Figure 7. Measured bandwidth of the Antenna resonating at 1.96GHz on Rogers (RT/Duroid5880tm) of Substrate permittivity 2.2.From the plot, it is clear that the value of the Bandwidth obtained is 0.672GHz with a -10dB impedance bandwidth extending between 1.7 GHz to 2.37GHz respectively as indicated by markers 2 and 3.

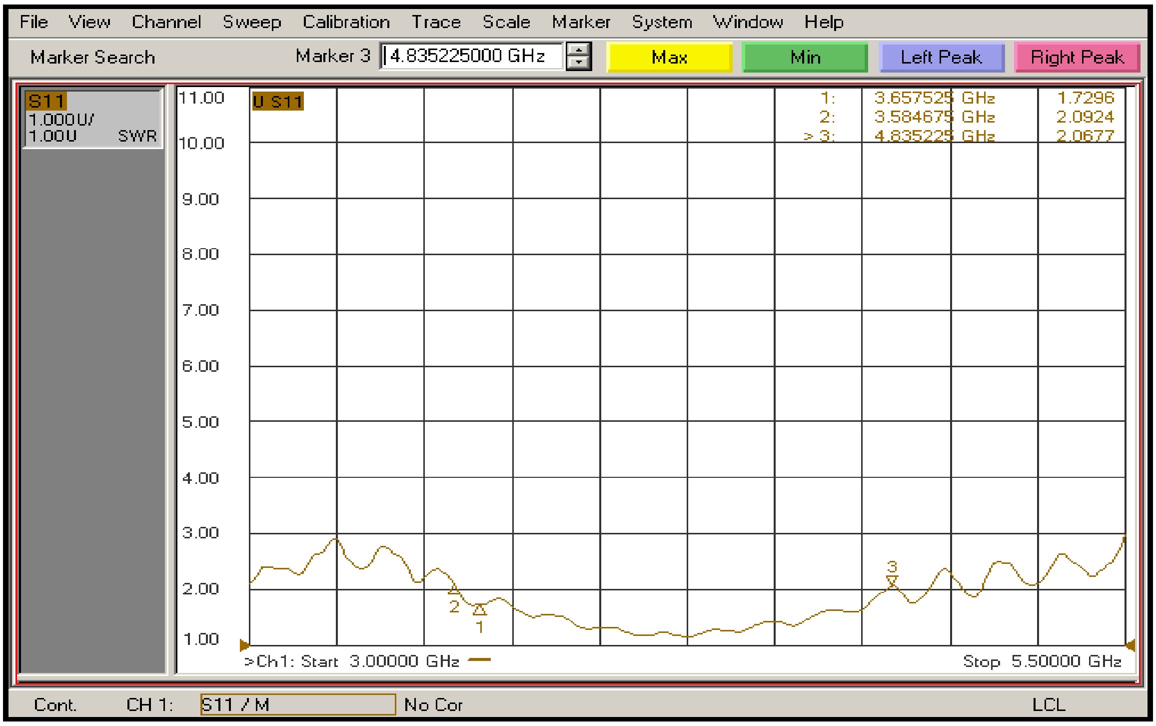

Figure 8. Measured bandwidth of the Antenna resonating at 3.6GHz on Rogers (RT/Duroid5880tm) Substrate of permittivity 2.2.From the plot, it is clear that the value of the Bandwidth obtained is 1.25GHz with a -10dB impedance bandwidth extending between 3.584 GHz to 4.835GHz respectively as indicated by markers 2 and 3.

