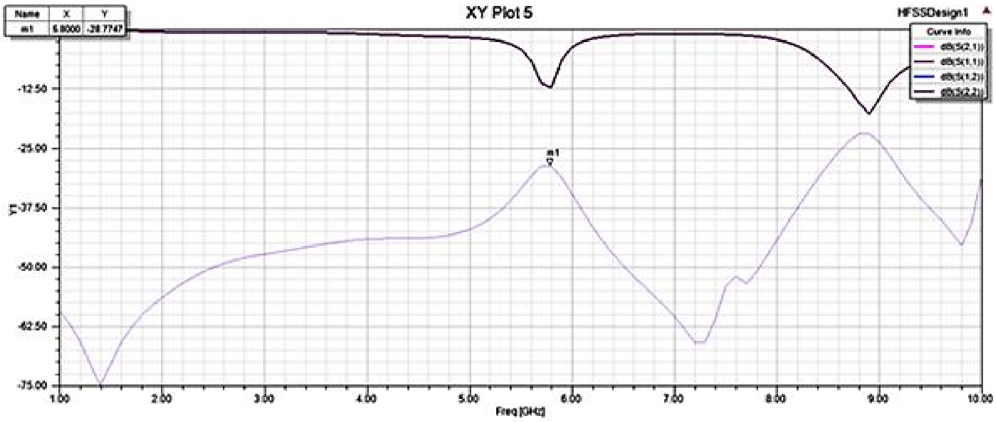


Figure 4(a). Magnitude (dB) vs. Frequency (GHz)

Figure 4(b). Magnitude (dB) vs. Frequency (GHz)

Figure 4(a,b). Simulated S_{12}/S_{21} parameter with mushroom structure

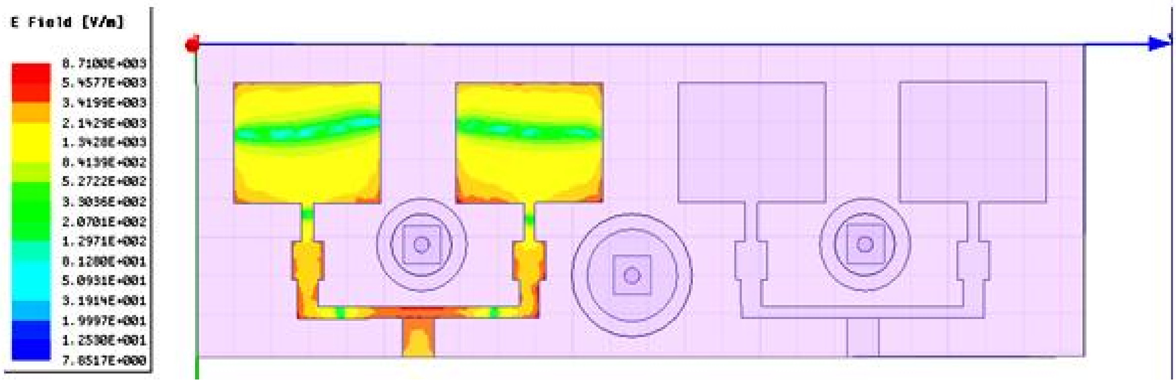


Figure 5(a). E-Field distributions at port 1

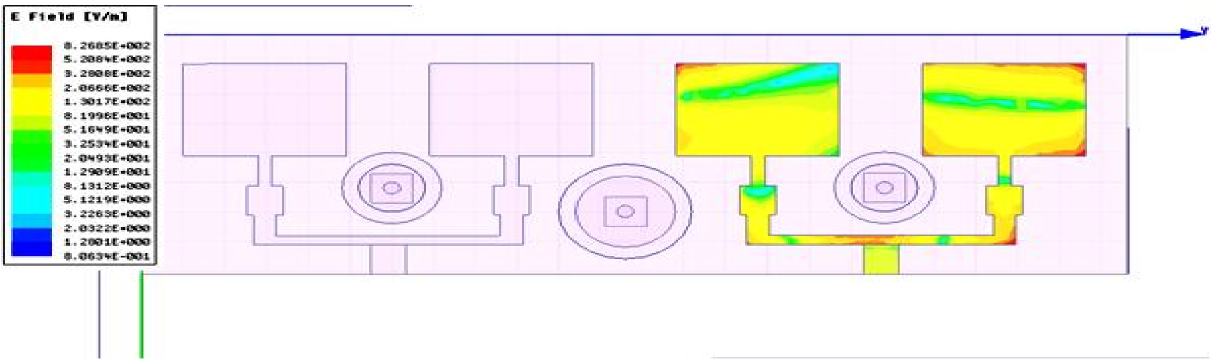


Figure 5(b). E-Field distributions at port 2

Figure 5(a,b). E-Field distributions of antenna

4. CONCLUSION

The superstrate layer with the mushroom-like loadings has been proposed to improve the gain, bandwidth and the interelement isolation of an antenna for MIMO applications. The proposed antenna has been designed on the FR-4 substrate to achieve higher performance. The advantage of this proposed antenna is that its execution gets enhanced by including superstrate layers with the mushrooms. The superstrate layers are spaced away from the patch for reduced the loading effect on the antenna. The simulated results have validated the simulation with the gain of 12.14dB, a bandwidth of 310MHz at 4.3GHz, a bandwidth of 340GHz in the resonating frequency 2.4GHz and the interelement coupling of less than -46.69dB. The proposed antenna has been designed for Wi-MAX and Wi-Fi applications.

