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Multi-resonant Slotted Microstrip Antenna for *C, X and Ku*-Band Applications

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Abstract : *A compact slotted patch antenna with single layer, single feed is simulated in this paper. By cutting two unequal slots at the upper right and lower left corner from the conventional microstrip patch antenna, resonant frequency has been reduced drastically compared to a conventional microstrip patch antenna and also simulated antenna size has been reduced by 34.22% with an increased frequency ratio.*
Keywords: *Bandwidth, Compact, Patch, Resonant frequency, Slot.*

I. INTRODUCTION

In recent years demand, a small and light weight compact multi-resonant microstrip antenna which supports the high mobility, necessity for a wireless telecommunication device and for high resolution mapping, for radar communication [1-6]. Due to many reasons, mainly because there are various wireless communication systems and many telecommunication operators using various frequencies, multiband characteristic is more desirable than having one antenna for each frequency band. Most effective technique is cutting slot in proper position on the microstrip patch. In this paper includes by cutting two unequal rectangular slots at the upper right and lower left corner from the conventional microstrip patch antenna, to increase the return loss and gain-bandwidth performance of the simulated antenna (Fig. 2). To reduce the size of the antenna substrates are chosen with higher value of dielectric constant [7-10]. 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 4.90 dBi and presents a size reduction of 34.22% when compared to a conventional microstrip patch (14mm X 12mm). The simulation has been carried out by IE3D [11] 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.

The C, X band and Ku-Band defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 4.0 to 8.0 GHz , 8.0 to 12.0 GHz and 12.0 to 18.0 GHz respectively. Nearly all C-band communication satellites use the band of frequencies from 3.7 to 4.2GHz for their downlinks, and the band of frequencies from 5.925 GHz to 6.425 GHz for their uplinks. The X band is used for short range tracking, missile guidance, marine, radar and airbone intercept. Especially it is used for radar communication ranges roughly from 8.29 GHz to 11.4 GHz. The Ku band 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.

II. ANTENNA DESIGN

The configuration of the conventional printed antenna is shown in Fig. 1 with L=12 mm, W=14 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= 14 mm for efficient radiation and using the equation [6],

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

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

$$L = L_{eff} - 2\Delta L \qquad .....(2)$$

$$\text{where, } \frac{\Delta L}{h} = \left[0.412 \times \frac{(\varepsilon_{reff}+0.3)\times(W/h+0.264)}{(\varepsilon_{reff}-0.258)\times(W/h+0.8)}\right] \qquad .....(3)$$

$$\varepsilon_{reff} = \left[\left(\frac{\varepsilon_r+1}{2}\right) + \frac{\varepsilon_r-1}{\left(2\times\sqrt{\left(1+12\times\frac{h}{W}\right)}\right)}\right] \qquad .....(4)$$

$$\text{and} \quad L_{eff} = \left[\frac{c}{2\times f_r \times \sqrt{\epsilon_{eff}}}\right] \qquad .....(5)$$