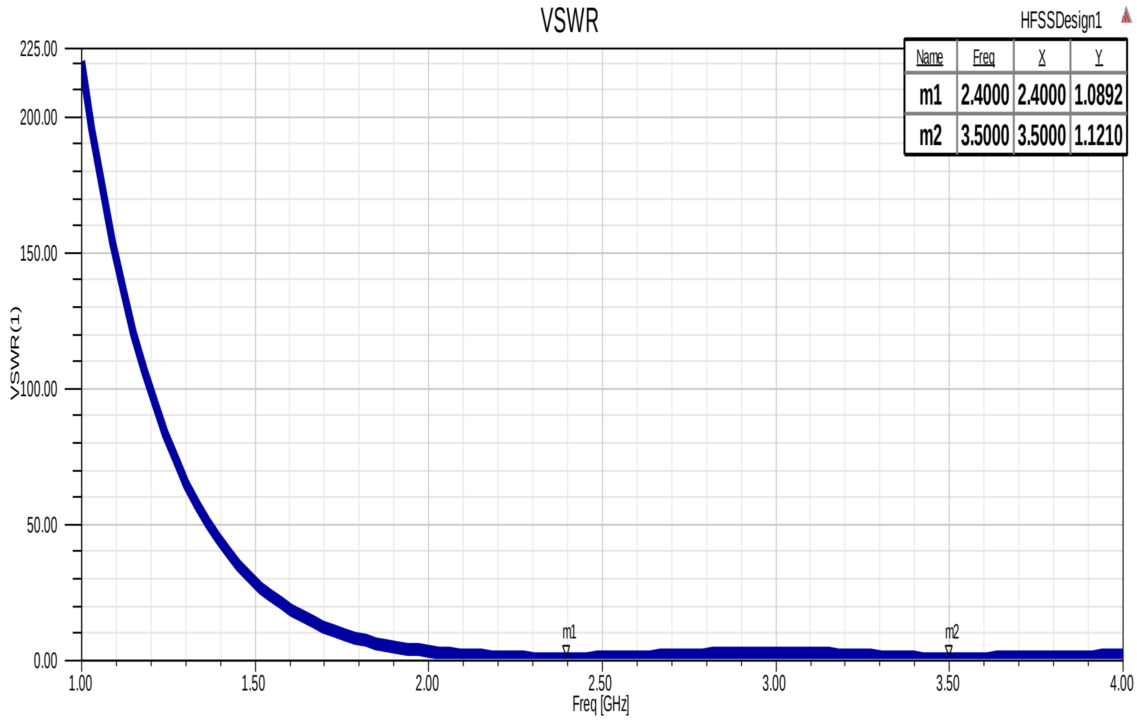

Figure 9. Simulated vswr plot of the antenna resonating at 2.4 GHz and 3.5GHz on Rogers (RT/Duroid5880tm) substrate of permittivity 2.2.indicating a value of 1 and 1.12 at 2.4GHz and 3.5GHz frequency bands respectively.

Figure 10. Measured VSWR plot of the Antenna resonating at 1.96 GHz and 3.66GHz indicating a value of 1.48 and 1.52 respectively for the lower and the upper band respectively as indicated by markers 1 and 3 on Rogers(RT/Duroid) substrate of permittivity 2.2.

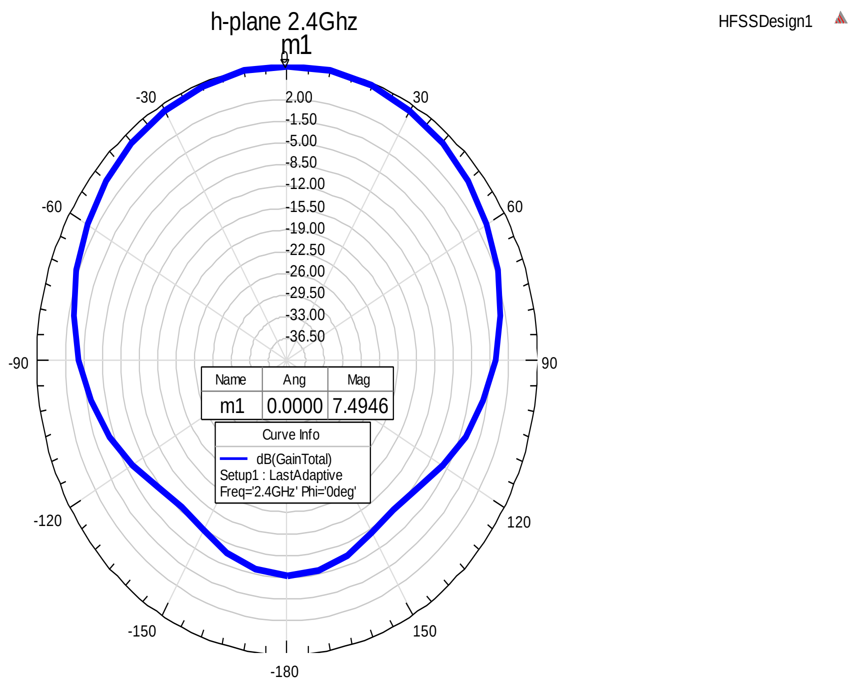

Figure 11. Simulated radiation pattern of the Monopole Antenna on Rogers(RT/Duroid 5880tm)substrate of permittivity 2.2 indicating a peak boresight gain of 7.49dB under H plane at 2.4GHz as shown by marker m1.The radial axis represents the Gain(in dB) while the angular axis represents the scan angle(in degrees)

