U-T Shape Ultra Wide Band Antenna for IEEE802.15.3a Applications

P. S. Ashtankar[1] and C. G. Dethe[2]

[1]*Department of Electronics & Communication Engineering, KITS, Ramtek (M.S.), India-441106*

[2]*Priyadarshini Institute Of Engineering & Technology, Nagpur (M.S.), India-440019*

psashtankar@gmail.com, cgdethe@gmail.com

Abstract

In this paper, we propose a new ultra-wideband (UWB) antenna for UWB applications. The proposed antenna is designed to operate from 2 to 12 GHz. It consists of a T shape patch united with U shape patch with a partial ground plane to form an antenna. The proposed antenna is successfully simulated, designed, fabricated and measured. The measured results show that the proposed antenna with dimensions of 75 mm (Wsub) ×100 mm (Lsub) ×1:6 mm (H) has a large bandwidth over the frequency band from 2 GHz to 12 GHz with VSWR less than 2. The proposed antenna exhibits nearly omni directional radiation pattern, stable gain, and small group delay variation over the desired frequency bands. Details of the proposed antenna design and measured results are presented and discussed

Keywords: *U-T Shape, UWB, IEEE802.15.3a*

1. Introduction

The Ultra-wideband (UWB) system covers the frequency range from 3.1-10.6 GHz, which based on narrow pulses to transmit data at extremely low power, and looks like random noise to most conventional radio systems. The UWB technology offers several advantages over conventional communications systems. For instance, there is no carrier frequency. Instead, UWB emits timed "pulses" of electromagnetic energy. Therefore transmitter and receiver hardware can be made very simple, which is necessary for the portable devices. There is a wide range of applications for UWB technology, which includes wireless communication systems, position and tracking, sensing and imaging, and radar. Antenna plays an essential task in UWB system, which is different from narrowband system. UWB systems transmit extremely narrow pulses on the order of 1ns or less resulting in bandwidths in excess of 1 GHz or more. However, the design and fabrication of high-performance transmitting/receiving antennas often present significant challenges in the implementation of these systems. The challenge lies in the development of an antenna, capable of handling these high-speed pulse trains. The design of a UWB antenna is very difficult, because the fractional bandwidth is actually big, and antenna must cover multiple-octave bandwidths in order to transmit pulses that are of the order of a nanosecond in duration. Since data may be contained in the shape of the UWB pulse, antenna pulse distortion must be kept to a minimum. From a system design perspective, the impulse response of the antenna is of particular interest, because it has the ability to alter or shape the transmitted or received pulses. In practice, attempt must be made to limit the amplitude and group delay distortion below certain threshold that will ensure reliable system performance. Recently, the ability to incorporate more than one communication standard into a single system has become an increasing demand for a modern portable wireless communication device. Due to the limited space, it often requires an antenna to operate at several bands [1]. Ultra-wideband (UWB) technology is emerging as a solution for IEEE 802.15.3a (TG3a) standard [24,25].The standardization of the UWB radio is ongoing under IEEE 802.15 WPAN High Rate Alternative PHY Task Group 3a (IEEE802.15.3a) and wireless personal area network (WPAN) is originated by the Bluetooth (IEEE802.15.1). IEEE802.15.3a is trying to establish the new standard of WPAN to drastically increase the data rate, which is a weak point of Bluetooth. Now IEEE802.15.3a considers the use of UWB, following the tentative regulation of FCC (Federal Communications Commission, USA), to achieve the bit rate of 110 Mb/s at 10 m and 200 Mb/s at 4 m. The purpose of this standard is to provide a specification for a low cost, low complexity, low power, and high data-rate wireless connectivity among devices within personal operating space. UWB technology has received an impetus and attracted academia and industrial attention in the wireless world ever since Federal Communication Commission released a 10 dB bandwidth of 7.5 GHz (3.1-10.6 GHz) with an effective isotropic radiated power (EIRP) spectral density of 41:3dBm/MHz for communication applications [3]. The release of an extremely wide spectrum of 3.1-10.6 GHz for commercial applications has generated a lot of interest in the research and development of UWB technology for short range wireless communications, imaging radar, remote sensing, and localization applications. Various planar monopole antennas with ultra-wideband characteristic have been reported [14, 15]. Beside UWB, Bluetooth applications also have the advantage of license free operation in the industrial, scientific and medical (ISM) band