5. REFERENCES.

[1] IEEE Standard for Information Technology Telecommunication and Information Exchange between System local and Metropolitan Area Network-Specific Requirment, IEEE Std 802.11n-2009.Oct. 2009.

[2] IEEE Standard for Information Technology Telecommunication and Information Exchange between System Local and Metropolitan Area Network-Specific Requirment, IEEE Std 802.11ac-2013.Dec. 2013.

[3] Chouti L and Behloul L and Messaoudene I,(2014) "*Numerical Analysis of a Microstrip MIMO Antenna Array*" IEEE Conference on Mediterranean Microwave Symposium, pp.1-4.

[4] Girish Kumar and K.P. Ray (2003) *Broadband Microstrip antennas*, Norwood Artech House.

[5] Ramesh Garg, P. Bhartia, Inder Bahl, A. Ittipiboon,(2000) *Microstip Antenna Design Handbook*, Artech House.

[6] C. A. Balanis, "Antenna Theory,(1997) *Analysis and Design*, John Wiley & Sons, New York.

[7] Ali, Zakir; Singh, Vinod Kumar; Singh, Ashutosh Kumar; Ayub, Shahanaz,(2011) "*E shaped Microstrip Antenna on Rogers Substrate for WLAN Applications*", IEEE Conference on Computational Intelligence and Communication Networks, pp. 342-345.

[8] Guohua Zhai, Zhi Ning Chen, (2016) "*Mutual Coupling Reduction of a Closely Spaced Four-Element MIMO Antenna System Using Discrete Mushrooms*", IEEE Transactions Microwave Theory and Techniques, Vol. 64, No.10, pp.3060-3067.

[9] Dandker, K.R., H. Ling, and G. Xu, (2000) "*Effect of Mutual Coupling on Direction Finding in Smart Antrenna Applications*", Electronics Letters, Vol. 36, No. 22, 1886-1891.

[10] W. Swelam and M. Ali Soliman,(2010) "*Compact Dual-Band Microstrip Patch Array Antenna for MIMO 4G Communication Systems*", IEEE International Symposium on Antennas and Propagation Society, pp. 1-4.

[11] Kanika Joshi, Srishti Saraswat, et al.(2015) "*Superstrate Layer in Patch Antenna A Review*", International Journal in Latest Trends in Engineering and Technology, Vol 6, Issue 2, pp. 340-345.

[12] David.R.Jackson and Nicolos G.Alexopoulos,(1985) "*Gain Enhancement Method for Printed Circuit Anteenna*", IEEE Transection on Antenna and Propagation, Vol. 33, No.9.

[13] Guohua Zhai, Zhi Ning Chen,(2015) "*Isolation Enhancement Between Two Closely Spaced SICB Slot Antenna Using Discrete Mushrooms*", IEEE Conference on Asia-Pacific Microwave, Vol. 3, pp.1-3.

[14] Pozar.D, (2008) *Microwave Engineering*, John Wiely & Sons, New York, NY, USA.

[15] Ashok Kumar, Garima Saini, (2016) "*A Review on Feature Planar Transmission Line*", Electrical and Electrical Engineering Review Article, pp. 1-12.
[16] R. Gonzalo, P. Maagt, and M. Sorolla, (1999) "*Enhanced Patch Antenna Performance by Suppressing Surface Waves Using Photonic Bandgap Substrates*", IEEE Transaction on Microwave Theory Techniques, Vol.47, pp. 2131-2138.
[17] Anshika Khanna, D K Srivastava, J P Sain, (2015) "*Bandwidth Enhancement of Modified Square Fractal Microstrip Patch Antenna Using Gap Coupling*", Science Direct Hosted by ELSEVIER, Vol. 18, pp. 286-293.
[18] Cason Neo, Yee Hui Lee, (2013) "*Patch Antenna Enhancement using a Mushroom-like EBG Structures*", IEEE International Symposium on Antennas and Propagation Society, pp. 614 - 615.
[19] Christopher Arnold, Magda El-Shenawee, (2015) "*Design of Multi-Band Uniplanar MIMO Antenna for Mobile Devices with LTE/WLAN Operation*", IEEE International Symposium on Antennas and Propagation and National Radio Science, pp.1222-1224.
[20] Mohammed Ziaul Azad, MohammodAli, (2008) "*Novel Wideband Directional Dipole Antenna on a Mushroom Like EBG Structure*",IEEE Transactions on Antennas and Propagation, Vol.56, pp.1242-1250.

Author Profile

Prashant Kumar received the Bachelors of Technology degree in Electronics and Communication Engineering from Uttar Pradesh Technical University, Lucknow, India in 2013. He has two years teaching experience. He is pursuing Masters of Engineering degree in Electronics and Communication Engineering from National Institute of Technical Teachers' Training & Research, Panjab University, Chandigarh, India.

Garima Saini is currently working as an Assistant Professor in ECE Deptt. In National Institute of Technical Teachers‟ Training and Research, Chandigarh. She has completed M.Tech in Electronics and Communication Engg. Her research areas of interest are Wireless and Mobile Communication and Antenna.