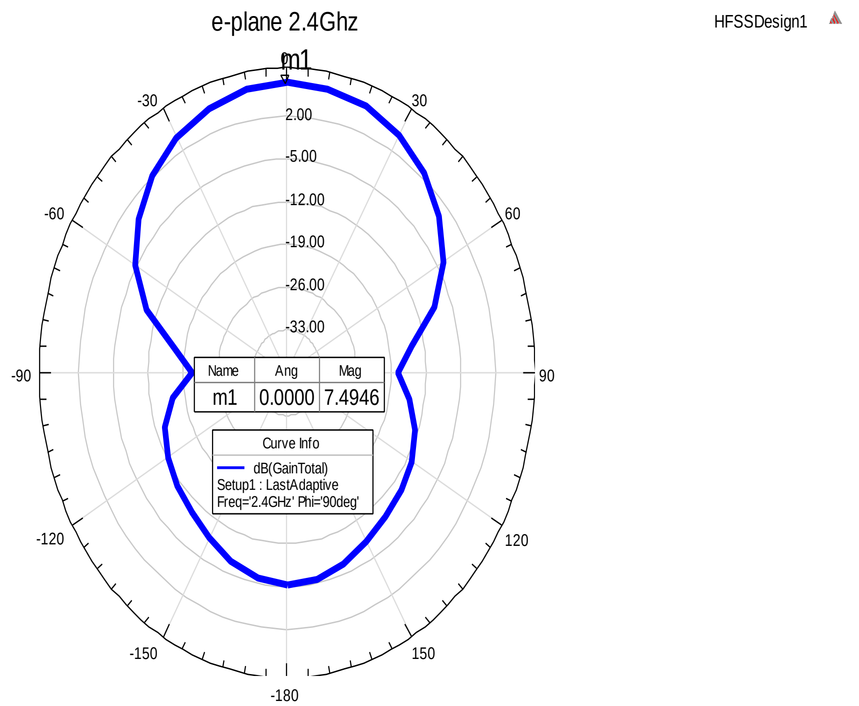

Figure 12. Simulated radiation pattern of the Monopole Antenna on Rogers(RT/Duroid 5880tm)substrate of permittivity 2.2 indicating a peak boresight gain of 7.49dB under E plane at 2.4GHz as shown by marker m1.The radial axis represents the Gain(dB) while the angular axis represents the scan angle(in degrees)

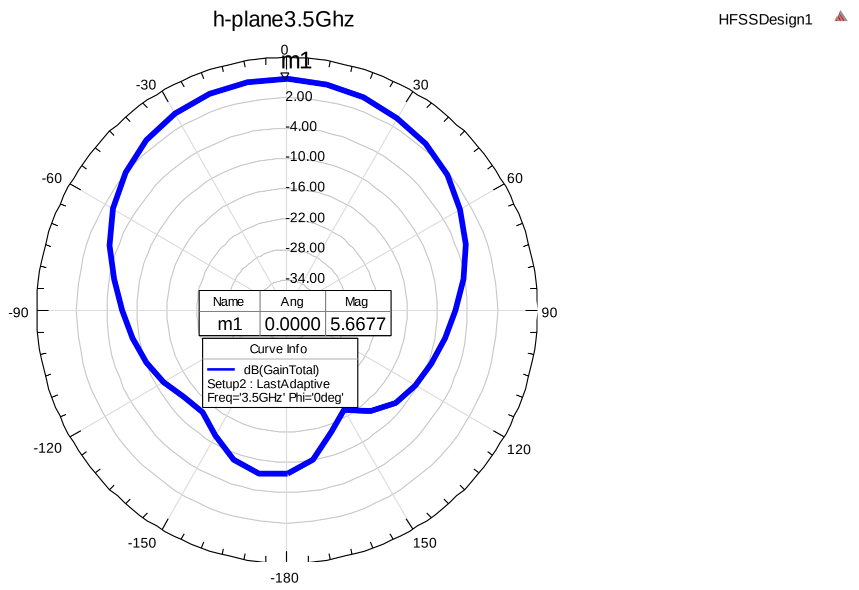

Figure 13. Simulated radiation pattern of the Monopole Antenna on Rogers (RT/Duroid 5880tm)substrate of permittivity 2.2 indicating a peak boresight gain of 5.66dB under H plane at 3.5GHz as shown by marker m1.The radial axis represents the Gain(dB) while the angular axis represents the scan angle(in degrees)

