CPW feed UWB Antenna for Next Generation Personal Wireless Communication Devices

Jayesh Dharne[1], Prof. V. M. Kulkarni[2]
[1,2] *Dept of E&TC, MIT, Aurangabad, MS, India*

Abstract- **In this paper, design and performance analysis of Co-Planar Wave-guide (CPW) feed ultra-wide band (UWB; 3.1 ~ 10.6 GHz) for next generation wireless communication devices has been investigated. The proposed antenna is fabricated on a FR-4 substrate of thickness h = 1.6mm having loss tangent of 0.02 and dielectric constant of ξr = 4.4 and has been analyzed using HSFF simulation software. The proposed antenna provides a simulated VSWR ≤ 2 bandwidth of 2.35 – 10.78 GHz. The proposed antenna exhibits good electrical characteristics in both time and frequency domain, stable gain over the UWB range and almost omnidirectional radiation patterns making the antenna suitable for wireless applications.**

Index Terms- Ultra-wide band (UWB) antenna, Co-planar wave-guide (CPW), gain improvement.

I. INTRODUCTION

Ultra-wide band (UWB) refers to the systems having bandwidth greater than 500 MHz. Federal Communication Commission (FCC) in the year 2002, assigned unlicensed use of 3.1-10.6 GHz (7.5 GHz) frequency spectrum for the use of UWB communication system. UWB system has a number of advantages in particular, UWB systems: have potentially low complexity and low cost; have noise-like signal; are resistant to severe multi path and jamming; have very good time domain resolution making suitable candidate for applications involving location and tracking [1]-[2].

- Perhaps the greatest advantage of UWB is most evident from the famous Shannon formula for the capacity of a band-limited channel in Gaussian noise:

$$C = W \log\left(1 + \frac{P}{WN_0}\right) ...(1)$$

where C is the channel capacity (in bps), W is the channel bandwidth (in Hz), P is the signal power (in Watts) and No is the noise power spectral density (in Watts/Hz). The Shannon formula shows that, given the noise power spectral density N0 of the channel, the signal power P can be traded off with the bandwidth (W) while maintaining the same channel capacity [2].

These advantages of UWB make it even more attractive for consumer communication applications such as smart-phones, laptops, tablets, smart TV, wireless printers and local wireless device connectivity, etc…

Antennas play a vital role in design of wireless devices or systems. Wireless systems now a days require to be miniaturized meaning antennas embedded in this systems should be even smaller. However, while minimizing the size of antenna it should defy its electrical characteristics. Researchers in [3]-[5], have presented compact UWB micro-strip antennas. Micro-strip patch antennas wherein patch resides on one side of the PCB and ground resides on the other; are a popular choice because of its easy of modelling and fabrication. However, integrating these antennas with integrated circuits on single sided PCB becomes tedious. To overcome this problem, co-planar wave-guide feed UWB antennas were designed and presented in[6]-[8]. In this paper, a Co-Planar Wave-guide feed UWB antenna which is an extension of micro-strip antennas is designed and analyzed for the next generation wireless applications mentioned earlier. The proposed antenna meets the stringent requirements of low power consumption, compact size, high gain, directional radiation pattern, con formality, rigidness and robustness. The proposed antenna is designed and analyzed using Ansys HFSS simulation software. The antenna is fabricated on a low cost FR4 glass epoxy substrate of thickness 1.6mm. The antenna is tested in an open environment using a Vector Network Analyzer. Simulated and measured results are verified to validate the design.

II. ANTENNA DESIGN

The printed CPW line feed UWB antenna consists of circular radiating patch of radius R, CPW feed line of length Lp and width Wp and complementary ground structures (CGS) of length Lg and width Wg on the top side of the PCB. The radius of the circular radiating patch is calculated using equations 1 and 2 following [9]-[10]:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \quad \text{.. (2)}$$

And

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \quad \text{...(3)}$$

Where h = thickness of substrate in cm, is the dielectric constant of the material.

Fig. 1 shows the structure of CPW feed UWB Antenna which is an extended version of micro-strip feed line UWB antenna. With radiating patch and ground plane on the same side of PCB, integration of CPW feed antenna with other components on the PCB becomes more convenient.