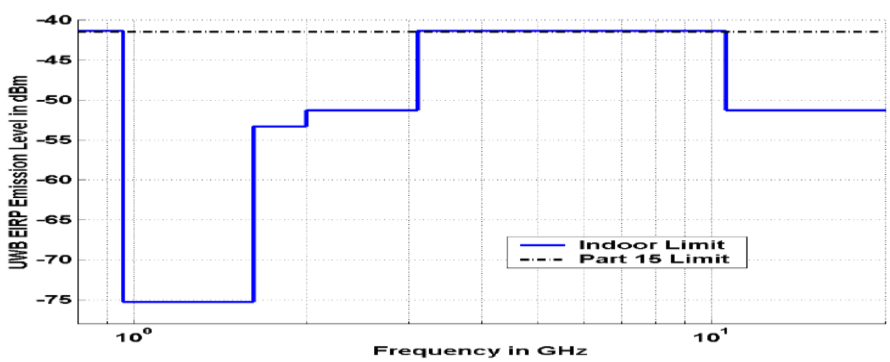


Figure 1. UWB Spectral Mask per FCC (Modified) Part 15 Rules [1]

Ultra wideband (UWB) is a leading candidate for short-range, wireless personal area networks, or WPANs. With this technology, people will be sharing photos, music, video, data and voice among networked consumer electronics, PCs and mobile devices throughout the home and even remotely. For example, users will be able to stream video content from a PC or consumer electronics (CE) device, such as a camcorder, DVD player or personal video recorder, to a flat screen HDTV (high-definition television) display without the use of any wires. In this application, a wireless universal series bus (W-USB) is required to replace cables and build up high speed wireless link between personal computers and other devices. The W-USB has strong demands for high-performance UWB antennas which will be facing three most challenging issues namely miniaturized size, reduced ground plane reliance, and enhanced diversity performance [30]. The design is based on a MEDIUM SIZE printed UWB antenna [30,31] with dimension of 75 mm × 100 mm × 1.6 mm. T shape strip is attached to the top side of the radiator to manage the radiation pattern for high gain. A Fork shape radiator united with the T shape radiator to form antenna. The ground-plane effect on impedance performance of the antenna has been significantly reduced due to partial length of the ground plane. This idea is an effective method to alleviate the problem of the ground plane reliance. This Medium size printed antenna should be reduced further in order to fit within the W-USB dongle.

2. Antenna Design and Simulated Return Loss

Figure 2 shows the evolution of the proposed UWB antenna, which consists of a rectangular partial ground plane and a radiator. The patch radiator has two antenna united together one is U shape and second is T shape. The antenna size is 75 mm × 100 mm × 1.6 mm and printed on the substrate of the same size. The substrate material is FR4 with εr =4.4 and tanδ=0.02

