IJETST- Vol.||04||Issue||10||Pages 6221-6230||October||ISSN 2348-9480 2017

Open access Journal **International Journal of Emerging Trends in Science and Technology**
IC Value: 76.89 (Index Copernicus) Impact Factor: 4.219 DOI: https://dx.doi.org/10.18535/ijetst/v4i10.07

A Design of Rectangular Microstrip Patch Antenna Based on Fractal Geometry for Wideband Applications

Authors
Romeesa, Narinder Sharma
Amritsar College of Engineering and Technology, Amritsar, Punjab, India (M.Tech Scholar) Department of Electronics and Communication Engineering, Amritsar College of Engineering and Technology, Amritsar, Punjab, India (Associate professor)

Abstract
This manuscript presents the novel design of rectangular microstrip patch antenna based on fractal techniques for wideband applications. In this design, T-slots are introduced in rectangular patch geometry by varying the dimensions of slots which follow the concept of fractal properties. The HFSS V13 software is used to design, simulate and analyze the proposed antenna. Low cost FR4 glass epoxy substrate with thickness 1.6mm and dielectric constant 4.4 is used to design the proposed antenna at resonant frequency of 2.45GHz. Proposed antenna efficiently works on four frequency bands (2.0GHz, 6.5GHz, 8.4GHz and 9.7GHz) with acceptable value of gain, returns loss and also reports wide bandwidth. It exhibits the good omnidirectional and bi-directional radiation pattern at the frequency band of 2.0GHz. Proposed antenna can be used for different wireless applications such as point to point high speed wireless communication (5.925GHz – 8.5GHz), bluetooth (2.41 – 2.49GHz) and X-band application.

1. Introduction

The microstrip patch antenna gaining momentum in the field of wireless communication system due to its unique features; such as light weight, low cost, low volume, low profile, conformal configuration, ease of installation and compatibility with integrated circuits [1]-[2]. These antennas are consist of dielectric substrate on which the patch is situated on one side and ground plane on other side. Antennas are excited by different feeding techniques which setup the strong field inside the cavity and strong distribution of current on the surface of patch and ground plane [3]. Due to the advantages of microstrip patch antenna these are widely used in modern communication devices for wireless application. There are also some disadvantages have been reported in microstrip patch antennas such as narrow bandwidth [4] and less gain [5] which limits its use in applications like satellite and mobile communications. To overcome these drawbacks large number of techniques has been employed by the researchers in the geometry of microstrip patch [6] such as introduction of slots [7], using different types of substrate material, using fractal geometry, using partial or defected ground structures and using capacitive and inductive loading [8]. By employing all these techniques the microstrip antennas are able to achieve multiband and wideband characteristics. Multiband and wideband antennas are used for different wireless applications because the single antenna is capable to work under various application, which limits the use of different antennas for different applications and also reduce the size of antenna [9]. Different types of feeding techniques such as probe/coaxial fed, CPW fed and transmission line fed is also helpful in for the antenna to resonate at various frequency bands [10]. By designing the multiband and wideband antennas we can fulfill the demand of modern communication system, because it covers most of the applications in the field of wireless and microwave communication such as WiMAX, WLAN, bluetooth, GPS, GSM, CDMA, RADAR, PCS, satellite and many more wireless applications [11].

