Single Layer Monopole Hexagonal Microstrip Patch Antenna for Direct Broadcast Satellite (DBS) System

Supriya Jana[1], Bipadtaran Sinhamahapatra[2], Sudeshna Dey[3], Arnab Das[4], Bipa Datta[5], Moumita Mukherjee[6], Samiran Chatterjee[7]

[1,2,3,4,5]ECE Department, West Bengal University of Technology, Brainware Group of Institutions, Barasat, West Bengal, India.

[6]Centre for Millimeter wave Semiconductor Devices and Systems, University of Calcutta, West Bengal, India

[^7]University of Kalyani, Kalyani, West Bengal, India.

Abstract:

In recent years, great interest was focused on microstrip antennas for their small volumes, low profiles, excellent integration, low costs and good performance. With the continuous growth of wireless communication service and the constant miniaturization of communication equipment, there are higher and higher demands for the volume of antennas, integration and working band. This paper presents a single layer monopole hexagonal microstrip patch antenna is thoroughly simulated for wireless communications system application which are suitable for the 13.71GHz operations. These systems may include direct broadcast satellite (DBS) system, also known as "Direct-To-Home". DBS systems are commonly referred to as "mini-dish" systems. DBS uses the upper portion of the Ku band. The initial design and optimization of the patch antenna is operating in Ku band (12-18GHz).It has been performed in Zeland IE3D software.

Keywords: Compact, Patch, Slot, Resonant frequency, Bandwidth, DBS System.

1. INTRODUCTION

In recent years, demand for small antennas on wireless communication has increased the interest of research work on compact microstrip antenna design among microwave and wireless engineers [1-6]. Because of their simplicity and compatibility with printed-circuit technology microstrip antennas are widely used in the microwave frequency spectrum. Simply a microstrip antenna is a rectangular or other shape, patch of metal on top of a grounded dielectric substrate. Microstrip patch antennas are attractive in antenna applications for many reasons. They are easy and cheap to manufacture, lightweight, and planar to list just a few advantages. Also they can be manufactured either as a stand-alone element or as part of an array. However, these advantages are offset by low efficiency and limited bandwidth. In recent years much research and testing has been done to increase both the bandwidth and radiation efficiency of microstrip antennas.

Due to the recent interest in broadband antennas a microstrip patch antenna [7-8] was developed to meet the need for a cheap, low profile, broadband antenna. This antenna could be used in a wide range of applications such as in the communications industry for cell phones or satellite communication. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. The proposed antenna (substrate with ε_r = 4.4) has a gain of 3.19 dBi and presents a size reduction of 56.55% when compared to a conventional microstrip patch (10mm X 6mm). The simulation has been carried out by IE3D [19] software which uses the MoM method. Due to the small size, low cost and low weight this antenna is a good entrant for the application of X-Band microwave communication and Ku-Band RADAR communication & satellite communication. The X band and Ku-Band defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 8.0 to 12.0 GHz and 12.0 to 18.0 GHz respectively[10]. The X band is used for short range tracking, missile guidance, marine, radar and air bone intercept. Especially it is used for radar communication ranges roughly from 8.29 GHz to 11.4 GHz. The Ku band [11-18] is used for high resolution mapping and satellite altimetry. Especially, Ku Band is used for tracking the satellite within the ranges roughly from 12.87 GHz to 14.43 GHz. In this paper the microstrip patch antenna is designed for use in a satellite TV at 13.7173 GHz. The results obtained provide a workable antenna design for incorporation in a satellite TV. We consider the satellite TV has two different bands one is FSS-band and another is DBS-band. The DBS systems can also run on C-band satellites and have been used by some networks in the past to get around legislation by some countries against reception of Ku-band transmissions.

2. ANTENNA DESIGN

The configuration of the conventional printed antenna is shown in Figure 1 with L=6 mm, W=10 mm, substrate (PTFE) thickness h = 1.6 mm, dielectric constant ε_r = 4.4. Coaxial probe-feed (radius=0.5mm) is located at W/2 and L/3. Assuming practical patch width W= 10 mm for efficient radiation and using the equation [6],

$$f_r = \frac{c}{2W} \times \sqrt{\frac{2}{(1+\varepsilon_r)}}$$

Where, c = velocity of light in free space. Using the following equation [9] we determined the practical length L (=6mm).