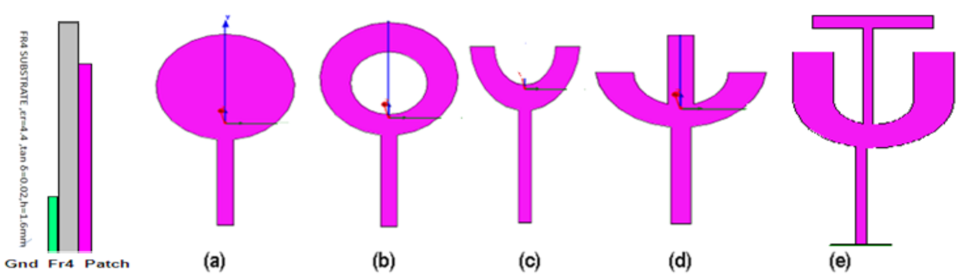


Figure 2. Evolution of the Proposed Dual Band Antenna

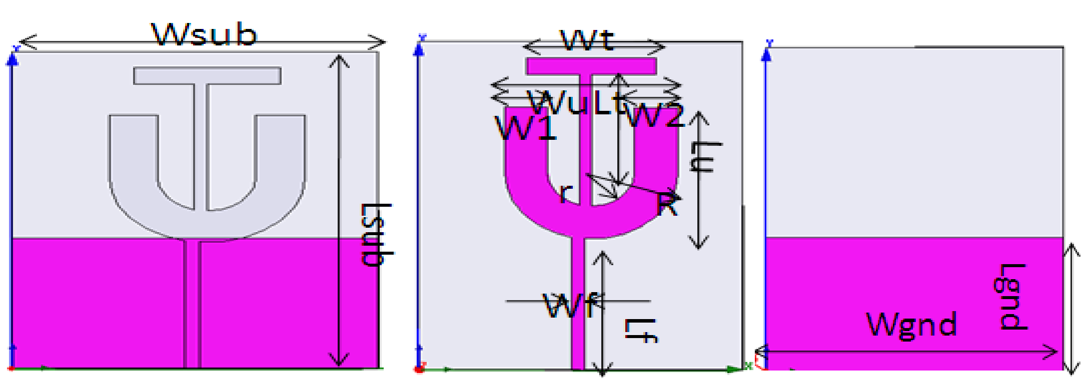


Figure 3. Geometry of Proposed Antenna

The optimum dimension of the antenna is as follows: Wsub= 75 mm, Lsub=100mm, Wt=45mm, Lt=45mm, Wu=55mm, Lu=40mm,Lg 40mm,Wf=3mm, Lf=43mm, R=20mm, r=10mm, W1=15mm, W2=15mm, Wg=75mm, Lg=39.5mm. By selecting these parameters, the antenna can be tuned to operate in the 2 GHz to 12 GHz frequency range with return loss below -10 dB as shown in Figure 4. The excitation is a 50Ω microstrip line printed on the partial grounded substrate. To design the antenna, two techniques are used: (i) two antenna united as a single patch, (ii) a partial ground plane, which can lead to a good impedance matching.

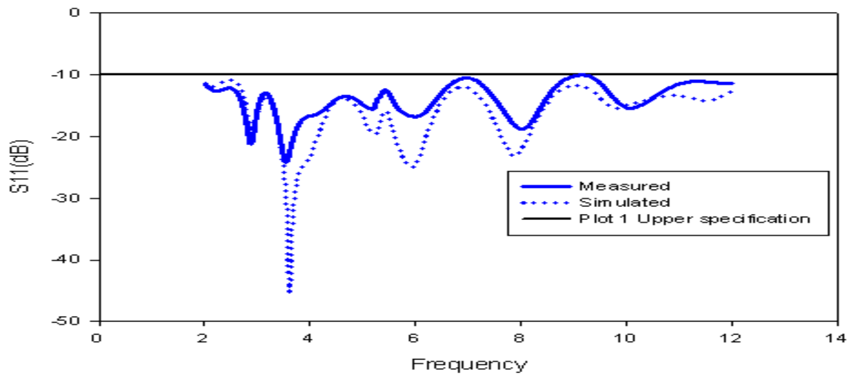


Figure4: Measured and Simulated Return Loss (S11) Curves of Proposed Antenna at Lg=39.5mm

3. Parametric Study

Parametric study has been conducted to optimize the design of the antenna. This study is crucial as it gives approximation measure before antenna fabrication can be done. The performance of U-T shaped dual UWB antenna with 2-12 GHZ band characteristic depends on number of parameters, such as length of the ground plane, gap (g) between radiating patch and ground plane, width of the substrate (Wsub) and length of the substrate (Ls), length and width of the ground plane, width (W) and length (L) of the U-T shape radiating patch. Beside these, antenna performance also depends on ground plane size and shape. The impedance bandwidth of the proposed antenna at different Lg is shown in Figure5. The optimum impedance bandwidth is obtained at Lg=39.5mm, the capacitance that results from the spacing between edge of ground plane and radiating patch reasonably balances the inductance of the antenna. Figure4 shows return loss S11 (dB) at 39.5mm.

