Study of the Effect of Substrate Materials on the Performance of UWB Antenna

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Abstract:

In this paper, a compact Ultra Wide Band antenna prototyped on FR4 Substrate is proposed and analyzed. The antenna is fed by linearly tapered Co-planar waveguide (CPW) transmission line. The parametric study is first performed on the feed of different substrate materials. The simulated results of proposed antenna has an advantages of low power consumptions, security systems, tracking applications, low data rate and low complexity. The simulation results for the voltage standing wave ratio (VSWR), Return loss, Radiation pattern and Impedance matching are in good agreement with the measurements. Moreover the Ultra wide band antennas enable the user to achieve a lower visual profile, lower radar cross sections (RCS) and a lower space. The model is analyzed for different substrate thicknesses using Finite Element Method based Ansoft High Frequency Structure Simulator v.13.

Index Terms: *CPW, FCC, VSWR, UWB.*

I. INTRODUCTION

Over the years, several studies used various antenna structures in Ultra wideband antenna design. The UWB antenna, which is an essential part of the UWB system.UWB also refers to a broad frequency range encompassing many narrow band frequencies, requires UWB antennas to transmit and receive throughout all narrow band frequencies in the range. However, the allocated frequency band for the UWB is 3.1-12.6 GHz[1] in between there exists a several wireless frequency bands such as WIMAX operates at 3.3-3.7 GHz and 5.8 GHz, IEEE 802.11a,WLAN operates at 5.15-5.35 and 5.725-5.825 GHz, downlink of X band satellite communication operates at 7.25-7.75 GHz and ITU services operates at 8.025-8.4 GHz.

The conventional method is to cutting a slot on the patch, inserting a slit on patch. The typical shapes of the patch antenna are circular, ellipse [2],[3]and rectangular[4],[5]. The main objective of this paper is to design UWB with different substrate materials. Here, we are going to use fr4 as a best substrate material as it gave best results regarding utilization of band width, resonating frequency and return loss. FR4 have good fabrication process, good electrical insulator as its features. Fr4 is also used in relays, switches, washers and transformers.Here we are going to use CPW feed.CPW is a transmission line system consisting of a central current carrying trace on top of substrate. Coplanar with side grounds extending beyond a symmetric gap to either side of the trace. Here we are going to use finite ground transmission line [6]. CPW has the same advantage as micro strip, in that the signal is carried on an exposed surface trace, on which surface-mount components can be attached and has little parasitic losses between surface mounted components and an underlying ground plane. Both the radiating patch and the ground plane are beveled to cover the entire UWB band from 3.1 to 12.6 GHz with VSWR less than 2. Characteristics of the proposed antenna are simulated using HFSS.

II. ANTENNA DESIGN

The proposed antenna has dimensions of 26mm x 31.8 x 1.6mm. It is prototyped on FR4 substrate of with dielectric constant, $\varepsilon_r = 4.4$ and fed by Coplanar Waveguide transmission line. The Geometrical parameters are shown in Figure 1. The model consists of a circular patch of radius 10mm. The gap between ground plane and patch is 0.4mm. To increase the performance of antenna two identical trapezoidal ground planes are designed. The antenna parameters are as follows: Lsub=31.8mm, Wsub=26mm, R1=10mm, L1=8mm, L2=10mm, L3=10.8mm, W1=4.3mm, g=0.4mm, Wf=2.6mm.

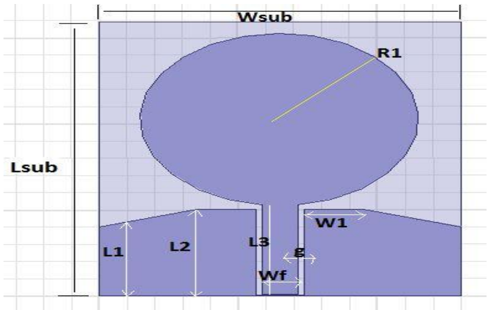


Figure 1: Proposed UWB Antenna Model

The antenna with the proposed geometry is analyzed using High Frequency Structure Simulator. It exhibits a Voltage Standing Wave Ratio (VSWR) of less than 2 in the operating frequency range with less Return Loss and acceptable Gain quasi omni-directional and bi-directional radiation patterns. A comparative analysis is made by varying the substrate materials and its effect on Return Loss is observed.

