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The Application of Ku-band VSAT Systems to Single Layer Hexagonal Micro strip Patch Antenna

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Abstract: *The application of Ku-band VSAT Systems to single layer hexagonal micro strip patch antenna is thoroughly simulated in this paper. The radiating elements in this antenna are composed of two triangular and one rectangular slots from the conventional micro strip patch antenna. These slots are engraved in the rectangular and triangular patch, joined together in two structures, and by single probe feed. The rectangular and triangular slots make the antenna to operate at multiband with relatively high gain. Therefore, this antenna can be used for wireless communication applications like WLAN, WiMax, radar system applications, satellite communication and VSAT systems. The initial design and optimization of the prototype operating in Ku-band has been performed in planar simulator Zeland IE3D software. The simulated antenna size has been reduced by 52.64% with an increased frequency ratio.*

Keywords: *Compact, Gain, Patch, Slot, Resonant frequency, Bandwidth.*

I. INTRODUCTION

Micro strip patch antennas have a huge number of advantageous features, their narrow bandwidths, however, has been one of the most noticeable limitations hindering their wider applications [1-8], such as mobile cellular telephones, cordless phones, pagers, WLAN and mobile radios. Because of their simplicity and compatibility with printed-circuit technology micro strip antennas are widely used in the microwave frequency spectrum. Simply a micro strip antenna is a rectangular or other shape, patch of metal on top of a grounded dielectric substrate. Micro strip 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. Throughout the years, authors have dedicated their investigations to creating new designs or variations to the original antenna that, to some extent, produce wider bandwidth and radiation efficiency of micro strip antennas.

The recent interest in broadband antennas as a micro strip patch antenna [10-13] 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 [18-20] 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 $\varepsilon_r = 4.4$) has a gain of 3.19 dBi and presents a size reduction of 52.64% when compared to a conventional micro strip patch antenna (10mm X 6mm). A logical approach, therefore, is to use a thick substrate or replacing the substrate by air or thick foam, dielectric constants are usually in the range of ($2.2 \le \varepsilon_r \le 12$)[9]. 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.

Ku-Band [12-18GHz] is used for most VSAT systems on yachts and ships today. VSAT Vessels moving from region to region need to change satellite beams, sometimes with no coverage in between beams. VSAT Antenna sizes typically range from the standard 1 meter to 1.5. Some frequencies in this radio band are used for vehicle speed detection by law enforcement, especially in Europe.

Generally, VSAT technology can be applied in the following aspects. It can be applied for popularizing satellite television broadcast and satellite television [14-17], and transmitting signal of broadcast television and business television, financial system and securities system to dynamically track and manage market situation, which greatly shortens cash conversion cycle, water conservancy to manage and hydrological change in order to prevent and reduce natural disaster, meteorological satellite, maritime satellite, resource satellite and ground detection station ,military, emergency communication and communication in remote areas. VSAT is the most convenient emergency communication backup system for natural disaster or emergency incident.

II. 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 $\varepsilon_r = 4.4$. 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) & width W (=10mm).

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

$$W = \frac{c}{2f\sqrt{(\mathcal{E}_r + 1)/2}}$$

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

$$\mathcal{E}_{reff} = \left[\left(\frac{\mathcal{E}_{\mathrm{r}}+1}{2}\right) + \frac{\mathcal{E}_{\mathrm{r}}-1}{\left(2\times\sqrt{\left(1+12\times\frac{h}{W}\right)}\right)}\right]$$

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

Where, $\mathrm{L_{eff}}$ = Effective length of the patch, ΔL/h =Normalized extension of the patch length, $\varepsilon_{\mathrm{reff}}$ = Effective dielectric constant.