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

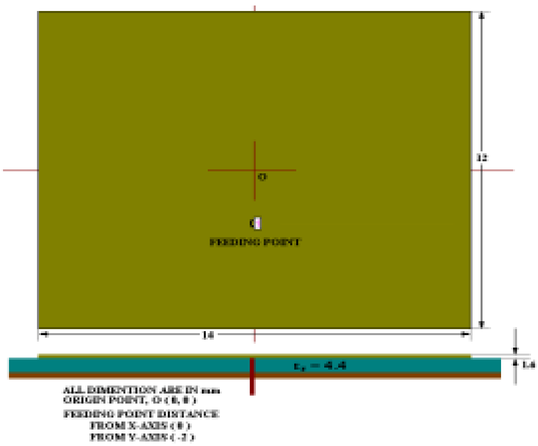

Figure 1: Conventional Antenna configuration

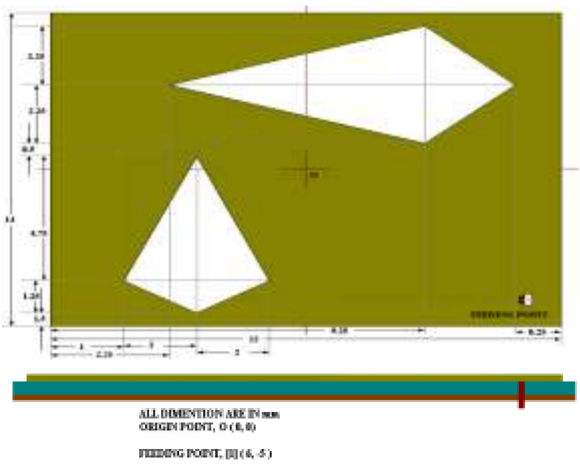

Figure 2: Simulated Antenna configuration

Fig. 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. By cutting two unequal rectangular slots at the upper right and lower left corner from the conventional microstrip patch antenna and the location of coaxial probe-feed (radius=0.5 mm) are shown in the Fig. 2.

III. Results And Discussion

Simulated (using IE3D [11]) results of return loss in conventional and simulated antenna structures are shown in Fig. 3-4. A significant improvement of frequency reduction is achieved in simulated antenna with respect to the conventional antenna structure.

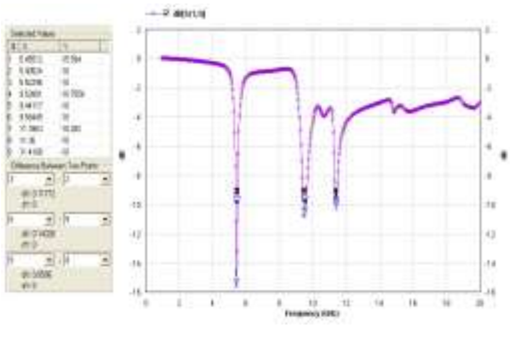

Figure 3: Return Loss vs. Frequency (Conventional Antenna)

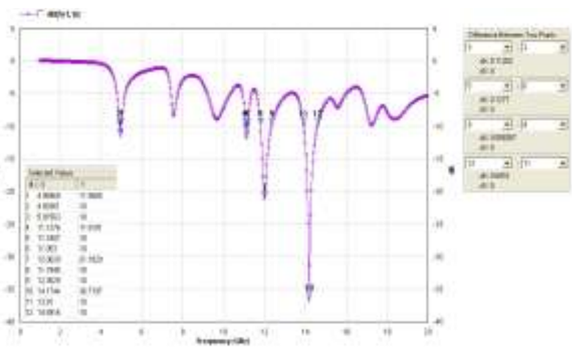

Figure 4: Return Loss vs. Frequency (Slotted Antenna)

In the conventional antenna return loss of about f_{c1} = -15.59 dB is obtained at 5.46 GHz. Corresponding 10 dB bandwidth is 117.72 MHz. The second resonant frequency is obtained at f_{c2} = -10.76 dB is obtained at 9.53 GHz. The third resonant frequency is obtained at f_{c3} = -10.28 dB is obtained at 11.40 GHz. Corresponding 10 dB bandwidth obtained for conventional antenna at f_{c2} and f_{c3} are 143.28 MHz and 50.80 MHz respectively. 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 4.96 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 4.96 GHz where the return loss is as high as -11.58 dB.

Due to the presence of slots in simulated antenna resonant frequency operation is obtained with large values of frequency ratio. The first, second, third and forth resonant frequency is obtained at f_{s1}, f_{s2}, f_{s3} and f_{s4} are 4.96 GHz, 11.13 GHz, 12.00 GHz and 14.17 GHz with return loss of about -11.58 dB, -11.82 dB, -21.18 dB and -36.72 dB respectively. Corresponding 10dB band width obtained for slotted antenna at f_{s1}, f_{s2}, f_{s3} and f_{s4} are 112.02 MHz, 127.70 MHz, 558.36 MHz and 681.60 MHz respectively.

The simulated E plane and H-plane radiation patterns (2D) for conventional antenna are shown in Fig. 5-7.