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

Where, $\frac{\Delta L}{h} = \left[0.412 \times \frac{(\varepsilon_{reff}+0.3)\times(W/h+0.264)}{(\varepsilon_{reff} - 0.258)\times(W/h+0.8)}\right]$

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

and $L_{eff} = \left[\frac{c}{2\times f_r \times \sqrt{\varepsilon_{eff}}}\right]$

Where, L_{eff} = Effective length of the patch, $\Delta L/h$ =Normalized extension of the patch length, ε_{reff} = Effective dielectric constant.

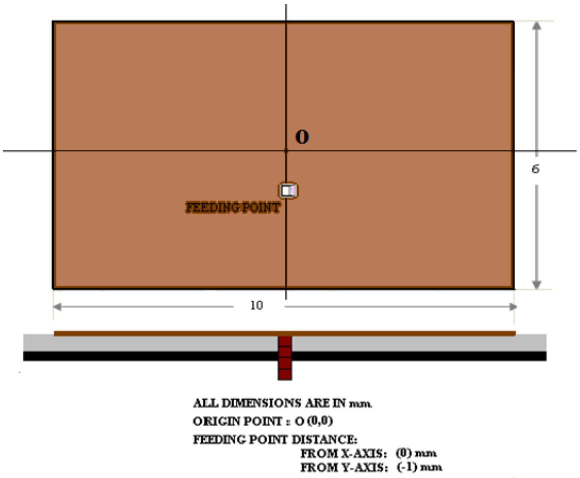

Figure 1: Conventional Antenna configuration

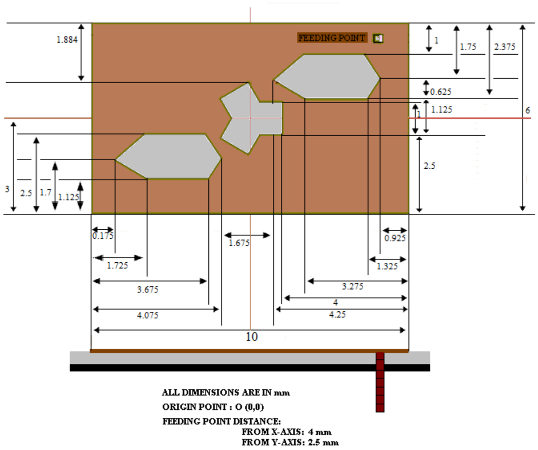

Figure 2: Simulated Antenna configuration

Figure 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. Two equal slots which are the combinations of two triangular and a rectangular slot at the upper right and lower left corner and the location of coaxial probe-feed (radius=0.5 mm) are shown in the figure 2.

3. Results And Discussion

Simulated (using IE3D [19]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved in simulated antenna with respect to the conventional antenna structure.

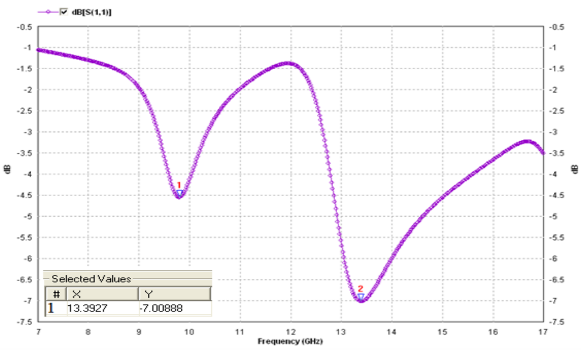

Figure 3: Return Loss vs. Frequency (Conventional Antenna)

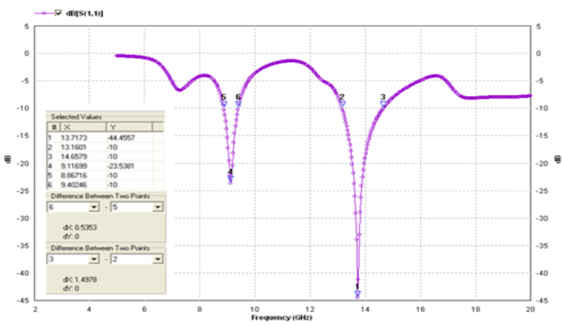

Figure 4: Return Loss vs. Frequency (Slotted Antenna)

In the conventional antenna return loss of about -7.01 dB is obtained at 13.39 GHz. Comparing fig.3 and fig.4 it may be observed that for the conventional antenna (fig.3), there is practically no resonant frequency at around 9.12 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 9.12 GHz where the return loss is as high as -23.43 dB.