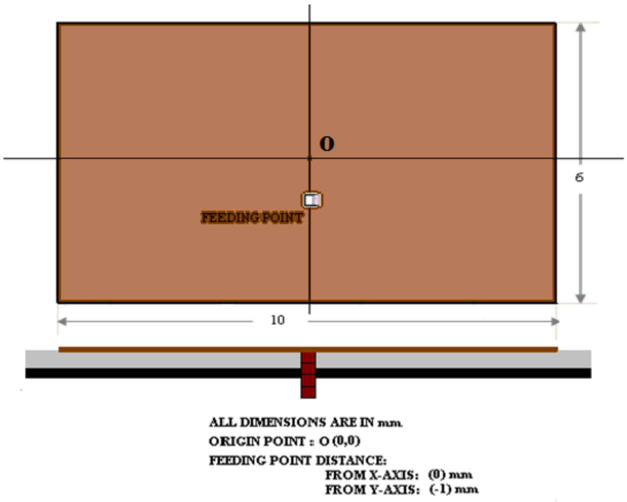


Figure 1: Conventional Antenna configuration

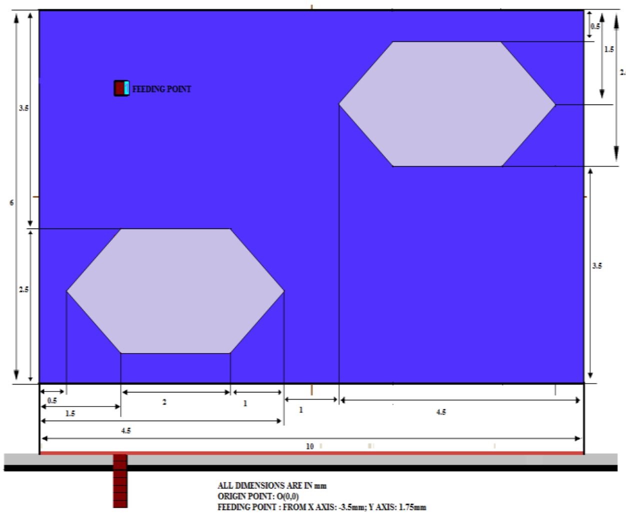
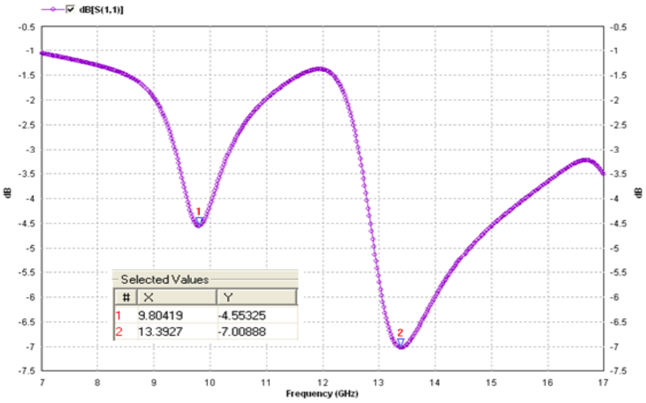


Figure 2: Simulated Antenna configuration

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.

III. RESULTS AND DISCUSSION

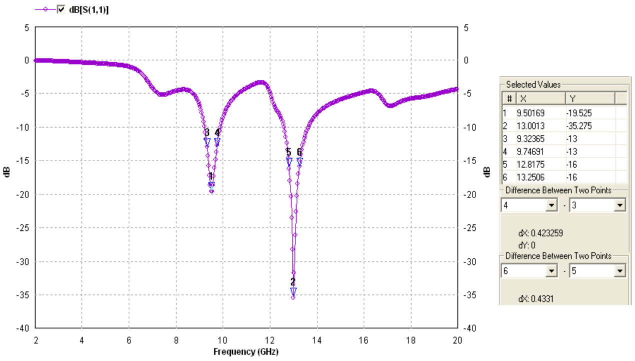
Simulated (using IE3D [21]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved in simulated antenna with respect to the conventional antenna structure.



Selected Values

#	X	Y
1	9.80419	-4.55325
2	13.3927	-7.00888

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



Selected Values

#	X	Y
1	9.50169	-19.525
2	13.0013	-35.275
3	9.32365	-13
4	9.74691	-13
5	12.8175	-16
6	13.2506	-16

Difference Between Two Points
4 - 3
dX: 0.423259
dY: 0
Difference Between Two Points
6 - 5
dX: 0.4331

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 9.50 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 9.50169 GHz where the return loss is as high as -19.525 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= 9.50169 GHz with return loss of about -19.525 dB and at f_2 = 13.0013 GHz with return losses -35.275 dB respectively.

Corresponding 10dB band width obtained for Antenna 2 at f1, f2 are 423.259 MHz and 0.4331 GHz respectively. The simulated E plane and H-plane radiation patterns are shown in Figure 5-14. The simulated E plane radiation pattern of simulated antenna for 9.50169 GHz is shown in figure 5.