Extensive research has been carried out in the field of microstrip patch antennas. Some of them has been discussed in this work such as; double C shaped microstrip antenna has been designed for UWB applications and exhibit the gain of 6.18dB with a narrow bandwidth of few MHz [12], a triple band stacked patch antenna uses the slotted ground structure having a narrow bandwidth with a maximum gain of 5.8dB [13], rectangular antenna has been designed for WLAN applications to achieve the gain of 3.35dB at 2.45GHz frequency band, it also shows the bandwidth of few MHz [14], rectangular microstrip antenna with truncated corners using T and U shaped slots have been designed for single frequency band of operation and exhibit narrow bandwidth [15], compact size slotted microstrip patch antenna is designed for multiband operation with a gain of 2.8dB and bandwidth of 500MHz, 400MHz and 550MHz [16], L-shaped slotted patch antenna is designed for bluetooth, WLAN, WiMAX applications and does not give any detail about the gain and bandwidth of antenna [17] and multiband fractal antenna array for wireless power transmission has been designed to achieve a gain of 2.47dB and 4.30dB with a bandwidth of 370MHz and 550MHz [18]. Microstrip patch antennas are designed by using hybrid fractal slots which report wider bandwidth 2260MHz and 2440MHz[19].

This paper presents the novel design of rectangular microstrip patch antenna composed of fractal geometry for wideband applications. Manuscript comprises of different sections in which the first section explains the introduction about different type of antennas. Second and third section of antenna explains the detail of antenna design configuration and different results of proposed antenna respectively.

2. Antenna Design and Configuration

Proposed antenna comprises of three iterations, in which T-slots are etched from the geometry of rectangular microstrip patch which are shown in Fig.1. The basic geometry of rectangular patch has been designed by using equations (1) to (4)[20]. Basic parameters which are used to calculate the length and width of patch are material of substrate, dielectric constant of substrate, thickness of substrate and resonant frequency of antenna. In this design FR4 glass epoxy substrate is used with dielectric constant 4.4 and a thickness of 1.6mm with resonant frequency 2.45GHz. The 0^{th}, 1^{st} and 2^{nd} iterations of proposed antenna are shown in Fig.1 (a), (b) and (c) respectively. In 1^{st} iteration, T-slots are subtracted from the rectangular patch and the 2^{nd} iteration is derived from 1^{st} iteration by subtracting the small T-slots with varying dimensions at different scaling positions. The procedure of designing the T-slots with parametric dimensions is shown in Fig.2. These slots are designed and etched from the basic geometry of rectangular patch; to increase the performance of proposed antenna in terms of return loss, bandwidth and gain.

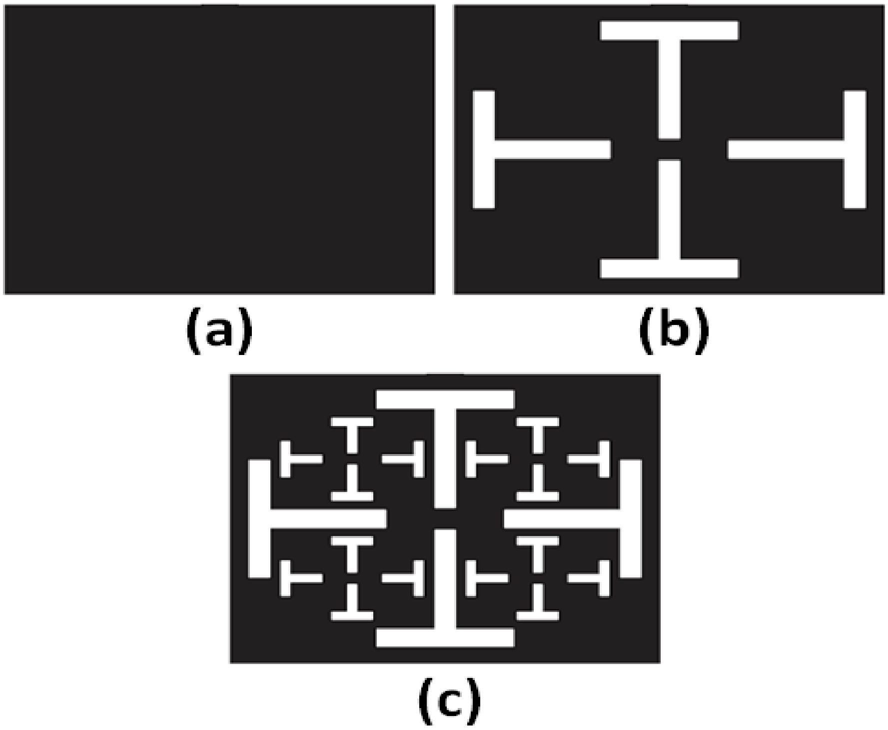

Figure 1. Patch structure of proposed antenna (a) 0th iteration, (b) 1st iteration and (c) 2nd iteration