III. RESULTS ANALYSIS

A CPW fed Ultra Wide Band antenna with a Circular shaped patch is simulated using HFSS. By varying the substrate materials, the variations in Return Loss are observed and shown in Figure 2. Among the substrate materials FR4, Teflon, Rogers RT/Duroid, Quartz, Polystyrene and Neltec, wide operating bandwidth is obtained for FR4 substrate.

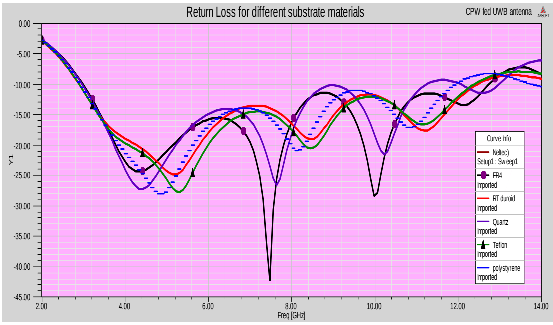


Figure 2: Return Loss curves for different substrate materials

For different substrate materials, the corresponding bandwidth, resonant frequencies and their Return Losses are shown in Table 1. The operating bandwidth of UWB antenna with FR4 Substrate is 9.745GHz from 2.9980GHz – 12.7350GHz and resonated at frequencies 4.3356GHz, 7.4765GHz, 9.9732GHz, 12.1477GHz with a corresponding Return Loss of -24.3854dB, -42.2670dB, -28.4086dB, -13.4235dB. The Frequency versus Return Loss is shown in figure 3.

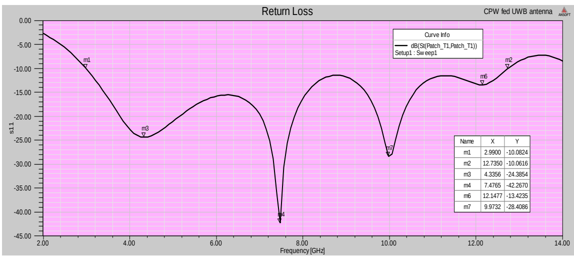


Figure 3: Frequency vs. Reflection Coefficient

Figure 4 shows the Voltage Standing Wave Ratio plot and desirable VSWR is less than 2 and the proposed design has VSWR<2 in the entire operating range. VSWR is a function of Reflection Coefficient and it describes the power reflected from the antenna. The VSWR values at the resonant frequencies are 1.13, 1.02, 1.08 and 1.54 respectively.

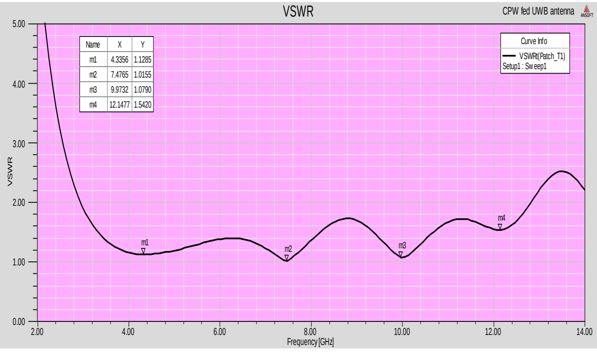


Figure 4: VSWR vs. Frequency

The impedance of an antenna relates voltage to the current at the input to the antenna and hence called as Input Impedance. The input impedance in smith chart is shown in Figure 5. The proposed model achieved an impedance bandwidth of 21%.

Material	Dielectric Constant	Band Width (GHZ)	Resonant Frequency (GHZ)	Return loss (dB)
FR4	4.4	9.745 (2.9980-12.7350)	4.3356	-24.3854
			7.4765	-42.2670
			9.9732	-28.4086
			12.1477	-13.4235
TEFLON	2.1	9.4893 (2.9000-12.3893)	5.3020	-27.7461
			8.4430	-20.5721
			11.1812	-16.6554
ROGERS RT DUROID	2.2	9.552 (2.8980-12.4500)	5.2215	-24.8585
			8.4430	-19.0736
			11.1812	-17.6819
QUARTZ	3.78	8.28 (2.9700-12.1200)	4.4161	-27.2814
			7.6376	-26.6020
			10.2148	-21.5166
POLYSTYRENE	2.6	9 (2.9350-13.8230)	4.8993	-28.0574
			8.2013	-20.8018
			10.8591	-17.1622
NELTECH	3	8.91 (2.9400-12.8000)	4.5772	-28.2154
			7.9597	-24.1389
			10.6174	-21.4509

Table 1: Bandwidth, Resonant Frequencies and Return Loss for different substrate materials