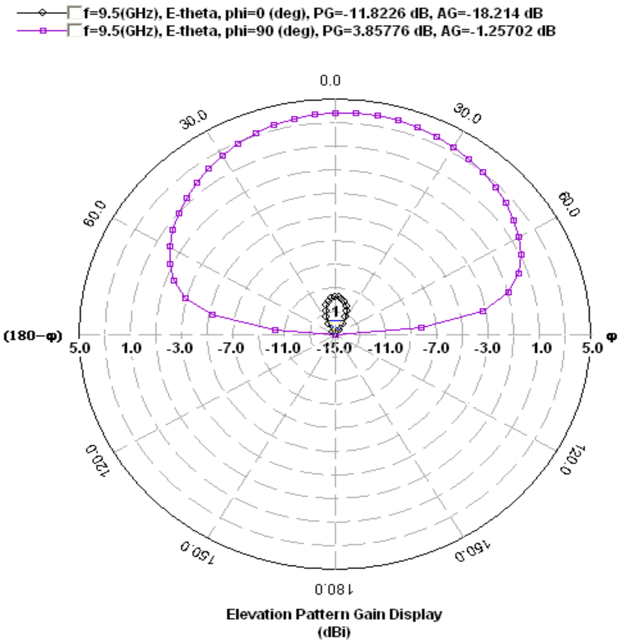


Figure 5: E-Plane Radiation Pattern for Slotted Antenna at 9.50 GHz

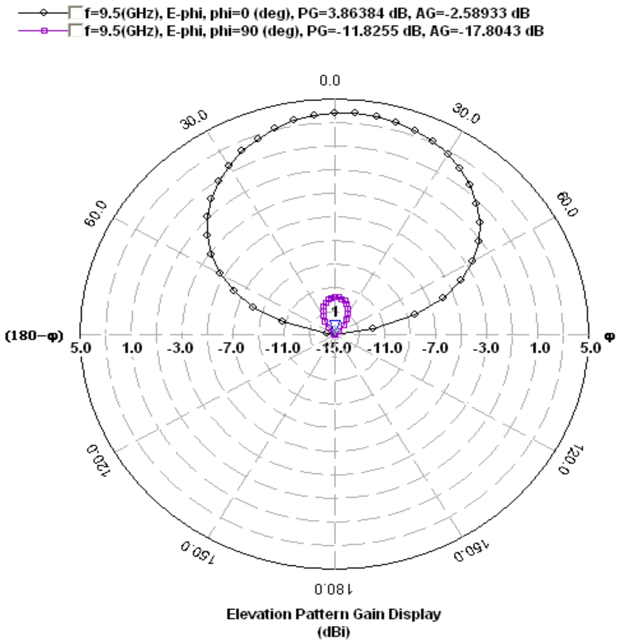


Figure 6: H-Plane Radiation Pattern for slotted Antenna at 9.50 GHz

The simulated H plane radiation pattern of simulated antenna for 9.50169 GHz is shown in figure 6.The simulated E plane radiation pattern of slotted antenna for 13.0013 GHz is shown in figure 7. The simulated H plane radiation pattern of slotted antenna for 13.0013 GHz is shown in figure 8.