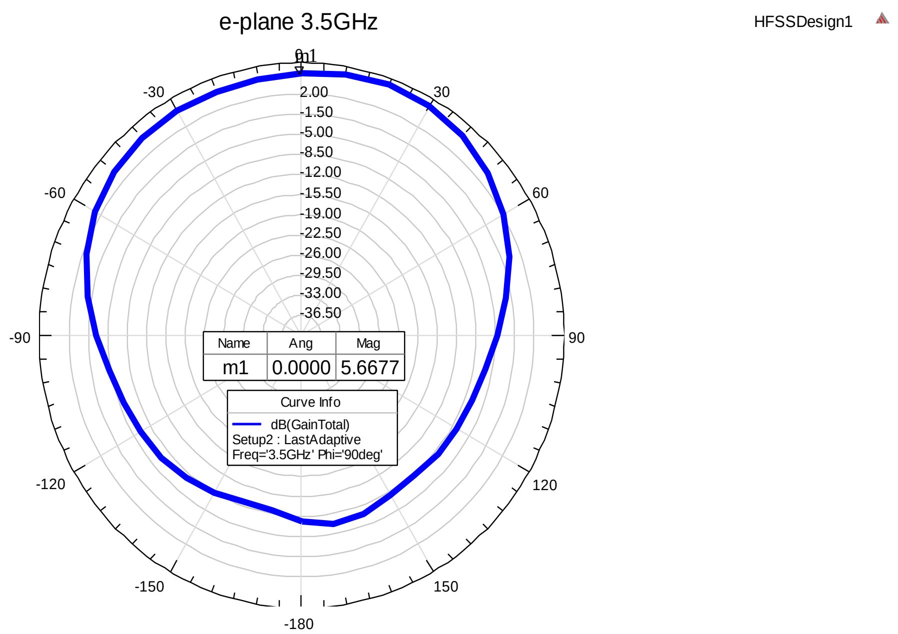

Figure 14. Simulated radiation pattern of the Monopole Antenna on Rogers(RT/Duroid 5880tm)substrate of permittivity 2.2 indicating a peak boresight gain of 5.66dB under E plane at 3.5GHz as shown by marker m1.The radial axis represents the Gain(dB) while the angular axis represents the scan angle(in degrees)

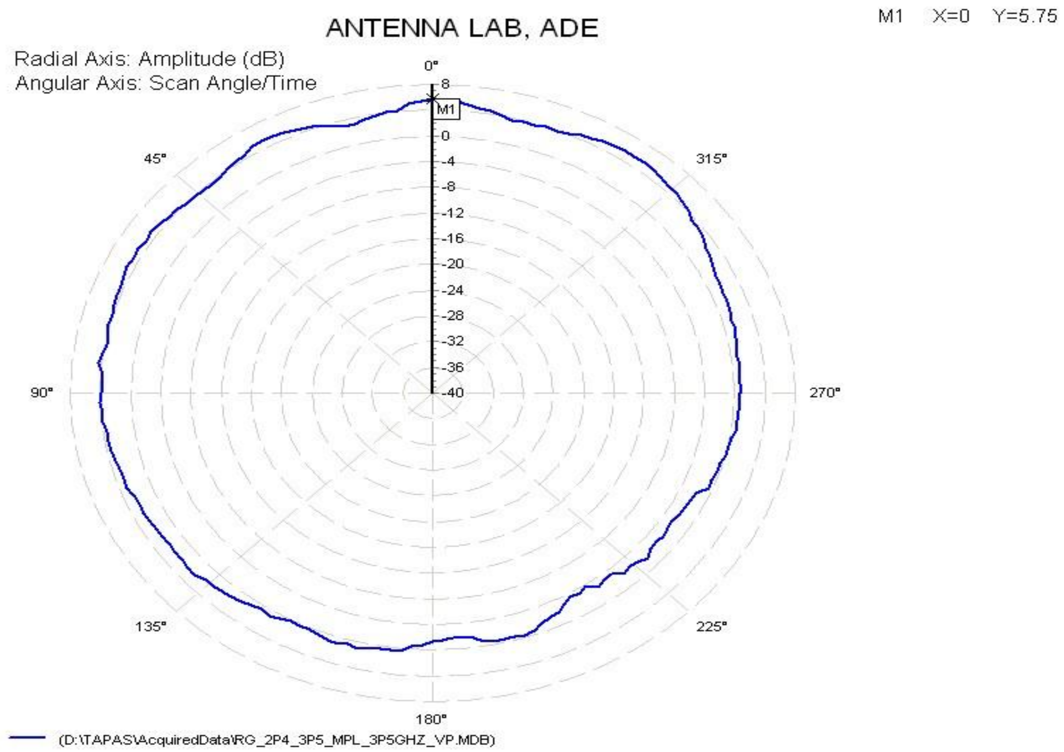

Figure 15. Measured radiation pattern of the monopole antenna on Rogers (RT/Duroid substrate (5880tm)) and permittivity 2.2 indicating a peak bore sight gain of 5.75B under E plane at 3.5GHz, as shown by marker m1.The radial axis represents the Gain (in dB) while the angular axis represents the scan angle(in degrees).