Due to the presence of slots in simulated antenna resonant frequency operation is obtained with large values of frequency ratio. The first and second resonant frequency is obtained at f_1= 9.12 GHz with return loss of about -23.43 dB and at f_2 =

13.71 GHz with return losses -44.457 dB respectively. Corresponding 10dB band width obtained for Antenna 2 at f1, f2 are 535.30 MHz and 1.49 GHz respectively. The simulated E plane and H-plane radiation patterns are shown in Figure 5-16. The simulated E plane radiation pattern of simulated antenna for 9.12GHz is shown in figure 5.

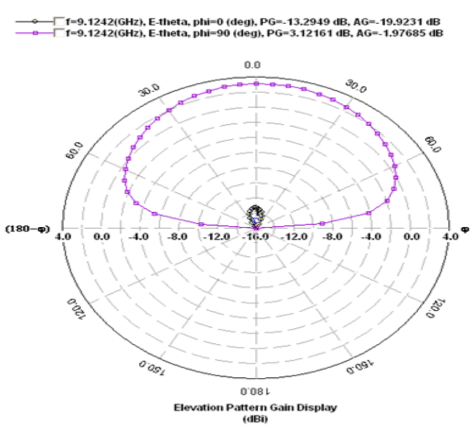

Figure 5: E-Plane Radiation Pattern for Slotted Antenna at 9.1242 GHz

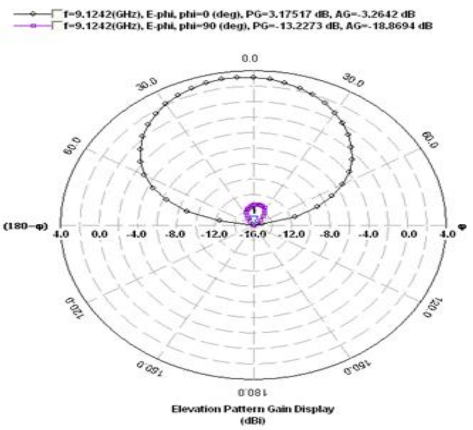

Figure 6: H-Plane Radiation Pattern for slotted Antenna at 9.1242 GHz

The simulated H plane radiation pattern of simulated antenna for 9.12 GHz is shown in figure 6.
The simulated E -plane & H-plane radiation pattern (3D) of simulated antenna for 9.12 GHz is shown in figure 7 & figure 8.

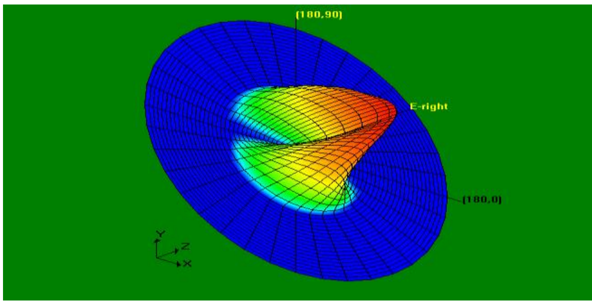

Figure 7: E-Plane Radiation Pattern (3D) for slotted antenna at 9.12GHz

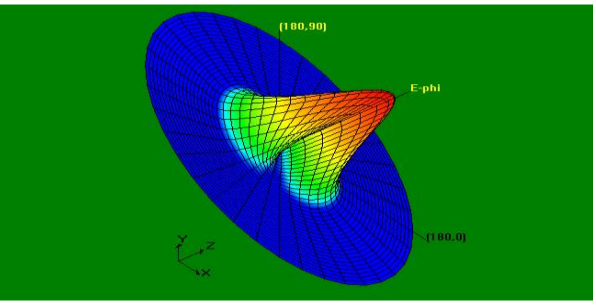

Figure 8: E-Plane Radiation Pattern (3D) for slotted antenna at 9.12 GHz

The simulated E plane radiation pattern of slotted antenna for 13.71 GHz is shown in figure 9. The simulated H plane radiation pattern of slotted antenna for 13.71 GHz is shown in figure10.