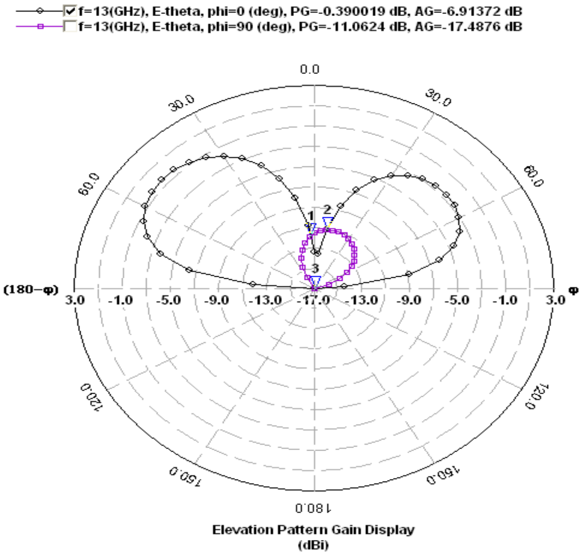


Figure7: E-Plane Radiation Pattern for slotted antenna at 13 GHz

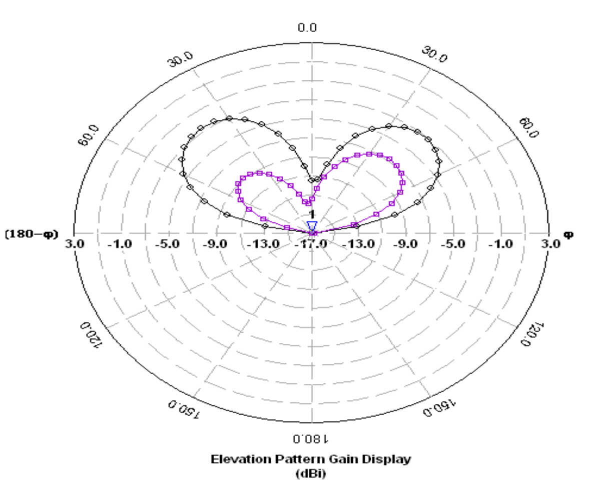


Figure 8: H-Plane Radiation Pattern for slotted antenna at 13 GHz

The simulated Cartesian E -plane & H-plane radiation pattern (2D) of simulated antenna for 9.50169 GHz is shown in figure 9 & figure 10.

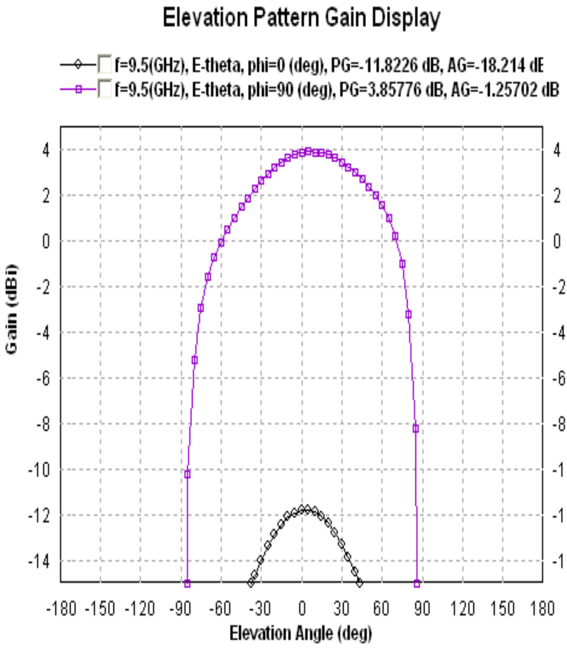


Figure 9: E-Plane Radiation Pattern (2D) for slotted antenna at 9.50 GHz

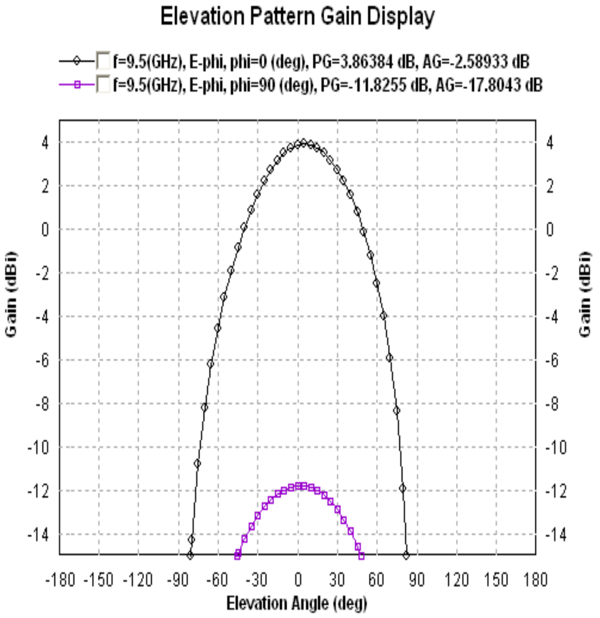
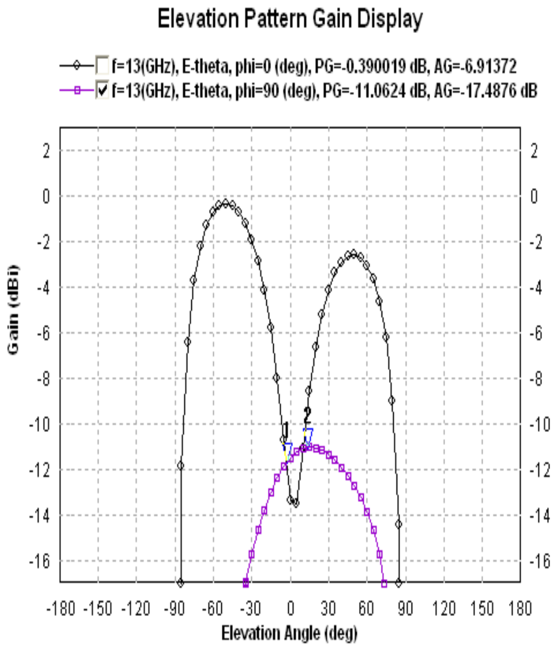