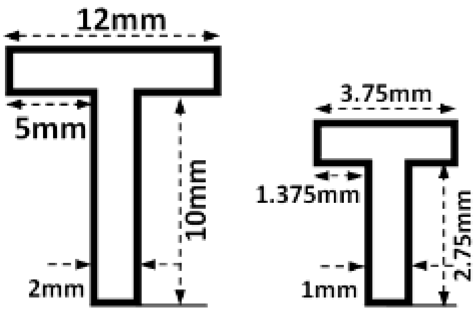

Figure 2. Dimensions and procedure for designing the T-slots of proposed antenna

$$W_p = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

$$\varepsilon_{reff} = \left[\frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\right]\frac{1}{\sqrt{1+12h/W_p}} \quad (2)$$

$$\Delta L = h*0.412\left[\frac{(\varepsilon_{reff}+0.3)\left(\frac{W_p}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W_p}{h}+0.8\right)}\right] \quad (3)$$

$$L_P = \frac{1}{2f_r\sqrt{\mu_o\varepsilon_o}\sqrt{\varepsilon_r}} - 2\Delta L \quad (4)$$

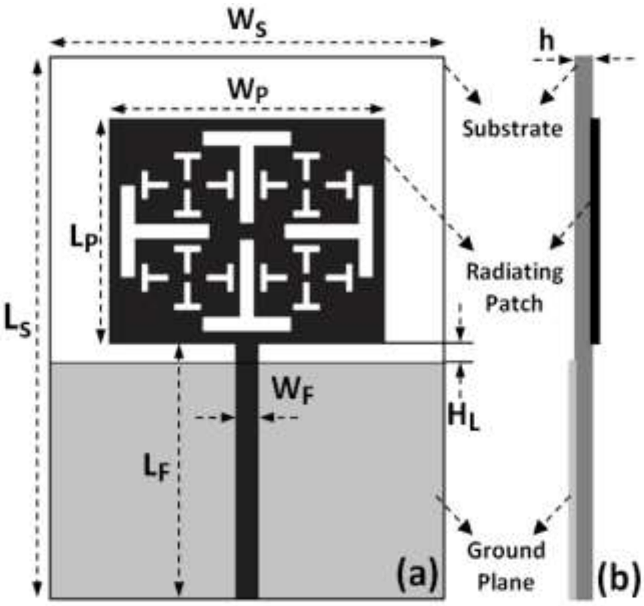

Figure 3. Simulated structure of proposed antenna; (a) front view and (b) side view

Table 1. Parametric values of proposed antenna

Parameters	Description	Values
W_S	Width of substrate	53mm
L_S	Length of substrate	70mm
W_P	Width of patch	37mm
L_P	Length of patch	29mm
W_F	Width of feedline	3.0mm
L_F	Length of feedline	33mm
H_L	Gap length	2.0mm
h	Thickness of substrate	1.6mm

The 2nd iteration of proposed antenna is excited by applying the transmission line feeding technique. Initially the full ground plane is used to analyze the different parameters of antenna. Further, a partial ground plane is employed in the geometry of proposed antenna to increase the bandwidth of antenna. The length of ground plane is varied to further enhance the bandwidth and other parameters of proposed antenna. HFSS V13 Simulator is used to design and analyze the different parameters of proposed antenna. The simulated structure of designed antenna with different views is shown in Fig.3 and the parametric dimensions are tabulated in Table 1.