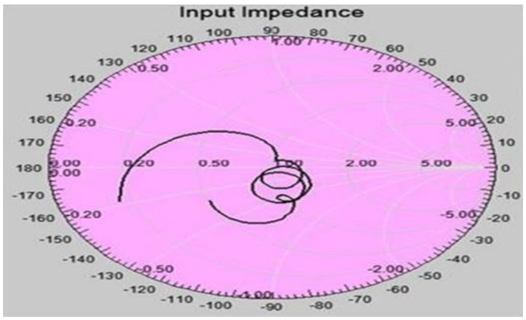


Figure 5: Input Impedance Smith Chart

Antenna gain is often related to the gain of an isotropic radiator, resulting in units dBi. Antenna gain at all the Resonant Frequencies is observed and shown in Figure 6. Maximum Gain is of 4.5 dBi is obtained at 9.9732 GHz.

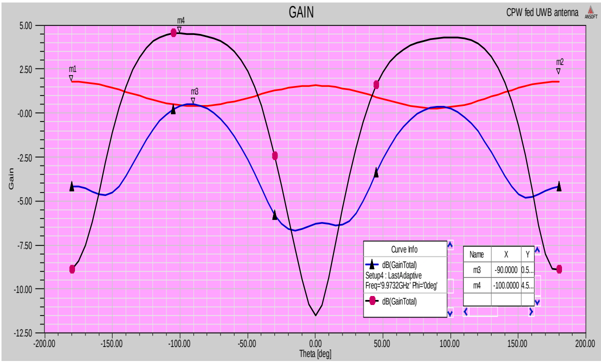
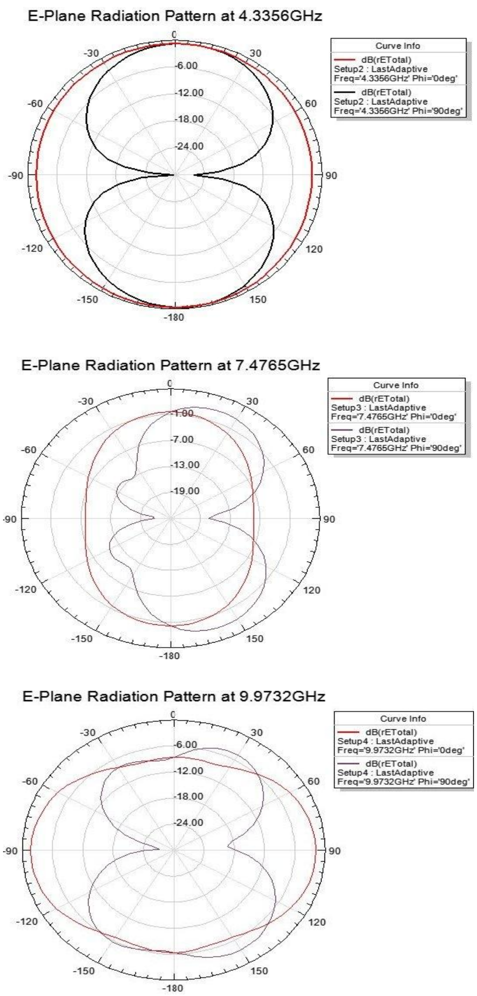


Figure 6: Gain vs. Frequency

E-Plane and H-Plane Radiation Patterns at the Resonant Frequencies 4.3356GHz, 7.4765GHz, 9.9732GHz, 12.1477GHz are shown in Figures 7 and 8 respectively. The far-zone electric field lies in the E-plane and far-zone magnetic field lies in the H-plane. The patterns in these planes are referred to as the E and H plane patterns respectively. Figure 7 shows the radiation pattern in E-plane for Phi=0 degrees and Phi=90 degrees for all the four resonant frequencies. Figure 8 shows the radiation pattern in H-plane for Theta=0 degrees and Theta=90 degrees for all the four resonant frequencies.



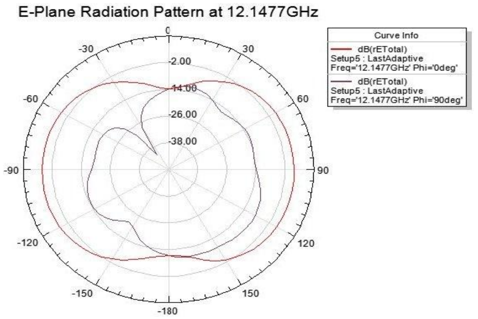


Figure 7: E-Plane Radiation Patterns at Resonant Frequencies

A Quasi Omni Directional Radiation pattern is observed from the simulated patterns.