Figure 10: H-Plane Radiation Pattern (2D) for slotted antenna at 9.50 GHz

The simulated Cartesian E -plane & H-plane radiation pattern (2D) of simulated antenna for 13.0013 GHz is shown in figure 11 & figure 12.



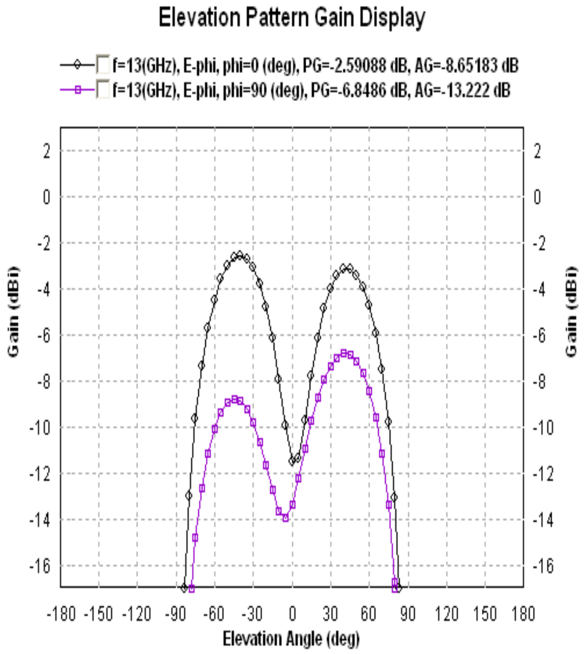
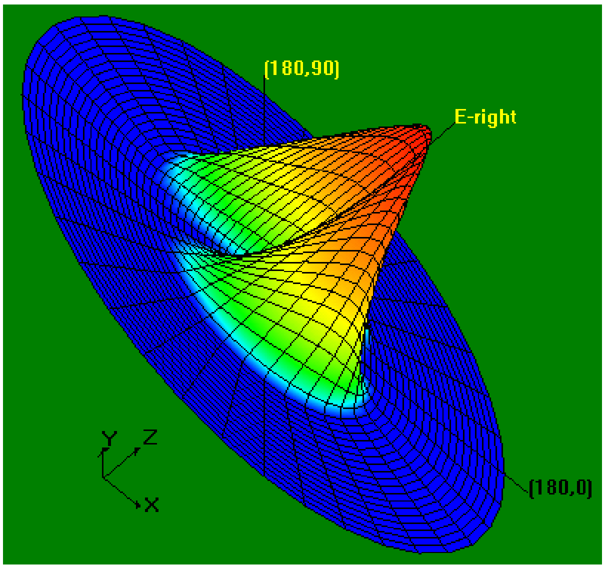


Figure 11: E-Plane Radiation Pattern (2D) for slotted antenna at 13 GHz
Figure 12: H-Plane Radiation Pattern (2D) for slotted antenna at 13 GHz

The simulated E plane & H-plane radiation pattern (3D) of simulated antenna for 9.50169 GHz is shown in figure 13 & figure 14.