3. Result and Discussions

3.1 Return loss and Bandwidth

The simulated return loss and bandwidth of 2nd iteration of proposed antenna has been presented and analysed in this section. Initially, the full ground plane has been used and observed that antenna exhibits a multiband behaviour with very less bandwidth (narrow bandwidth).

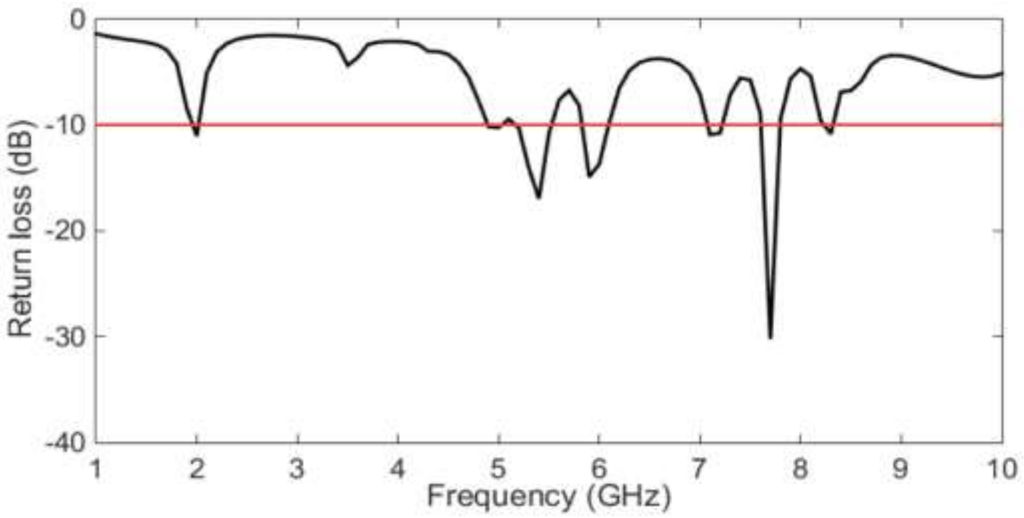

Figure 4. Return loss curve of proposed antenna with full ground plane

Return loss curve of proposed antenna with full ground plane is shown in Fig.4. Bandwidth of antenna is increased by employing the partial ground plane and it is further enhanced by varying the 'H_L' parameter as shown in Fig.3. H_L parameter is the gap between patch and partial ground plane. When the length of gap 'H_L' is taken as 3.0mm, antenna works on two frequency bands 1.8GHz and 8.1GHz with corresponding bandwidth of 1700MHz and 840MHz respectively. Similarly, when 'H_L' is decreased by the scale of 0.5mm, antenna exhibits three frequency bands such as 1.9GHz, 6.5GHz and 8.2GHz with value of bandwidth as 1637MHz, 190MHz, 780MHz respectively. On further decreasing the gap length, the proposed antenna works on four resonant frequencies. The return loss plot of proposed antenna with variation in 'H_L' parameter is depicted in Fig.5. It is observed that antenna with gap length 2.0mm reports wider bandwidth as compared to the other variations. To understand in a better way, the values of different performance parameters with variation in gap length have been delineated in Table 2. It is also observed that fundamental frequency of antenna shifted towards the lower side from 2.45GHz to 2.0GHz; which shows that miniaturization has been achieved without changing the dimensions of the proposed antenna. So, at last the gap length H_L=2.0mm is reserved for the final design of antenna and the separate return loss curve is depicted in Fig.6.; which shows that the antenna operates efficiently on four distinguished frequency bands with acceptable value of return loss. From, the above discussion, it is very obvious that the proposed antenna can be used for different wireless standards such as point to point high speed wireless communication (5.925GHz – 8.5GHz), bluetooth (2.41 – 2.49GHz) and X-band applications.