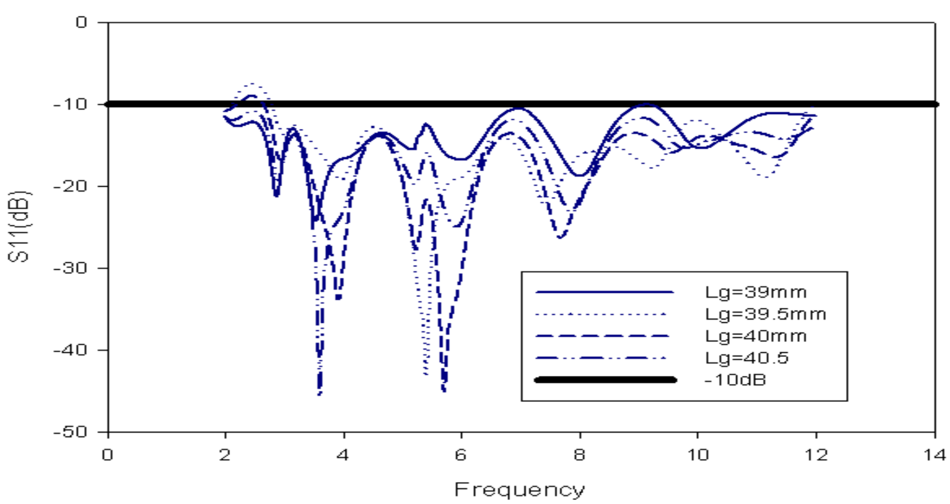


Figure5. Simulated Return Loss (S11) Curves of Proposed Antenna for Different Ground Length (ref to Figure 3)

Two cases are considered when the Lg=40mm and Lg=40.5mm, the resonance n figure5. When the feed location changes to d = 6.9 mm, the return loss frequency range is 3.8 GHz to 8.5 GHz; and when the feed location changes to d = 5.9 mm, the return loss frequency range is 3.3 GHz to 11.5 GHz and higher. Hence, the antenna performs more or less worse in both these changes than the optimized case in Figure 5. Further analysis of above cases should combine with the discussion of current distribution changes.

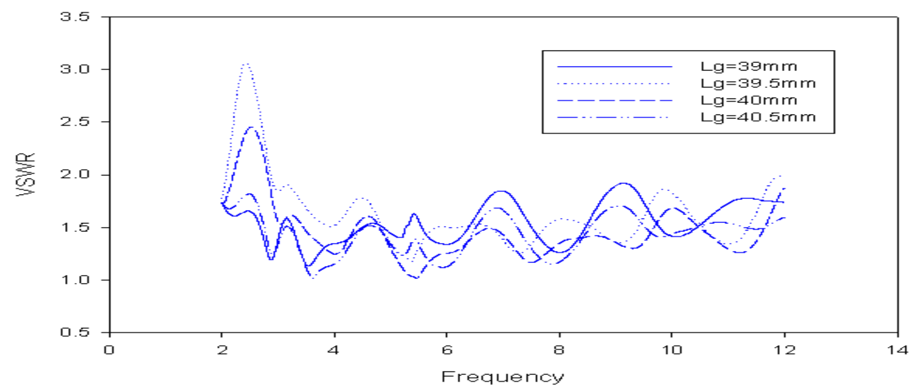


Figure6. Simulated VSWR Curves of Proposed Antenna for Different Ground Length (ref to Figure 3)

The VSWR of less than 2 is obtained for a band of 2-12GHz. To understand the working of antenna, we find a surface current at frequency of 3,5and 7 GHz. At 7 GHz whole current is concentrated in ground plane. So, radiation is not occur at 7 GHz and band-notched characteristic achieved. Surface current results are shown in fig 7.On the ground plane, the current is mainly distributed on the upper edge along the y-direction. That means the portion of the ground plane close to the disc acts as the part of the radiating structure. Consequently, the performance of the antenna is critically dependent on the width(Wg) of the ground plane [8, 9].However, it also leads to a disadvantage, i.e., when this type of antenna is integrated with printed circuit board, the RF circuitry cannot be very close to the ground plane. Simulations have shown that when the length of the ground plane is more than 39.5mm, the performance of the antenna is almost independent.