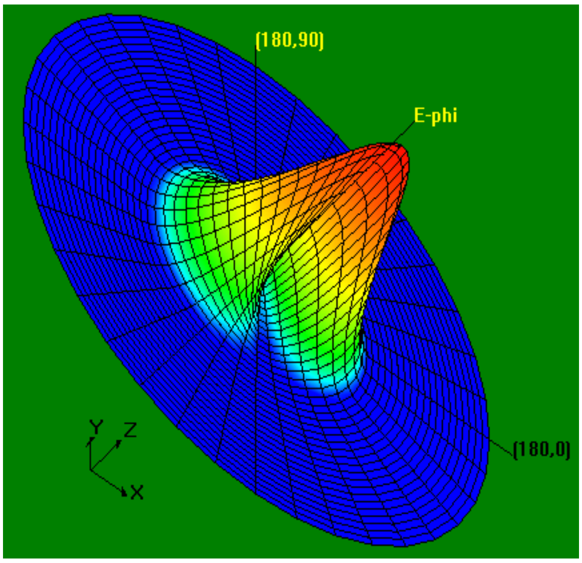
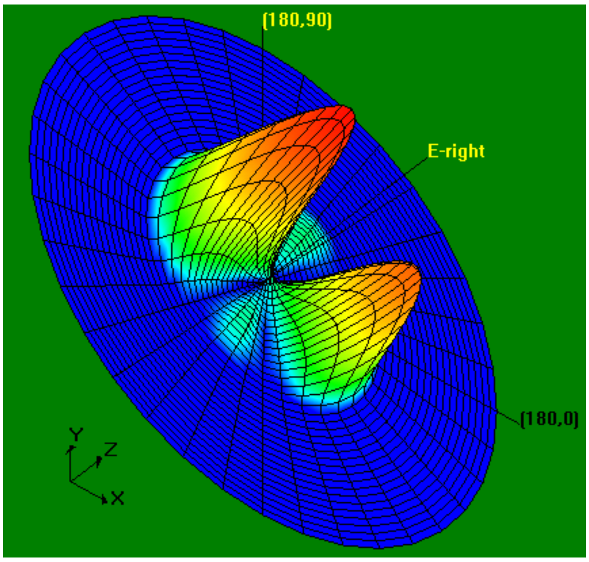


Figure 13: E-Plane Radiation Pattern (3D) for slotted antenna at 9.50 GHz
Figure 14: H-Plane Radiation Pattern (3D) for slotted antenna at 9.50 GHz

The simulated E plane & H-plane radiation pattern (3D) of simulated antenna for 13.0013 GHz is shown in figure 15 & figure 16.



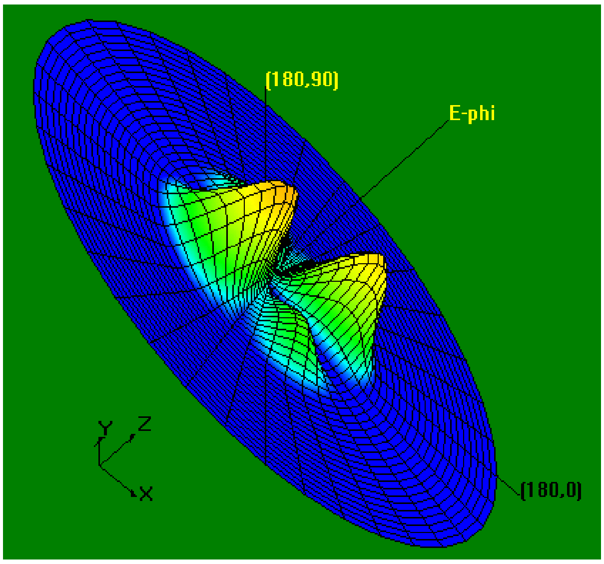


Figure 15: E-Plane Radiation Pattern (3D) for slotted antenna at 13 GHz
Figure 16: H-Plane Radiation Pattern (3D) for slotted antenna at 13 GHz

The simulated smith chart and VSWR of simulated antenna shown in figure 17 & figure 18.

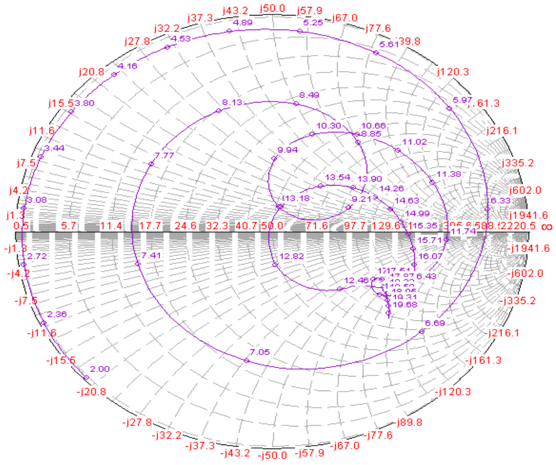
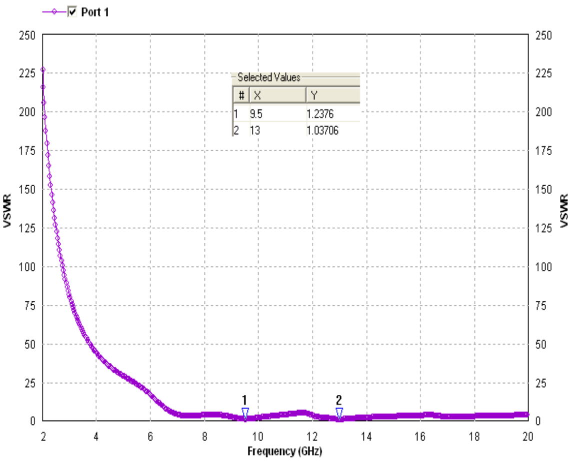