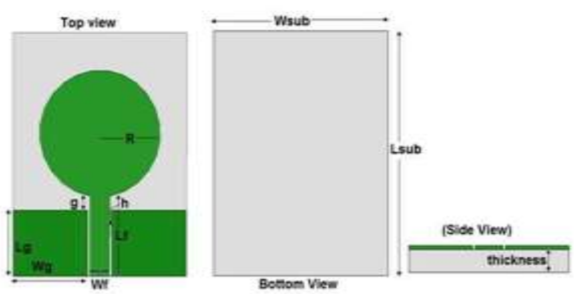


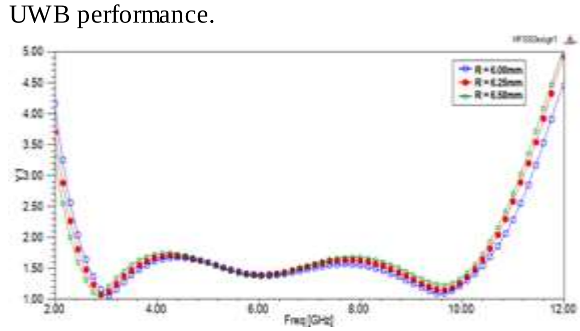
Fig. 1. Structure of CPW feed UWB Antenna

The antenna is fabricated on a low cost FR-4 substrate of height 1.6mm, dielectric constant (εr) = 4.4 and loss tangent of 0.02. The theoretical dimension of the radiating patch for resonant frequency of 3.1 GHz and FR-4 substrate is 6.1mm. The optimized dimensions of the CPW feed UWB antenna are as follows: R(radius of radiating patch) = 6.25mm, Lsub (length of substrate) = 24 mm, Wsub (width of substrate) = 20 mm, Wf (width of feed line) = 2 mm, Lf (Length of feed line) = 10mm, Lg (length of ground plane) = 8.75mm, Wg (width of ground plane) = 9.75mm, gap between radiating patch and ground plane g = 1.25mm, gap between CPW feed line and ground plane h = 0.25mm.

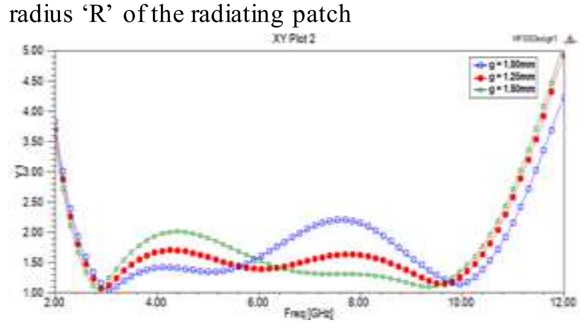
III. PARAMETRIC STUDY

The parametric study of radius 'R' of the radiating patch, gap 'g' between the radiating patch and ground plane and gap 'h' between the CPW feed and ground plane is carried out to understand their influence on the UWB characteristics.

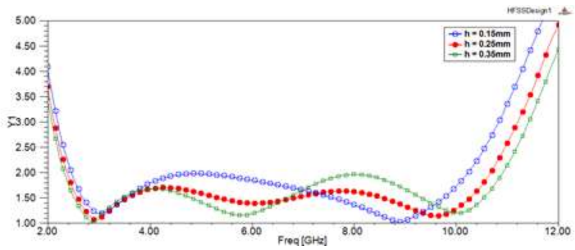
The radius 'R' of the radiating patch mainly affects the lower edge resonance frequency of the UWB band. As the radius of the patch goes on increasing, the lower edge resonance frequency of the UWB band goes on decreasing. This validates the inverse relation of the patch radius 'R' with frequency 'fr' given in Equation 1. The VSWR Vs frequency variation for different patch radius is shown in Fig 2(a). The gap 'g' is varied from 1mm to 1.5mm through optimized value 1.25mm. The gap mainly affects the center frequency band of the UWB band. Changing the gap changes the RLC tuning of the antenna causing impedance mismatch. Similarly, the gap 'h' is varied from 0.15mm to 0.35mm through optimized value of 0.25mm. Changing either of the gap causes impedance mismatch (impedance mismatch generates more reflected waves back to the source called the Standing Waves and the ratio of incident waves and reflected waves is termed as Standing Waves Ratio [SWR]) thereby affecting the UWB performance.



(a) Variation of VSWR Vs frequency for different radius 'R' of the radiating patch



(b) Variation of VSWR Vs Frequency for different gap- 'g' between radiating patch and ground plane



(c) Variation of VSWR Vs Frequency for different gap- 'h' between CPW feed line and ground plane

Fig. 2 Parametric study of CPW Feed UWB Antenna

The gap 'g' and 'h' mainly affect the higher edge frequency of the UWB band. The parametric study of variation of gap 'g' and gap 'h' for VSWR Vs frequency is shown in Fig. 2(b) and Fig. 2(c) respectively.

IV. RESULTS AND DISCUSSIONS

Furthermore, to have more insights into operation and working of CPW feed UWB antenna we study the current distribution, radiation pattern and gain of the antenna.