Figure 5: 2D Elevation Pattern Display for Conventional Antenna at 5.46 GHz

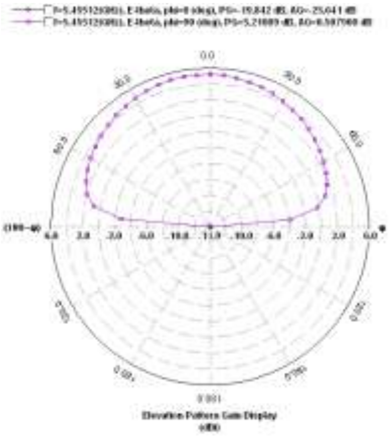

Figure 6: 2D E-Plane Radiation Pattern for Conventional Antenna at 5.46 GHz

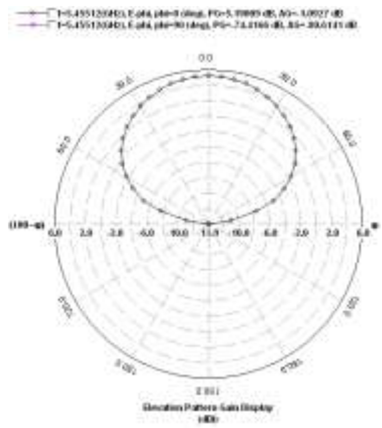

Figure 7: 2D H-Plane Radiation Pattern for Conventional Antenna at 5.46 GHz

The simulated E plane and H-plane radiation patterns (3D) for conventional antenna are shown in Fig. 8-10.

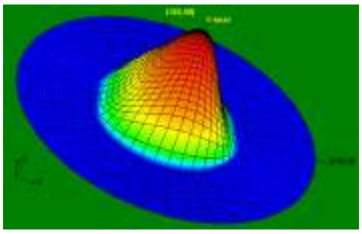

Figure 8: 3D Elevation Pattern Display for Conventional Antenna at 5.46 GHz

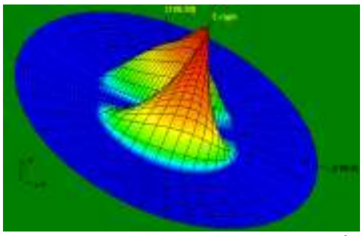

Figure 9: 3D E-Plane Radiation Pattern for Conventional Antenna at 5.46 GHz

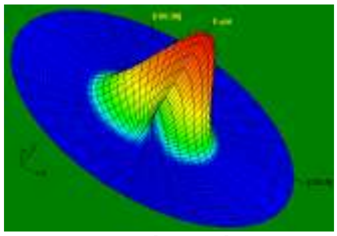

Figure 10: 3D H-Plane Radiation Pattern for Conventional Antenna at 5.46 GHz

The simulated E plane and H-plane radiation patterns (2D) for slotted antenna are shown in Fig. 11-22.