Figure17: Simulated Smith Chart for slotted antenna



Selected Values

#	X	Y
1	9.5	1.2376
2	13	1.03706

Figure 18: Simulated VSWR for slotted antenna

The simulation antenna showing the total current distribution and substrate in the following figure 19 & figure 20

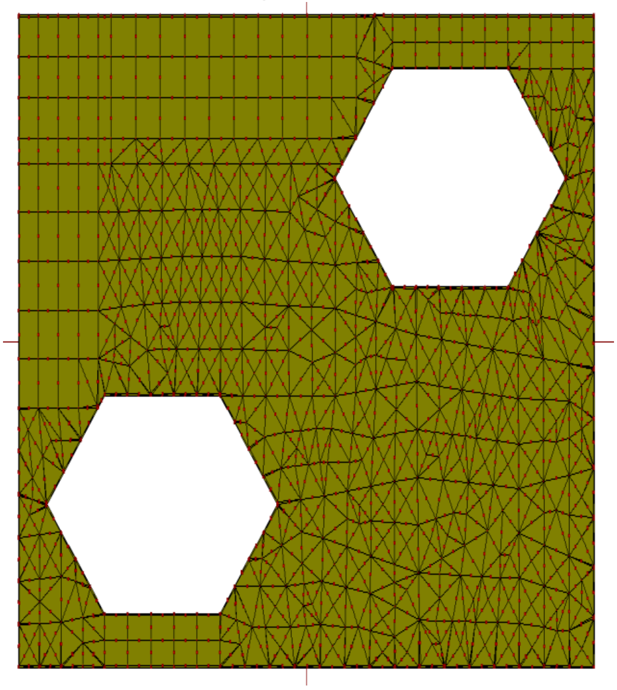


Figure 19: Total Current Distribution

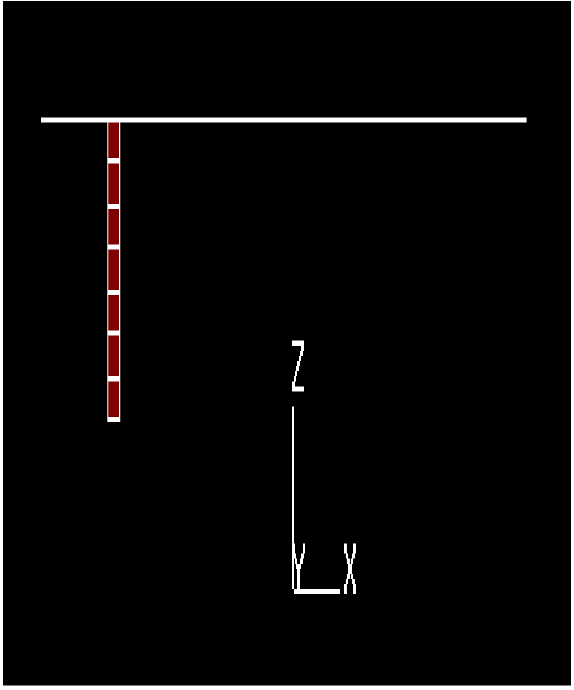


Figure 20: Substrate

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= 9.80	-4.55	NA
	f_2= 13.39	-7.01	NA
Slotted	f_1= 9.50169	-19.525	0.423259
	f_2 = 13.0013	-35.275	0.4331

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= 9.80	NA	NA
	f_2= 13.39	NA	NA
Slotted	f_1= 9.50169	132.714	3.97715
	f_2 = 13.0013	152.585	1.50649
Frequency Ratio for Conventional Antenna			$f_2 / f_1 = 1.366$
Frequency Ratio for Slotted Antenna			$f_2 / f_1 = 1.3683$

IV. CONCLUSION

This paper focused on the simulated design on differentially-driven microstrip antennas. Simulation studies of a single layer hexagonal microstrip patch antenna have been carried out using Method of Moment based software IE3D [21]. Introducing slots at the edge of the patch size reduction of about 52.64% has been achieved. The 3dB beam-width of the radiation patterns are 132.714° (for f_1), 152.585° (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 (-3.5mm, 1.75mm) considering the centre as the origin. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances.