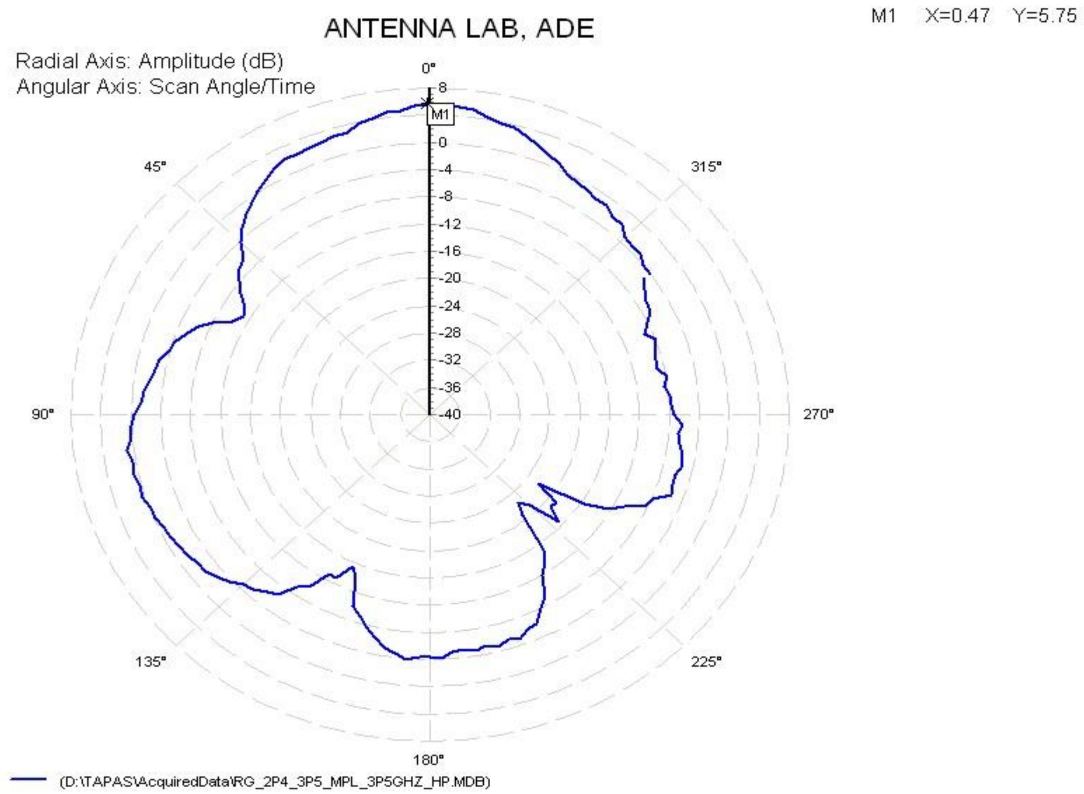

Figure 16. Measured radiation pattern of the monopole antenna on Rogers (RT/Duroid substrate (5880tm)) and permittivity 2.2 indicating a peak bore sight gain of 5.75dB under H plane at 3.5GHz, as shown by marker m1.The radial axis represents the Gain (in dB) while the angular axis represents the scan angle(in degrees).