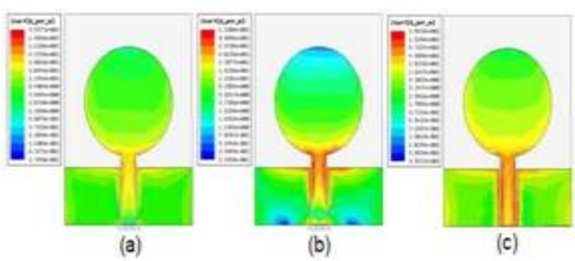


Fig. 3 Surface current distribution at (a) 3.2 GHz, (b) 5.5 GHz and (c) 7.5 GHz of CPW feed UWB Antenna

Fig. 3 shows the surface current distribution of the proposed antenna. The surface concentrates mainly on radiating patch at 3.1 GHz (or the lower edge frequency) and concentrates in the feed line at 5.5 GHz (or the centre frequency) and is uniformly distributed across the entire antenna geometry at 7.5 GHz (or the higher edge frequencies). Observing current distribution can help us analyze or modify the structure at certain frequencies. The simulated radiation patterns along E plane and H plane have been investigated at sampling frequencies of 3.1 GHz, 5.5 GHz and 7.5 GHz. The radiation patterns are almost omni directional along H plane and directional along E plane as shown in Fig. 4. Fig. 5 shows the simulated gain of the proposed antenna. The proposed antenna has a simulated gain of 0.68 dB, 2.28 dB and 3.8 dB at sampling frequencies of 3.1 GHz, 5.5 GHz and 7.5 GHz respectively. Simulated VSWR of the proposed antenna is shown in Fig. 6. The proposed antenna operates over a frequency of 2.35 GHz to 10.78 GHz which overs the Bluetooth (IEEE 802.11 b/g) /IMT-E (2.4–2.484GHz / 2.5– 2.6GHz), worldwide inter-operability for microwave access WiMAX IEEE 802.16 (3.3–3.6GHz) and 5.2/5.8 GHz WLAN IEEE 802.11 a (5.15–5.35GHz and 5.725–5.825GHz) and 5.5GHz HIPERLAN2 (5.47–5.725GHz) for Personal Wireless Communication Systems (PWCS) application frequency bands. Fig. 7 shows the fabricated prototype of the proposed antenna. Fig. 8 shows the measured VSWR results of the proposed antenna. The antenna is tested in an open environment using FieldFox Vector Network Analyzer (VNA).

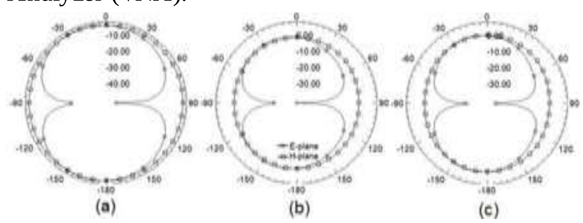


Fig. 4 Simulated radiation pattern along E plane and H plane at (a) 3.1 GHz, (b) 5.5 GHz and (c) 7.5 GHz of CPW feed UWB Antenna

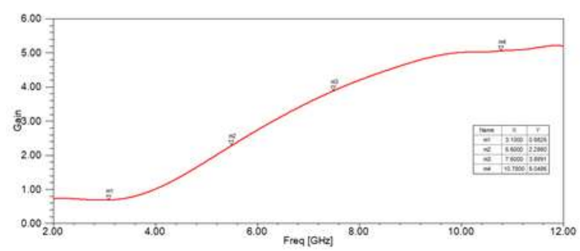


Fig. 5 Simulated gain of the proposed antenna

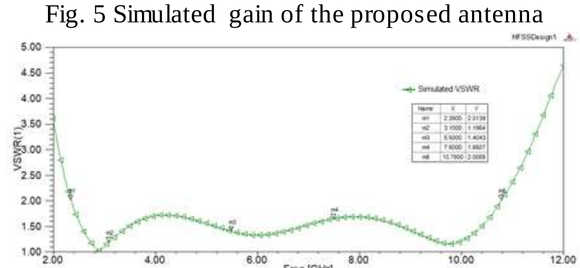


Fig. 6 Simulated VSWR of the proposed antenna

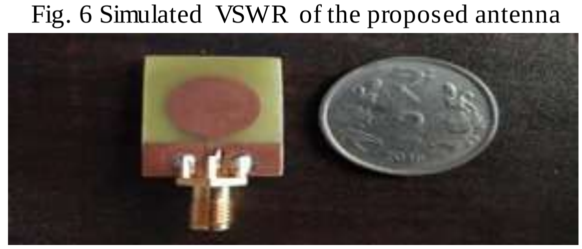


Fig. 7 Fabricated prototype of the proposed antenna

Fig. 8 Measured results of the proposed antenna

V. CONCLUSION

In this paper, design, analysis of CPW feed UWB antenna was carried out. The proposed antenna meets the FCC regulations of frequency bandwidth requirement of UWB systems and hence can be used for UWB applications. The antenna exhibit good time domain and frequency domain electrical characteristics and hence become a suitable candidate for applications in personal wireless communication devices which require stringent specifications of low power consumption, higher data rates, high bandwidth, stable gain and directional radiation pattern. The simulated and measured results are in good agreement with each other.

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