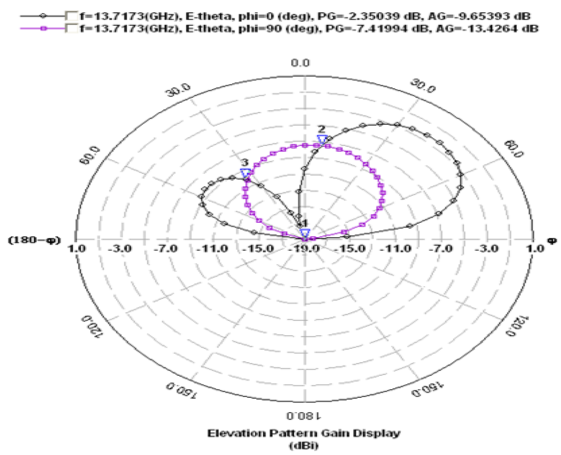

Figure9: E-Plane Radiation Pattern for slotted antenna at 13.71 GHz

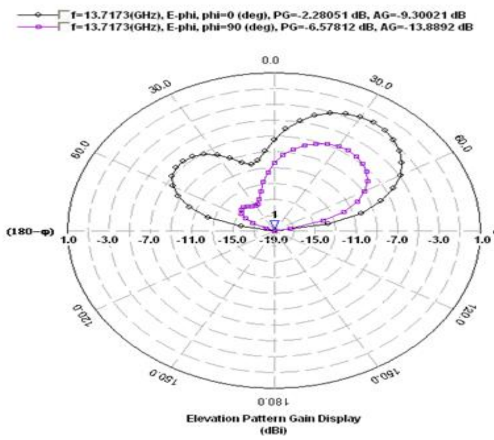

Figure 10: H-Plane Radiation Pattern for slotted antenna at 13.71 GHz

The simulated E -plane & H-plane radiation pattern (3D) of simulated antenna for 13.71 GHz is shown in figure 11 & figure 12.

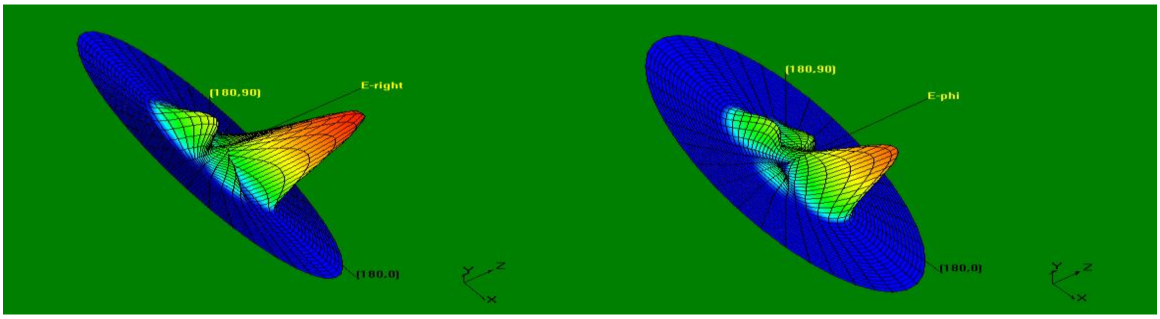

Figure11: E-Plane Radiation Pattern for slotted antenna at 13.71 GHz

Figure 12: H-Plane Radiation Pattern for slotted antenna at 13.71 GHz

The simulated smith chart and VSWR of simulated antenna shown in figure 13 & figure 14.

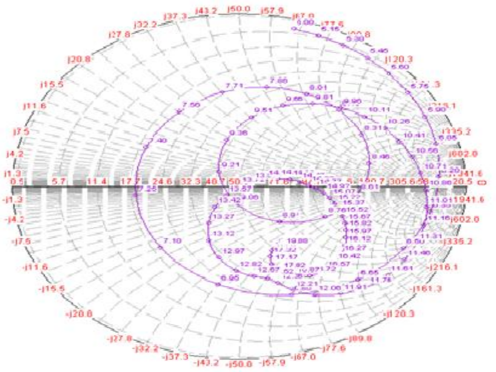

Figure13: Simulated Smith Chart for slotted antenna

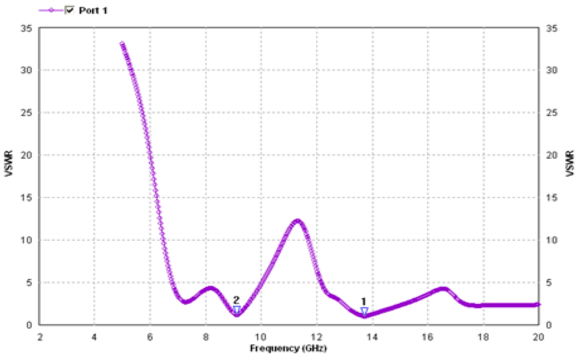

Figure 14: Simulated VSWR for slotted antenna

The simulated E -plane & H-plane radiation pattern (2D) of simulated antenna for 13.71 GHz is shown in figure 15 & figure 16.