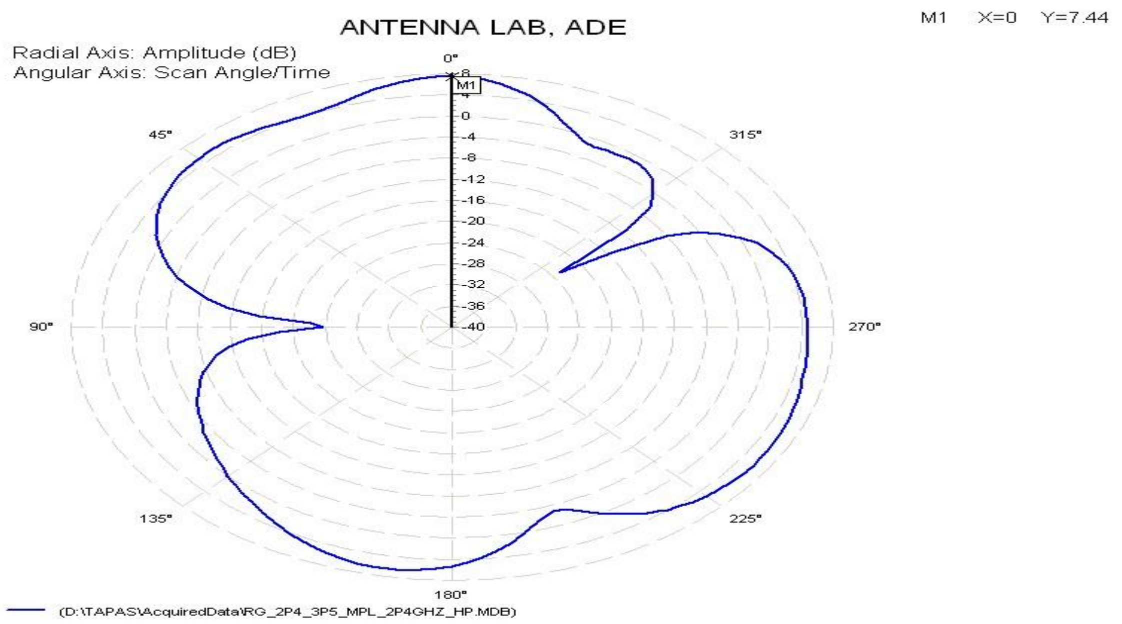

Figure 17. Measured radiation pattern of the monopole antenna on Rogers (RT/Duroid substrate (5880tm)) and permittivity 2.2 indicating a peak bore sight gain of 7.44dB under H plane at 2.4GHz, as shown by marker m1.The radial axis represents the Gain (in dB) while the angular axis represents the scan angle(in degrees).

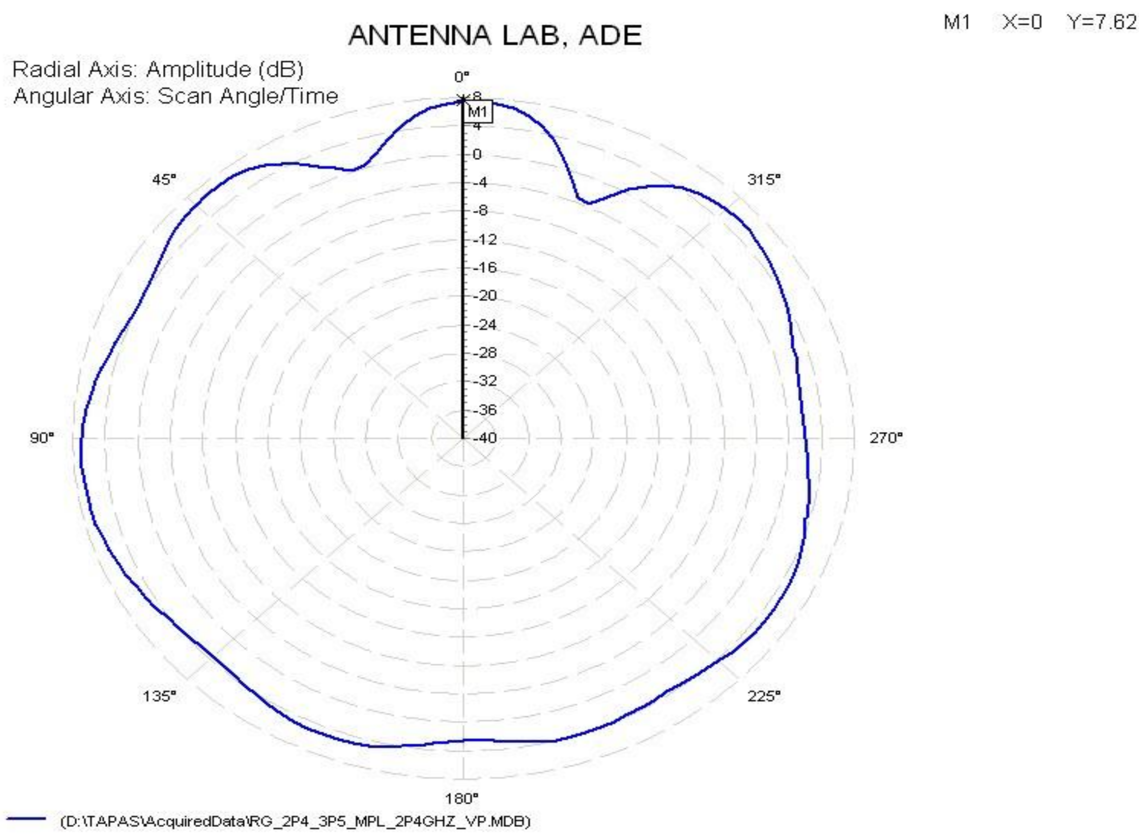

Figure 18. Measured radiation pattern of the monopole antenna on Rogers (RT/Duroid substrate (5880tm)) and permittivity 2.2 indicating a peak bore sight gain of 7.62B under E plane at 2.4GHz, as shown by marker m1.The radial axis represents the Gain (in dB) while the angular axis represents the scan angle(in degrees).