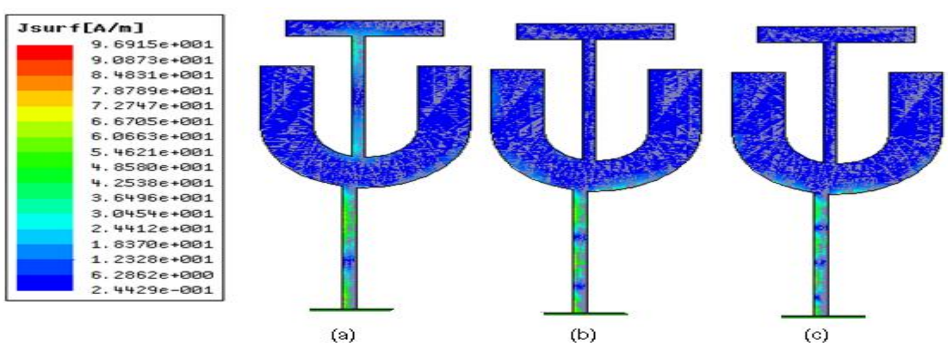


Figure 7. Surface Current Distributions of Proposed Antenna at 3, 5 and 7 GHz

Antenna radiation pattern demonstrates the radiation properties on antenna as a function of space coordinate. For a linearly polarized antenna, performance is often described in terms of the E and H -plane patterns. The E -plane is defined as the plane containing the electric field vector and the directions of maximum radiation while the H -plane as the plane containing the magnetic field vector and the direction of maximum radiation. The x- z plane elevation plane with some particular azimuth angle ϕ is the principle E -plane while for the x- y plane azimuth plane with some particular elevation angle θ is the principle of H -plane [3]. Figure 8 shows the simulated two-dimensional E and H -plane at three frequencies. In the E -plane, the value of azimuth angle ϕ of 0◦and 90◦ while in H -plane, the value of elevation angle θ of 0◦ and 90◦ are taken into consideration. The plot for radiation is utilized for three frequencies within pass band, which are 3 GHz at the lower bound, 5 GHz at the middle bound and 7 GHz at the upper bound. The simulated results of maximum gain in dBi of the designed antenna is as shown in Figures 8(i,j,k). The gain is simulated at the fix point on azimuth angle of ϕ at 0◦and 90◦and at different elevation angle of θ. It is observed that the gain pattern is not the same for all angle of ϕ.