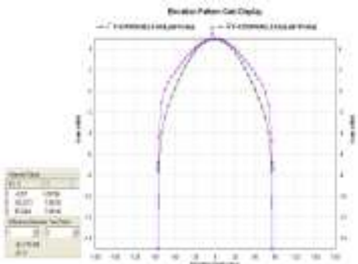

Figure 11: 2D Elevation Pattern Display at 4.96 GHz

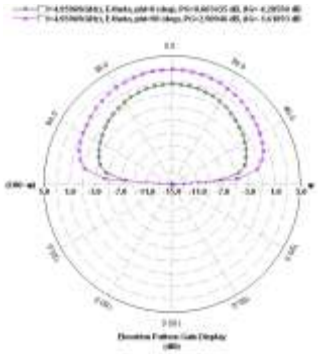

Figure 12: 2D E-Plane Radiation Pattern for Slotted Antenna at 4.96 GHz

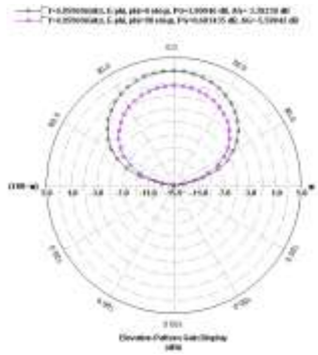

Figure 13: 2D H-Plane Radiation Pattern for slotted Antenna at 4.96 GHz

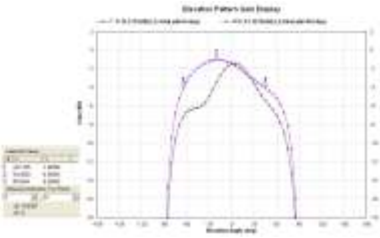

Figure 14: 2D Elevation Pattern Display at 11.13 GHz

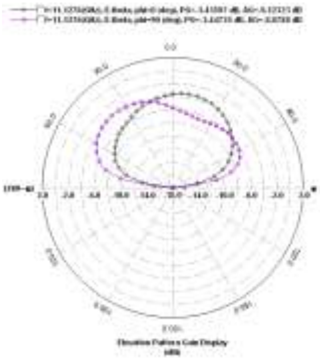

Figure 15: 2D E-Plane Radiation Pattern for Slotted Antenna at 11.13 GHz

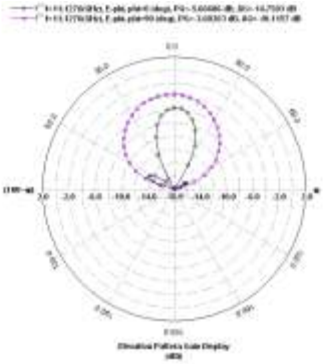

Figure 16: 2D H-Plane Radiation Pattern for slotted Antenna at 11.13 GHz

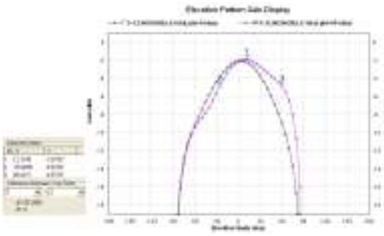

Figure 17: 2D Elevation Pattern Display at 12.00 GHz

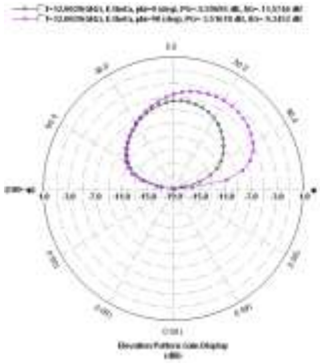

Figure 18: 2D E-Plane Radiation Pattern for Slotted Antenna at 12.00 GHz

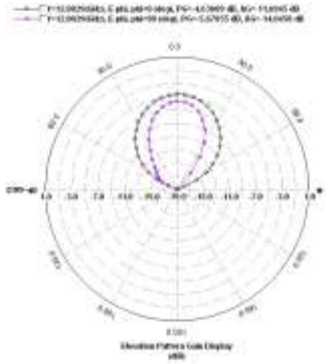

Figure 19: 2D H-Plane Radiation Pattern for slotted Antenna at 12.00 GHz

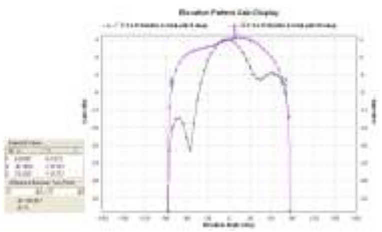

Figure 20: 2D Elevation Pattern Display at 14.17 GHz

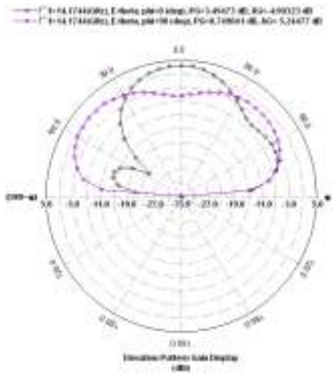

Figure 21: 2D E-Plane Radiation Pattern for Slotted Antenna at 14.17 GHz

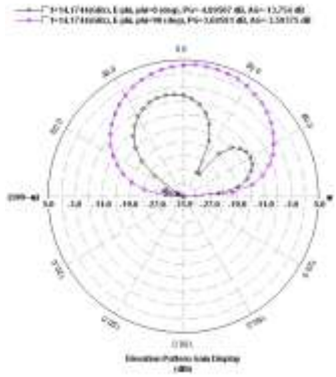

Figure 22: 2D H-Plane Radiation Pattern for slotted Antenna at 14.17 GHz

The simulated E plane and H-plane radiation patterns (3D) for slotted antenna are shown in Fig. 23-34.