Table 2. Simulated values of proposed antenna with variation in H_L parameter

Variation in H_L parameter	Resonant Frequency (GHz)	Return loss (dB)	Bandwidth (MHz)	Gain (dB)
3.0mm	1.80	-23.88	1700	-8.08
	8.10	-27.28	840	5.16
2.5mm	1.90	-19.40	1637	2.53
	6.50	-10.46	190	4.25
	8.20	-22.70	780	5.60
2.0mm	2.00	-16.24	1660	3.24
	6.50	-11.52	370	4.09
	8.40	-19.83	855	5.38

	9.70	-12.07	500	7.46
1.5mm	2.00	-13.26	1130	4.02
	6.50	-14.36	560	4.14
	8.50	-19.22	900	5.73
	9.70	-13.82	700	7.65
1.0mm	2.00	-12.13	930	1.84
	6.50	-16.64	820	4.24
	8.50	-17.43		5.95
	10.00	-15.63	1995	4.74

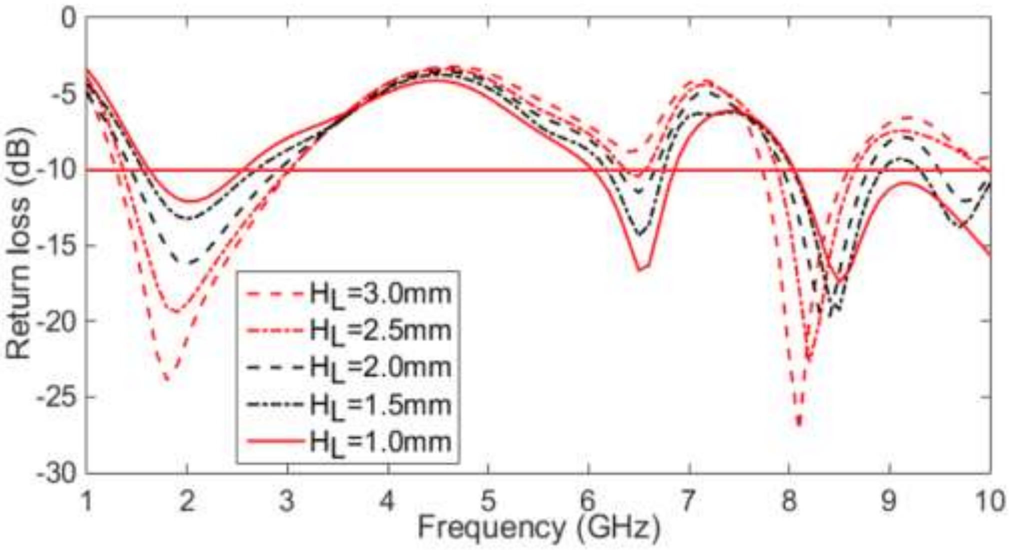

Figure 5. Return loss curve of proposed antenna with variation in ‘H_L’ parameters