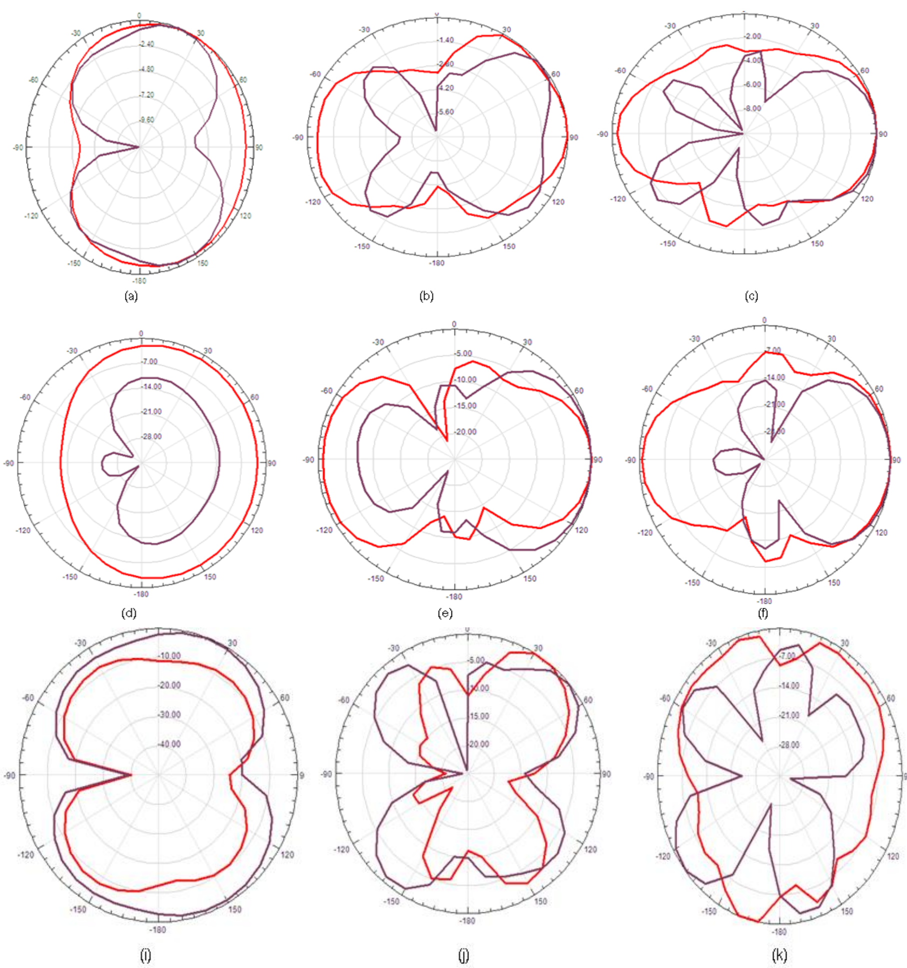


Figure 8(a,b,c). radiation patterns (reTotal) with 10 dB normalized value in the φ =0°and φ =90° planes of a proposed patch with εr =4.4 at 3,5,7GHZ ,
Figure 8(d,e,f). radiation pattern (re Phi with 10dB normalized value) in the φ =0°and φ =90° planes of a proposed patch with εr =4.4 at 3,5,7GHZ

4. Time Domain Analysis

In order to validate the efficiency of the antenna, the pulse base signal is excited with Gaussian pulse. It can be related to the dispersion of receive signal compared to transmitter signal. The time domain characteristics viz. group delay of the proposed antenna can be measured between two identical antennas placed at 0.3-0.4 m in the face-to-face orientations, using Vector Network Analyzer. As shown in Figure9, the measured group delay is constant over the operating bands except over the3-5 GHZ band. The fidelity factor is given by [31]

$$\rho = \max_{\tau} \left\{ \left| \frac{\int p(t)s(t-\tau)dt}{\sqrt{\int p^2(t)dt}\sqrt{\int s^2(t)dt}} \right| \right\} \quad \text{—1}$$

Where, τ is a delay which is varied to make the numerator in Equation (1) a maximum. It determines the correlation between the excited pulse signal p(t) and radiated or received pulse signals(t). The fidelity factor can also be measured between excited and radiated pulse while it is also measured between excited and received pulse, which is a slightly less than the fidelity factor between excited and radiated pulse. From those measurements the status of offering good pulse handling capability as demanded by modern Bluetooth and UWB communication systems can be understand