Table 1. Illustrating the comparison of the simulated & measured antenna parameters for Wi-Fi and the Wi-Max band using Rogers(RT/Duroid 5880tm) substrate of 2.2 permittivity.

Sl No	Antenna parameters	Simulated	Simulated	Measured	Measured
1	Resonant Frequency	2.4GHz	3.5GHz	2.0GHz	3.66GHz
2	Return loss	-35.27 dB	-25.985dB	-15.69dB	-13.94dB
3	VSWR	1.08	1.12	1.48	1.52
4	Gain	7.49dB (E&H)	5.66dB (E &H)	7.44dB(H) 7.62dB(E)	5.75dB (E&H)
5	Bandwidth	441MHz	557MHz	0.672GHz	1.25GHz
6	Frequency range	2.172GHz to 2.614GHz	3.299GHz to 3.856GHz	1.7 GHz-2.37GHz	3.584 to 4.835GHz
7	Radiation pattern	Figure of 8 under E plane and Hemispherical under H plane	Nearly Omni directional under E plane and H plane	Omni Directional	Omni Directional

VI RESULTS AND DISCUSSIONS

From the Table 1, the simulated return loss values were close to -35.27dB and -25.985dB in the lower and the upper frequency bands respectively indicating that the antenna radiates reasonably well in the Wi-Fi and the Wi-Max (3.5 GHz) frequency bands respectively. The simulated VSWR values were below 1.5 signifying that the impedance matching has been proper in Wi-Fi and Wi-Max frequency bands respectively. The simulated and the measured gains agree well. The structure resulted in a nearly omnidirectional radiation pattern along the elevation plane and characterized by the presence of nulls along the azimuth plane with a peak boresight gain of 5.75dB in the Wi-Max band as shown in Figure 15 and 16. While in the Wi-Fi band, the measured radiation pattern were omni under E plane and characterized by the presence of Nulls under H plane with a peak boresight gain of 7.62dB.The simulated and the measured bandwidths agree well. The measured bandwidths reported were 672MHz and 1.25GHz for the lower and the upper frequency bands respectively. The measured bandwidths were significantly higher in the Wi-Max band when compared with the Wi-Fi band.