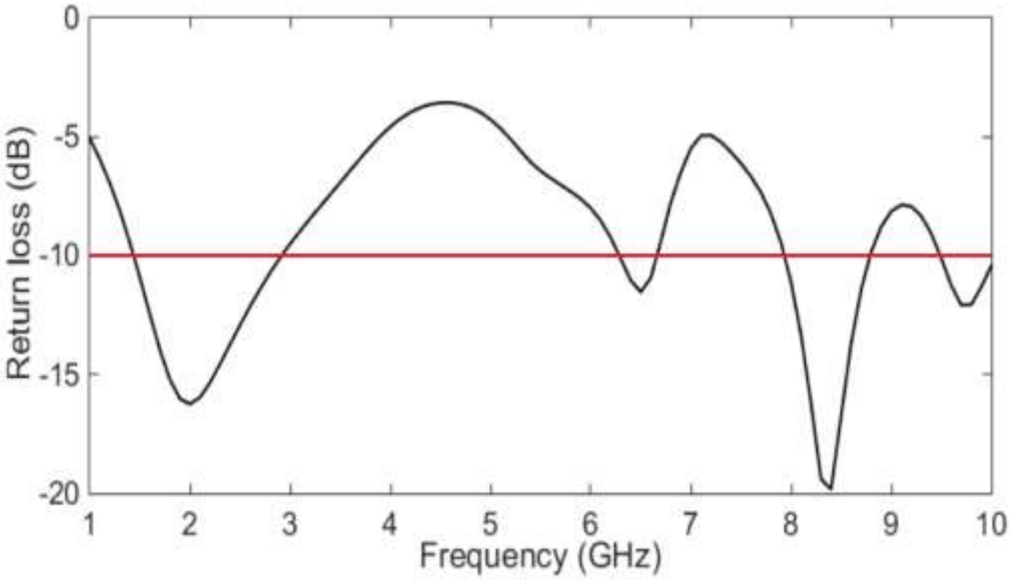

Figure 6. Return loss plot of proposed antenna with H_L=2.0mm

3.2 Radiation Pattern and Gain

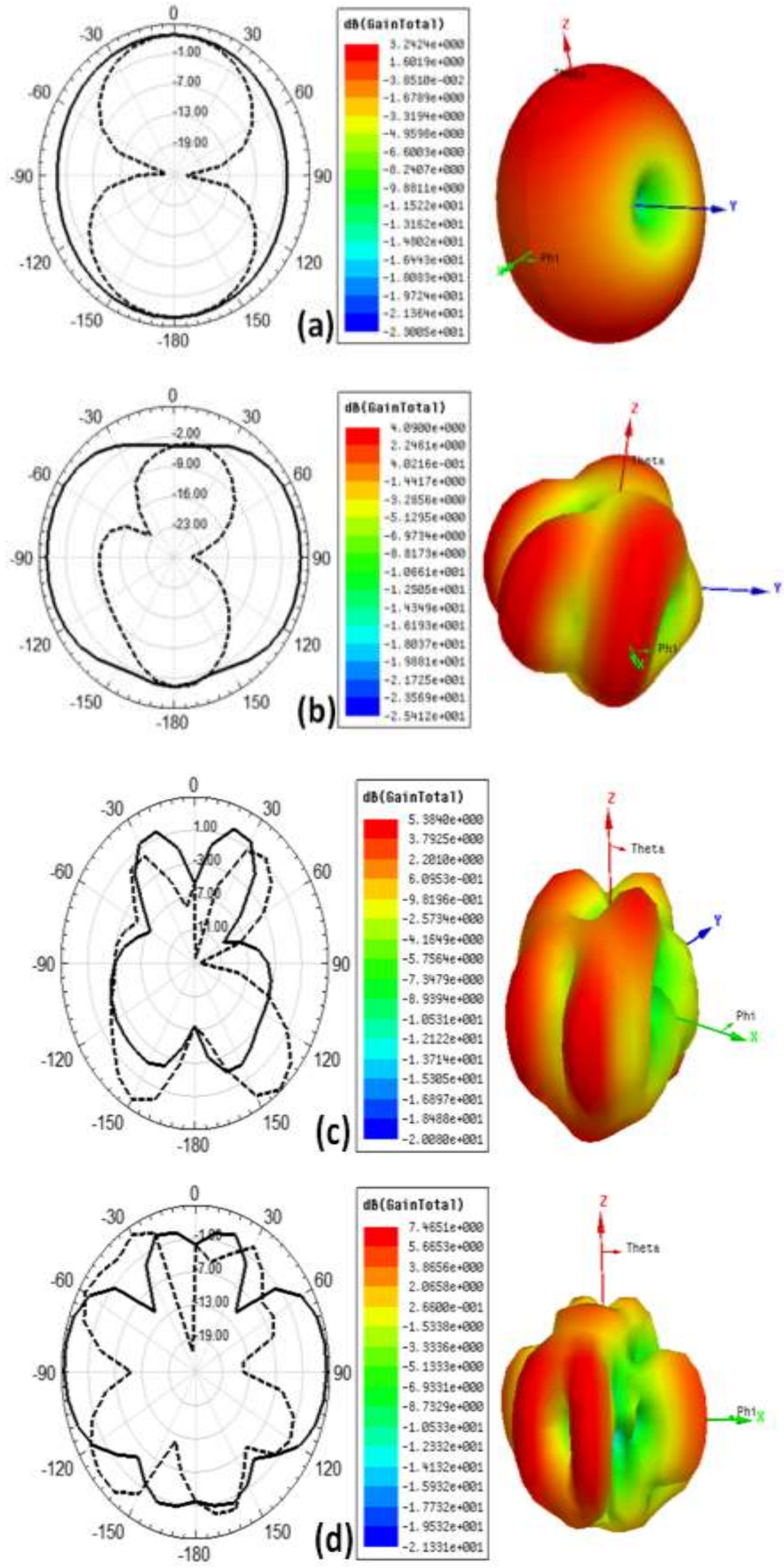

Figure 7. 2D and 3D radiation pattern of proposed antenna; (a) 2.21GHz and (b) 7.06GHz

The simulated 2D radiation pattern in H-plane and E-plane at 2.0GHz, 6.5GHz, 8.4GHz and 9.7GHz are shown in Fig. 7 (a), (b), (c) and (d) respectively. It is observed that the pattern is almost omnidirectional at lower frequency band as well as at the second frequency band. As the frequency of proposed antenna increases, the radiation pattern gets distorted due to the adjacent frequency bands. At the frequency band of 2GHz the antenna exhibits the bi-directional radiation pattern for phi = 90^o. It is also observed that the proposed antenna exhibits acceptable value of gain at all the frequency bands of operation. It shows 3.24dB, 4.09dB, 5.38dB and 7.46dB of gain at 2.0GHz, 6.5GHz, 8.4GHz and 9.7GHz frequency bands respectively. The values of gain at different values of H_L parameters have been shown in Table 2.

Conclusion

A design of novel rectangular patch antenna with fractal techniques for wideband applications has been presented and investigated in this manuscript. The partial ground plane has been employed in the geometry of proposed antenna to enhance the bandwidth. Gap between the ground plane and patch has also been varied to increase the bandwidth and it has been observed that the antenna with gap length 2.0mm exhibits optimal results as compared to the other values. The designed antenna works on four distinct frequency bands of operation 2.0GHz, 6.5GHz, 8.4GHz and 9.7GHz with acceptable value of return loss, gain and bandwidth. It also reports the good omnidirectional radiation and bi-directional pattern at 2.0GHz frequency band of operation. Proposed antenna can be used for different wireless applications such as bluetooth (2.41 – 2.49GHz), point to point high speed wireless communication (5.92 – 8.5GHz) and X-band applications.