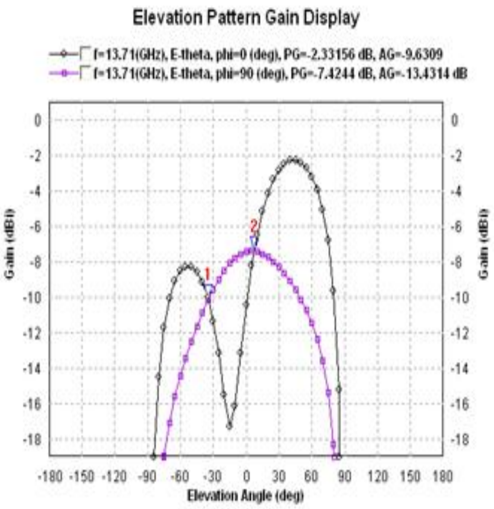

Figure9: E-Plane Radiation Pattern (2D) for slotted antenna at 13.71 GHz

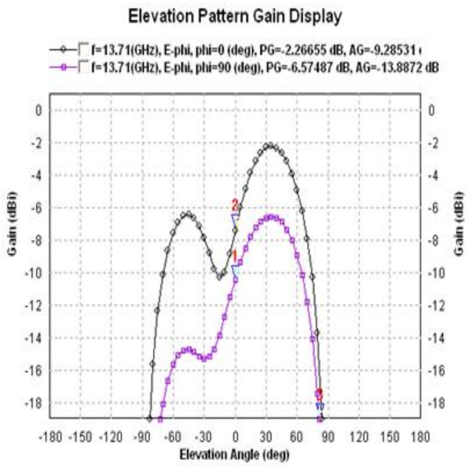

Figure 10: H-Plane Radiation Pattern (2D) for slotted antenna at 13.71 GH

All the simulated results are summarized in the following Table1 and Table2.

TABLE I: SIMULATED RESULTS FOR ANTENNA 1 AND 2 w.r.t RETURN LOSS

ANTENNA STRUCTURE	**RESONANT FREQUENCY (GHz)**	**RETURN LOSS (dB)**	**10 DB BANDWIDTH (GHz)**
Conventional	f_1= 13.39	-7.00	NA
Slotted	f_1= 9.1242	-23.43	0.5353
	f_2 =13.7173	-44.457	1.4978

TABLE II: SIMULATED RESULTS FOR ANTENNA 1 AND 2 w.r.t RADIATION PATTERN

ANTENNA STRUCTURE	**RESONANT FREQUENCY (GHz)**	**3DB BEAMWIDTH (^{0})**	**ABSOLUTE GAIN *(dBi)***
Conventional	f_1= 13.39	NA	NA
Slotted	f_1= 9.1242	162.914	3.19137
	f_2 =13.7173	64.47	0.627052
Frequency Ratio for Slotted Antenna			f_2 / f_1 =1.5034

4. Conclusion

This paper focused on the simulated design on differentially-driven microstrip antennas. Simulation studies of a single layer monopole hexagonal microstrip patch antenna have been carried out using Method of Moment based software IE3D. Introducing slots at the edge of the patch size reduction of about 56.55% has been achieved. The 3dB beam-width of the radiation patterns are 162.914° (for f_1), 64.47° (for f_2) which is sufficiently broad beam for the applications for which it is intended. The resonant frequency of slotted antenna, presented in the paper, designed for a particular location of feed point (4mm, 2.5mm) considering the centre as the origin. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances.

5. Acknowledgement

M. Mukherjee wishes to acknowledge Defense Research and Development Organization (DRDO, Ministry of Defense), Govt. of India for their financial assistance.

References

[1] I.Sarkar, P.P.Sarkar, S.K.Chowdhury "A New Compact Printed Antenna for Mobile Communication", 2009 Loughborough Antennas& Propagation Conference, 16-17 November 2009, pp 109-112.

[2] S. Chatterjee, U. Chakraborty, I.Sarkar, S. K. Chowdhury, and P.P.Sarkar, "A Compact Microstrip Antenna for Mobile Communication", IEEE annual conference. Paper ID: 510

[3] J.-W. Wu, H.-M. Hsiao, J.-H. Lu and S.-H. Chang, "Dual broadband design of rectangular slot antenna for 2.4 and 5 GHz wireless communication", IEE Electron. Lett. Vol. 40 No. 23, 11th November 2004.