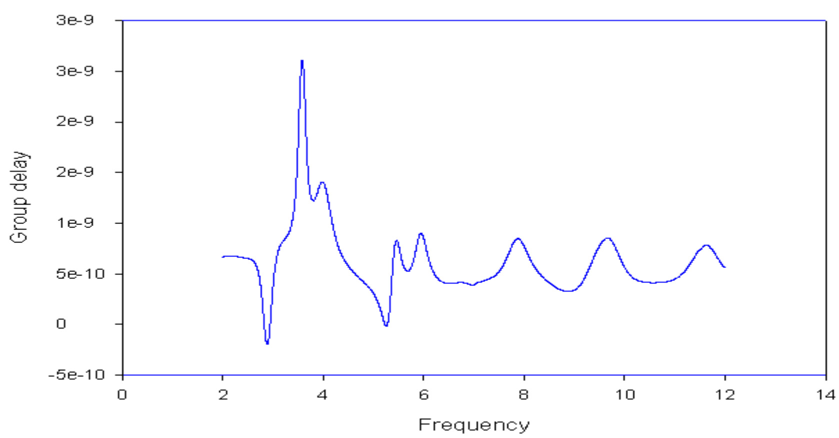
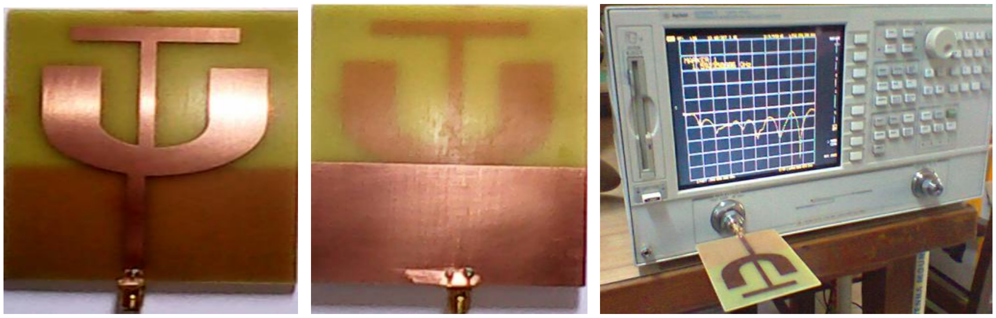


Figure 9. Simulated Group Delay of the Proposed Antenna

5. Fabrication and Measured Results

The antenna structure is fabricated on a printed circuit board (PCB) using Photolithography technique and tested. The fabricated antenna is shown in Figure12. Below fig clearly show the process for S11 (dB) measurement which is for Lg=45mm. The measured results reasonably agree with simulated results, by changing the length of the ground plane different S11 values can be obtained. The proposed antenna performs good impedance matching over the UWB band.



(a) Top View (b) Bottom View (c) Antenna under Test

Figure 12. Photograph of the Proposed Antenna

6. Conclusion

The printed U-T shape monopole antenna fed by microstrip line is investigated in this paper. It has been shown that the performance of the antenna in terms of its frequency domain characteristics is mostly dependent on the feed gap h, the width of the ground plane W and the dimension of the ant. The first resonant frequency is directly associated with the dimension of the U and T radiating patch of the antenna because the current is mainly distributed along the edge of the radiating patch. The partial ground shows better return loss compared to full ground patch on the bottom because the antenna is transformed from patch-type to monopole-type by the partial ground. In order to further improve its overall bandwidth two steps of feed line can be used but that may be used for different application. The feed line is connected to SMA center pin with width of 3 mm. This paper investigates antenna performance in terms of the radiation pattern and reflection coefficient. To control antenna behavior, it is necessary to observe the current distribution. The proposed antenna is fabricated on FR4 with $\varepsilon r=4.4$, $\tan\delta=0.02$ and the thickness is 1.6mm with the proposed dimension of 75mm x 100 mm×1.6mm. The simulated results of proposed antenna for return loss is less than -10 dB and VSWR is less than 2 satisfies the system requirements for S-DMB, WiBro, WLAN, CMMB and WPAN application at the operating frequency of 7 GHz.

Acknowledgements

The authors thank Prof. S.V Khobragade,BATU,Lonere,M.S. India, Sanjeev Mishra ,iit,bombay and PKamlesh Bhoyar of ASK, India Technology for providing antenna design, fabrication and characterization facilities.