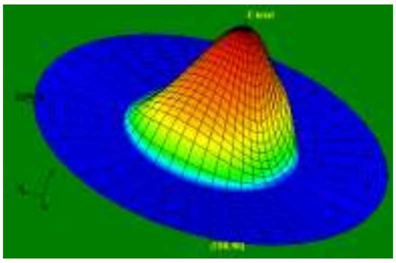

Figure 23: 3D Elevation Pattern Display at 4.96 GHz

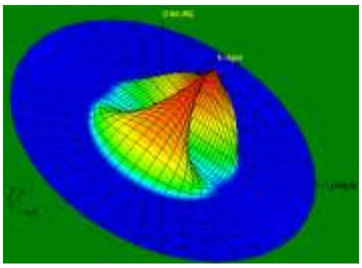

Figure 24: 3D E-Plane Radiation Pattern for Slotted Antenna at 4.96 GHz

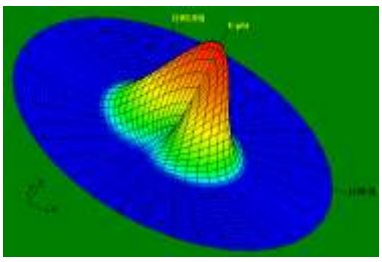

Figure 25: 3D H-Plane Radiation Pattern for slotted Antenna at 4.96 GHz

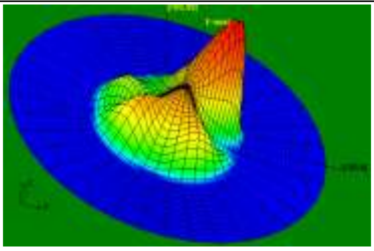
Figure 26: 3D Elevation Pattern Display at 11.13 GHz

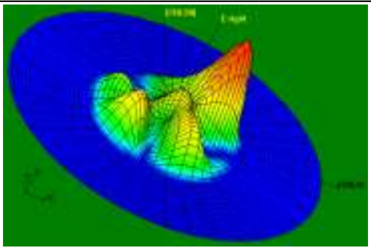
Figure 27: 3D E-Plane Radiation Pattern for Slotted Antenna at 11.13 GHz

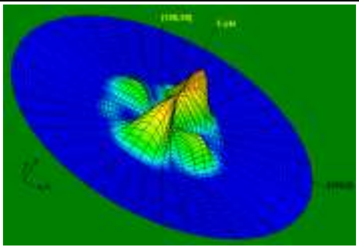
Figure 28: 3D H-Plane Radiation Pattern for slotted Antenna at 11.13 GHz

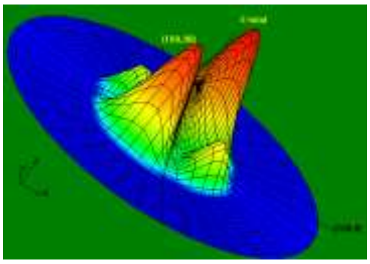
Figure 29: 3D Elevation Pattern Display at 12.00 GHz

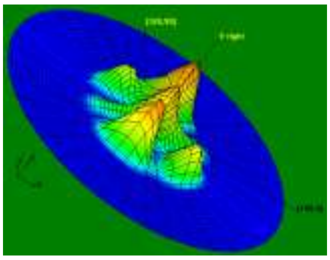
Figure 30: 3D E-Plane Radiation Pattern for Slotted Antenna at 12.00 GHz