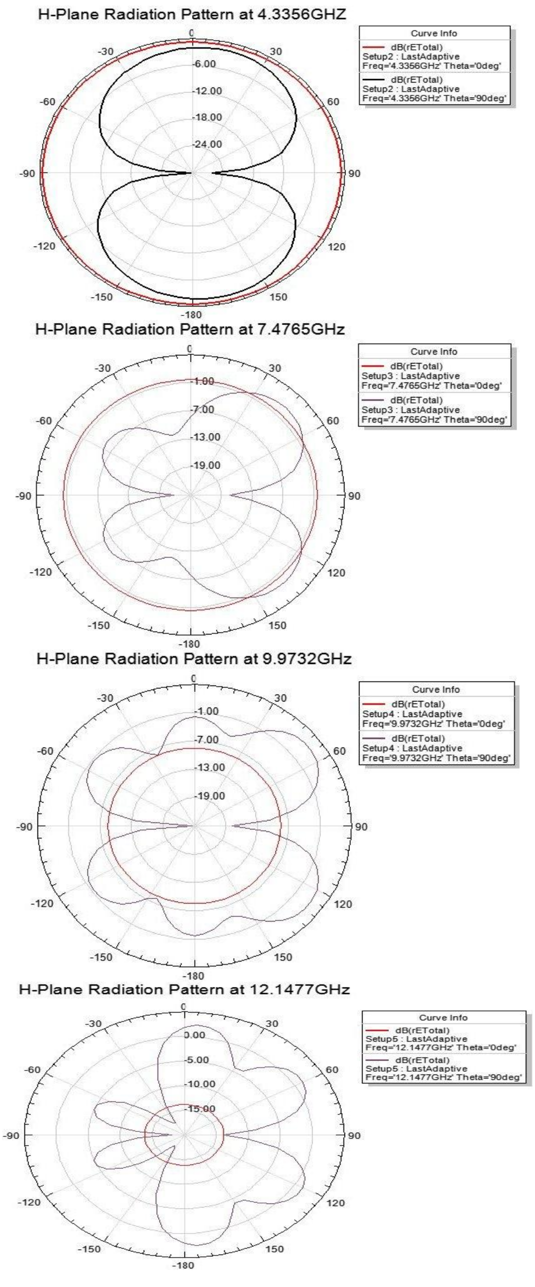


Figure 8: H-Plane Radiation Patterns at Resonant Frequencies

IV. CONCLUSION

A CPW fed Circular shaped patch with compact size is proposed and simulated. It can be used for number of wireless applications like WLAN, Wi-Fi, Wi-Max, Bluetooth etc. A comparative study is done on antenna by varying the substrate materials which are used in popular. Finally, it is observed that wide operating bandwidth of 9.745 GHz is obtained for FR4 substrate material. Hence, other parameters like Return Loss, VSWR etc. are analyzed for antenna prototyped on FR4 Substrate. The operating band is below -10dB and resonated at four frequencies. VSWR is less than 2. Peak Gain is 4.5 dBi. Quasi Omni-directional Radiation Pattern is observed.

V. ACKNOWLEDGMENT

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REFERENCES

[1] Federal Communications Commission (FCC), Washington, DC, "First report and order in the matter of revision of Part 15 of the commission's rules regarding ultra-wideband transmission systems," ET-Docket 98-153, 2002.

[2] N. P. Agra wall, G. Kumar, and K. P. Ray, "Wide-band planar monopole antennas," *IEEE Trans. Antennas Propag.*, vol. 46, no. 2, pp. 294–295, Feb. 1998.

[3] L. Jianxin, C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Trans. Antennas Propag.*, vol. 53, no. 11, pp. 3500–3504, Nov. 2005.

[4] M. J. Ammann and Z.-N. Chen, "Wideband monopole antennas for multi-band wireless systems," *IEEE Antennas Propag. Mag.*, vol. 45, no. 2, pp. 146–150, Apr. 2003.

[5] M. J. Ammann and Z. N. Chen, "A wide-band shorted planar monopole with bevel," *IEEE Trans . Antennas Propag.*, vol. 51, no. 4, pp. 901–903, Apr. 2003.

[6] K. P. Ray and S. Tiwari, "Ultra wideband printed hexagonal monopole antennas," *Microwave., Antennas Propag.*, vol. 4, no. 4, pp. 437–445,2010.

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