[4] U. Chakraborty, S. Chatterjee, S. K. Chowdhury, and P. P. Sarkar, "A comact microstrip patch antenna for wireless communication," Progress In Electromagnetics Research C, Vol. 18, 211-220, 2011 http://www.jpier.org/pierc/pier.php?paper=10101205

[5] Rohit K. Raj, Monoj Joseph, C.K. Anandan, K. Vasudevan, P. Mohanan, " A New Compact Microstrip-Fed Dual-Band Coplaner Antenna for WLAN Applications", IEEE Trans. Antennas Propag., Vol. 54, No. 12, December 2006, pp 3755-3762.

[6] Zhijun Zhang, Magdy F. Iskander, Jean-Christophe Langer, and Jim Mathews, "Dual-Band WLAN Dipole Antenna Using an Internal Matching Circuit", IEEE Trans. Antennas and Propag.,VOL. 53, NO. 5, May 2005, pp 1813-1818.

[7] J. -Y. Jan and L. -C. Tseng, " Small planar monopole Antenna with a shorted parasitic inverted-L wire for Wireless communications in the 2.4, 5.2 and 5.8 GHz. bands" , IEEE Trans. Antennas and Propag., VOL. 52, NO. 7, July 2004, pp -1903-1905.

[8] Samiran Chatterjee, Joydeep Paul, Kalyanbrata Ghosh, P. P. Sarkar and S. K. Chowdhury "A Printed Patch Antenna for

Mobile Communication", Convergence of Optics and Electronics conference, 2011, Paper ID: 15, pp 102-107

[9] C. A. Balanis, "Advanced Engineering Electromagnetics", John Wiley & Sons., New York, 1989.

[10] Bipa Datta, Arnab Das, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, "Design of Compact Patch Antenna for Multi-Band Microwave Communication", National Conference on Sustainable Development through Innovative Research in Science and Technology (Extended Abstracts), Paper ID: 115, pp 155, 2012

[11] Arnab Das, Bipa Datta, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, "Multi-Band Microstrip Slotted Patch Antenna for Application in Microwave Communication," International Journal of Science and Advanced Technology(IJSAT), (ISSN 2221-8386), Vol. 2, Issue-9, 91-95, September 2012.

[12] Bipa Datta, Arnab Das, S.Chatterjee, B. Sinhamahapatra, S. Jana, M. Mukherjee, S. Kr. Chowdhury "Monopole Slotted Patch Antenna for Microwave Communication," International Journal of Scientific and Research Publications (IJSRP), ISSN 2250-3153, Volume 2, Issue 11, November 2012.

[13] Bipa Datta, Arnab Das, S.Chatterjee, M. Mukherjee, S. Kr. Chowdhury"A Monopole Printed Antenna for Tracking the Satellite," International Journal on Electronics & Communication Technology (IJECT), ISSN: 2230-7109 (Online) | ISSN: 2230-9543 (Print), IJECT Vol. 3, Issue 4, Oct - Dec 2012, PP 57-63.

[14] Arnab Das, Bipa Datta, Samiran Chatterjee, Moumita Mukherjee, Santosh Kumar Chowdhury, "A Dual- Band Size Deducted Slotted Patch Antenna for Application in Microwave Communication," International Journal on Electronics & Communication Technology, , ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print), IJECT Vol. 3, Issue 4, Oct - Dec 2012, PP 51-56.

[15] Bipa Datta, Arnab Das, Samiran Chatterjee, Moumita Mukherjee, Santosh Kumar Chowdhury, "A Monopole Printed Antenna for Tracking the Satellite," International Journal on Electronics & Communication Technology, , ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print), IJECT Vol. 3, Issue 4, Oct - Dec 2012, PP 57-63.

[16] Bipa Datta, Arnab Das, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, "Design of Single layer, Single Feed Slotted Patch Antenna for Microwave Communication", International Symposium on Microwaves-2012 (ISM-12) Paper ID: 106, 2012.

[17] Bipa Datta, Arnab Das, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, "A Compact Multi-resonant Microstrip Antenna", National Conference on Antennas and Propagation Symposium (APSYM-2012), Paper ID: 13102, 2012.

[18] Bipa Datta, Arnab Das, Samiran Chatterjee, Moumita Mukherjee, Santosh Kumar Chowdhury, "Monopole Slotted Patch Antenna for Microwave Communication," International Journal of Scientific and Research Publications (IJSRP) ISSN 2250-3153, Volume 2, Issue 11, November 2012.

[19] Zeland Software Inc. IE3D: MoM-Based EM Simulator. Web: http://www.zeland.com/