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] James, J. R. and P. S. Hall, Handbook of Microstrip Antennas, Peter Peregrinus, London, 1989.

[8] Fujimoto, K. and J. R. James (eds.), Mobile Antenna Systems Handbook, Artech House, Norwood, MA, 1989.

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

[10] 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.

[11] 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.

[12] Supriya Jana, Bipadtaran Sinhamahapatra, Sudeshna Dey "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Fixed Service Satellite (FSS) System", 1st International e-Conference On Developments in Computer Sciences, Electronics and Communication Technologies(e-DCSECT-2013),March-2013; Organized by: Cosmic Journals; Under its : GREEN INITIATIVE PROGRAM; Published in: International Journal on Electronics & Communication Technology (IJECT), [ISSN:2230-7109(Online)] [,ISSN:2230-9543(Print)], Vol.4, Issue Spl-2 (January-March 2013),PP. 112-116; Global Impact Factor:0.306;Evaluation Score 2012: 12.31; Index Copernicus Evaluation Report 2011: 5.09.

[13] Supriya Jana , Bipadtaran Sinhamahapatra, Sudeshna Dey, Samiran Chatterjee, Arnab Das , Bipa Datta, Moumita Mukherjee, Santosh Kumar Chowdhury, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Microwave Communication", International Refereed Journal of Engineering and Science (IRJES),ISSN (Online) 2319-183X, (Print) 2319-1821 Volume 1, Issue 4(December 2012), PP.44-48.

[14] Supriya Jana, Bipadtaran Sinhamahapatra, Sudeshna Dey, Arnab Das, Bipa Datta, Moumita Mukherjee, Santosh Kumar Chowdhury, Samiran Chatterjee, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Satellite Television", International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307, Volume-2, Issue-6, January 2013, PP.321-324.

[15] Supriya Jana, Bipadtaran Sinhamahapatra, Sudeshna Dey, Arnab Das, Bipa Datta, Moumita Mukherjee, Samiran Chatterjee, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Direct Broadcast Satellite (DBS) System", International Journal of Computational Engineering Research (ijceronline.com), ISSN: 2250-3005(online), Vol. 3 Issue. 1, January 2013, PP.110-115.

[16] Bipadtaran Sinhamahapatra, Supriya Jana , Sudeshna Dey, Arnab Das , Bipa Datta, Moumita Mukherjee, Samiran Chatterjee, "Dual-Band Size Deducted Un-Equal Arm Y-Shaped Printed Antenna for Satellite Communication" International Journal of Engineering Research and Development (IJERD), **e**-ISSN: 2278-067X, **p**-ISSN : 2278-800X , Volume 5, Issue 9 (January 2013), PP. 36-40.

[17] Supriya Jana, Bipadtaran Sinhamahapatra, Sudeshna Dey, Arnab Das, Bipa Datta, Moumita Mukherjee, Samiran Chatterjee, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Satellite Television", National Conference on Advancement of Computing in Engineering Research (ACER-13),Article No.-51,PP.19-20,March-2013;Co-sponsored by: IEEE Kolkata Section; Operational Research Society of India(ORSI) Kolkata Chapter; Rural Development Forum Institution of Engineers(India)[IEI]; Publication Partner: Academy & Industry Research Collaboration Center(AIRCC), (ISSN:2231-5403); (ISBN:978-1-921987-11-3); DOI:10.5121/csit.2013.3234; CS&IT-CSCP2013; vol.3,No.2,2013; PP.369-375,March 2013.

[18] 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, (ISSN 2221-8386), Vol. 2, Issue-9, 91-95, September 2012.

[19] 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.

[20] Arnab Das, Bipa Datta, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, "A Compact Multi-resonant Microstrip Antenna", 13th Biennial National Symposium on Antennas and Propagation 2012 (APSYM 2012), Paper ID: 13102, 2012.Co-sponsored by: IEEE Student Branch, Cochin; UGC;Indian National Science Academy;AICTE;Department of Atomic Energy(Govt. Of India); Department of Science & Technology (Govt. Of India); CSIR (Govt. Of India); KSCSTE (Govt. Of India). Published by The Directorate of Relations and Publications; ISBN: 978-43-80095-40-0; PP.99-102, December 2012.

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

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