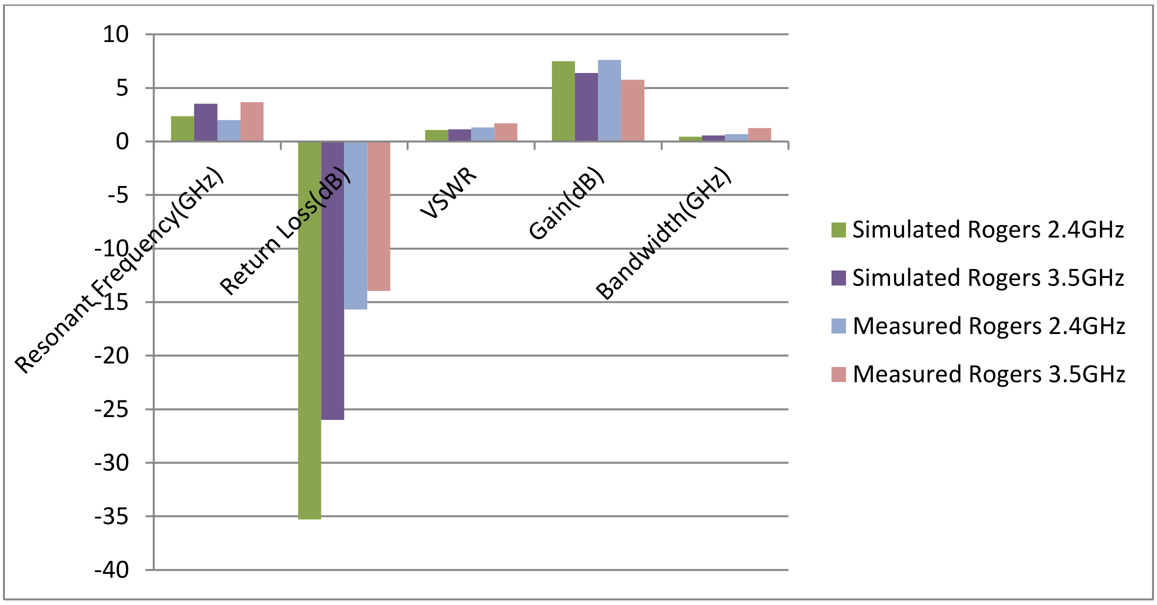

Figure 19. Comparison of the simulation and measured results of various Antenna performance parameters such as Resonant Frequency, Return Loss, VSWR, Gain and Bandwidth of the simulated and Fabricated Dual band Antenna resonating between Wi-Fi(2.4GHz) and Wi-Max(3.5GHz).

CONCLUSION

The simulated return loss values are close to -35.27 dB & -25.985dB indicating that the antenna radiates more efficiently in both the bands. The simulated vswr values are close to 1 in both the bands designed on Rogers indicating a good impedance matching. The simulated and the measured Gains agree well. The lowest reported Gain were 5.75dB in the 3.5GHz band while the highest reported value of the Gain were 7.62dB under E plane at 2.4GHz.The total Gain variation were in the range of 5.75dB to 7.62dB .The measured gains were comparatively higher in the 2.4GHz band when compared to 3.5GHz band. The measured Bandwidths reported were 672MHz (Wi-Fi band) and 1.25GHz (Wi-Max band).The measured bandwidths were significantly high in the Wi-Max band when compared to Wi-Fi band. The measured radiation patterns were Omni directional under E plane and characterized by the presence of nulls under H plane with a peak boresight gain of 7.62dB in the lower frequency band of interest.In the upper and the pattern were Omni directional under E plane and associated with nulls under H plane with a peak boresight gain of 5.75dB.

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REFERENCES

[1] S.A.Shah, M.F.Khan, S.Ullah,"Design and measurement of Planar Monopole Antennas for Multi-Band Wireless Applications", IETE Journal of Research, 2017.

[2] AdeelAfridi, SadiqUllah, ImadAli, ShahbazKhan, James A Flint,"Design and Parametric Analysis of a DualBandFrequency Reconfigurable Planar Dipole Using a Dual Band Artificial Ground plane", IETE Journal of Research, Vol. 60, No. 1, Jan-Feb 2014.

[3] M.Z.M.Nor, S.K.A, Rahim, M.I.Sabran, F.Malek,"Dual band, parabolic, slotted ground plane directive antenna for WLAN Applications", Journal of Electromagnetic waves and Applications, Vol. 27, No. 2, 2013.

[4] Li.Li, Shu-Hua. Rao, Bin.Tang and Ming-fu.Li, "*A Novel Compact Dual-band Monopole Antenna using Defected Ground Structure*", 2013 International Workshop on Microwave and Millimeter Wave Circuits and System Technology

[5] Jacob Abraham, Thomaskutty Mathew, "Dual Band David Fractal Microstrip Patch Antenna for GSM and WiMAX Applications", Wireless Engineering and Technology, Vol.6, pp: 33-40, 2015

[6] T. Wang, Y.Z. Yin, J. Yang, Y.L. Zhang, J. J. Xie, "*Compact Triple-Band Antenna Using Defected Ground Structure For WLAN/WIMAX Applications"*, Progress In Electromagnetics Research Letters, Vol. 35, 155–164, 2012.

[7] Issam Zahraoui, Ahmed Errkik, Jamal Zbitou, Elhassane Abdelmounim, Angel Sanchez Mediavilla "*A New Design of a Microstrip Antenna With Modified Ground for DCS and WiMAX Applications"*,International Journal Of Microwave And Optical Technology, Vol.11, No.4, July 2016.

[8] Z. Zakaria, N. A. Zainuddin, M. Z. A. Abd Aziz, M. N. Husain, M. A. Mutalib "*Dual-Band Monopole Antenna For Energy Harvesting System"*, 2013 IEEE Symposium on Wireless Technology and Applications (ISWTA), September 22-25, 2013, Kuching, Malaysia.

[9] S.M. Zhang, F.S. Zhang, W.M. Li, W.Z. Li, and H.Y. Wu, "*A multi-band monopole antenna with two different slots for WLAN and WIMAX applications"*, Progress In Electromagnetics Research Letters, Vol. 28, 173–181, 2012.

[10] He Huang, Ying Liu , Shaoshuai Zhang, and Shuxi Gong "*Multiband Metamaterial-Loaded Monopole Antenna for WLAN/WiMAX Applications*", IEEE Antennas and Wireless Propagation Letters, Vol. 14, 2015.