References

1. P. S. Bakariya and S. Dwari, “A compact super ultra wideband (UWB) printed monopole antenna,” *IEEE International Conference on Computers and Devices for Communication (CODEC)*, 2012. DOI: 10.1109/CODEC.2012.6509206.
2. D. K. Srivastava, A. Khanna and J. P. Saini, “Design of a wideband gap-coupled modified square fractal antenna,” *International Journal of Computational Electronics*, 2015. DOI: 10.1007/s10825-015-0740-y.
3. R. Bhargavi, K. Sankar and S. A. Samson, “Compact triple band H-shaped slotted circular patch antenna,” IEEE International Conference on Communication and Signal Processing, 2014, pp. 1159 – 1162.
4. S. S. Bhatia and J. S. Sivia, “A novel design of circular monopole antenna for wireless applications,” *Wireless Personal Communication an International Journal*, vol. 91, no. 3, pp. 1153 – 1161, Jul. 2016.
5. R. Wang, J. Wang, R. Xie, X. Wang, Z. Xu and S. Zhu, “A novel miniaturized microstrip antenna using interdigital capacitor based on defected ground structure,” Progress In Electromagnetic Research Symposium, pp. 450 – 453, 2016.
6. G. Bharti, S. Bhatia and J. S. Sivia, “Analysis and design of triple band compact microstrip patch antenna with fractal elements for wireless applications,” *International Conference on Computational Modeling and Security (CMS): Elsevier Computer Science Procedia*, vol. 85, pp. 380 – 385, 2016.
7. T. Shanmuganantham, K. Balamanikandan and S. Raghavan, “CPW fed slot antenna for wideband applications,” *International Journal of Antenna and Propagation*, vol. 2008, pp. 1 – 4, 2008.
8. P. R. Prajapati, G. G. Krishna Murthy, A. Patnaik and M. V. Kartikeyan, “Design and testing of a compact circularly polarized microstrip antenna with fractal defected ground structure for L-band applications,” *IET Microwave, Antenna and Propagation*, vol. 9, no. 11, pp. 1179 – 1185, 2015.
9. J. Abraham, A. K. K. John and T. Mathew, “Microstrip antenna based on durer pentagon fractal patch for multiband wireless applications,” *International Conference on Information Communication and Embedded Systems (ICICES)*, 2014. DOI: 10.1109/ICICES.2014.7033976.
10. W. C. Liu, C. M. Wu and Y. Dai, “Design of triple frequency microstrip fed monopole antennas using defected ground structure,” *IEEE Transactions on Antenna and Propagation*, vol. 59, no. 7, pp. 2457 – 2463, Jul. 2011.

11. S. Behera and D. Barad, "A novel design of microstrip fractal antenna for wireless sensor network," *IEEE International Conference on Computation of Power, Energy, Information and Communication*, pp. 0470 – 0473, 2015.
12. P. Kumar, A. Kumar and P. Bhardwaj, "Design of double C shaped microstrip antenna for application in UWB region," *IEEE International Conference on Communications and Signal Processing (ICCSP)*, pp. 0406 – 0408, 2015. DOI: 10.1109/ICCSP.2015.7322918.
13. A. Goyal, R. Kumar, K. Gupta and D. K. Singh, "A triple band stacked patch antenna with slotted ground structure," *International Conference on Futuristic Trend in Computational Analysis and Knowledge Management*, pp. 556 – 560, 2015.
14. S. K. Jose and S. Suganthi, "Rectangular microstrip antenna for WLAN application," *IEEE International Conference on Innovations in Information Embedded and Communication System*, 2015.
15. S. Mishra, P. Wankhade and A. Sahu, "Design and analysis of T and U shaped slots with truncated corner rectangular microstrip patch antenna for return loss enhancement, *Symposium on Colossal Data Analysis and Networking*, 2016.
16. R. K. Pandey and T. Shanmuganantham, "Miniaturization and bandwidth enhancement of a wideband slotted microstrip patch antenna," *International Conference on Circuit, Power and Computing Technologies*, 2016.
17. N. Mahmoud and E. K. I. Hamad, "Tri band microstrip antenna with L-shaped slots for bluetooth/WLAN/WiMAX applications," *National Radio Science Conference*, pp. 73 – 80, Feb. 2016.
18. T. Benyetho, L. E. Abdellaoui, J. Zbitou, H. Bennis, A. Tribak and M. Latrach, "Design of a new multiband planar fractal antenna array for wireless power transmission," *IEEE International Renewable and Sustainable Energy Conference*, 2016.
19. Sharma N and Sharma V, "A design of Microstrip Patch Antenna using hybrid fractal slot for wideband applications" Ain Shams Eng J (2017), http://dx.doi.org/10.1016/j.asej.2017.05.008
20. C. A. Balanis, Antenna theory: *Analysis and Design* (2nd ed.). London: Wiley, 1997.