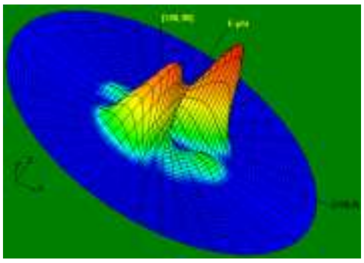
Figure 31: 3D H-Plane Radiation Pattern for slotted Antenna at 12.00 GHz

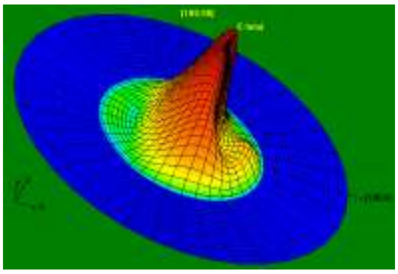
Figure 32: 3D Elevation Pattern Display at 14.17 GHz

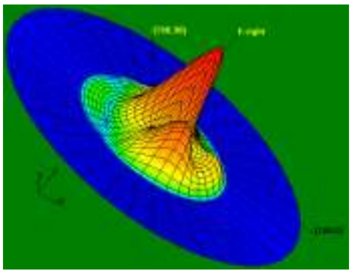
Figure 33: 3D E-Plane Radiation Pattern for Slotted Antenna at 14.17 GHz

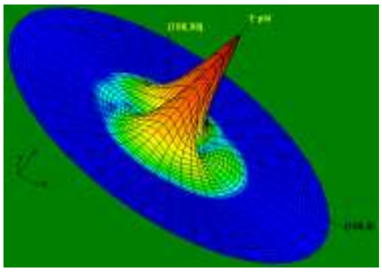
Figure 34: 3D H-Plane Radiation Pattern for slotted Antenna at 14.17 GHz

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

TABLE I:
SIMULATED RESULTS FOR ANTENNA 1 AND 2

ANTENNA STRUCTURE	RESONANT FREQUENCY (GH_Z)	FREQUENCY RATIO	3 DB BEAM-WIDTH (^{0})	ABSOLUTE GAIN (DBI)
Conventional	f_{c1}= 5.46		170.62^0	5.167
	f_{c2}= 9.53	f_{c2}/ f_{c1}=1.745	165.99^0	2.063
	f_{c3}= 11.40	f_{c3}/ f_{c1}=2.088	67.10^0	-4.24
Slotted	f_{s1}= 4.96		170.43^0	4.90
	f_{s2}= 11.13	f_{s2}/ f_{s1}=2.244	109.57^0	-1.09
	f_{s3}= 12.00	f_{s3}/ f_{s1}=2.419	86.29^0	-1.98
	f_{s4}= 14.17	f_{s4}/ f_{s1}=2.857	160.62^0	4.90

TABLE II:
SIMULATED RESULTS FOR ANTENNA 1 AND 2

ANTENNA STRUCTURE	RESONANT FREQUENCY (GH_Z)	RETURN LOSS (DB)	10 DB BANDWIDTH (MH_Z)
Conventional	f_{c1}= 5.46	-15.59	117.72
	f_{c2}= 9.53	-10.76	143.28
	f_{c3}= 11.40	-10.28	50.80
Slotted	f_{s1}= 4.96	-11.58	112.02
	f_{s2}= 11.13	-11.82	127.70
	f_{s3}= 12.00	-21.18	558.36
	f_{s4}= 14.17	-36.72	681.60

IV. CONCLUSION

Theoretical investigations of the single layer single feed multi-resonant microstrip printed antennas have been carried out using Method of Moment based software IE3D. Introducing slots at the edge of the patch size reduction of about 34.22% has been achieved. The 3dB beam-width of the radiation patterns are 170.43° (for f_{s1}), 109.57° (for f_{s2}), 86.29° (for f_{s3}) and 160.02° (for f_{s4}) whose are sufficiently broad beam for the applications for which it is intended. The resonant frequency of slotted antenna presented in the paper for a particular location of feed point (6 mm, -5 mm) considering the centre as the origin was quite large as is evident from table1. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances.

Acknowledgements

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