References

[1] "Federal Communications Commission revision of Part 15 of the com-mission's rules regarding ultra-widebandtransmission systems", FCC, Washington, DC, First Report and Order FCC, 02.V48, **(2002)**.
[2] C. A. Balanis, "Antenna theory analysis and design", John Wiley, **(1997)**.
[3] H. Schantz, "The Art and Science of U ltra-wideband Antennas", London, Artech House, **(2005)**.
[4] I. J. Bahl and P. Bhartia, "Microstrip Antennas", Chapter 3, Artech House, **(1980)**.
[5] Z. N. Chen, "Antennas for Portable Devices", Institute for Infocomm Research Singapore, New York, John Wiley&Sons Inc., **(2007)**.

[6] X. L. Bao and M. J. Ammann, "Investigation on UWB printed monopole antenna with rectangular slitted ground plane", Microw Opt Technol Lett., vol. 49, **(2007)**, pp. 1585–1587.
[7] Q. X. Chu and Y. Y. Yang, "A compact ultra-wideband antenna with 3.4/5.5 GHz dual band-notched characteristics", IEEE Trans Anten-nas Propag., vol. 56, **(2008)**, pp. 3637–3644.
[8] L. Luo, Z. Cui, J. P. Xiong, X. M. Zhang and Y. C. Jiao, "Compact printed ultra-wideband monopole antenna with dual band-notch characteristic", Electron Lett., vol. 44, **(2008)**, pp. 1106–1107.
[9] T. Yuan, C. W. Qiu, L. W. Li, M. S. Leong and Q. Zhang, "Ellipti-cally shaped ultra-wideband patch antenna with band-notch features", Microw Opt Technol Lett., vol. 50, **(2008)**, pp. 736–738.
[10] G. Kumar and K. P. Ray, "Broadband Microstrip Antennas", Norwood, MA: Artech house, **(2003)**.
[11] L. Yang and G. B. Giannakis, "Ultra-wideband communications: an idea whose time has come", IEEESignal Processing Magazine, **(2004)** November, pp. 26–54.
[12] Y. C. Lin and K. J. Hung, "Compact ultra wideband rectangular aperture antenna and band-notched designs", IEEE Trans. Antennas Propagation, vol. 54, no. 11, **(2006)**, pp. 3077-3081.
[13] K. Chung, S. Hong and J. Choi, "Ultra wide-band printed monopole antenna with band-notch filters", IET Microwaves, Antennas and Propagate, vol. 1, no. 2, **(2007)**, pp. 518-522.
[14] Q. X.Chu and Y. Y. ang, "A compact ultra-wideband antenna with 3.4/5.5 GHz dual band-notched characteristics", IEEE Trans. Antennas Propagation, vol. 56, no. 12, (2008) December, pp. 3637-3644.
[15] S. K. Mishra, R. K. Gupta and J. Mukherjee, "Parallel metal plated tuning fork shaped omnidirectional monopole antenna for UWB application", Microwave Opt. Technol. Lett., vol. 53, no. 3, **(2011)** March, pp. 601-604.
[16] G. -P. Gao, Z. -L. Mei and B.-N. Li, "Novel circular slot UWB antenna with dual band-notched characteristic", Progress In Electromagnetics Research C, vol. 15, **(2010)**, pp. 49-63.
[17] A. Edalati and T. A. Denidni, "A compact UWB antenna with dual band-notched characteristics", Microwave Opt. Tech. Lett., vol. 52, **(2010),** pp. 1183-1186.
[18] G. -P. Gao, M. Li, S. -F. Niu, X. -J. Li, B. -N. Li and J.-S. Zhang, "Study of a novel wideband circular slot antenna having frequencyband-notched function", Progress In Electromagnetics Research, vol. 96, **(2009)**, pp. 141-154.
[19] L. Luo, Z. Cui, J. P. Xiong, X. M. Zhang and Y. C. Jiao, "Compact printed ultra-wideband monopole antenna with dual band-notch characteristic", Electron. Lett., vol. 44, no. 19, **(2008)** September, pp. 1106- 1107.
[20] HFSS Version 11.0, Ansoft Software Inc., **(2009)**.
[21] Institute of Electrical and Electronics Engineers. IEEE Std 802.15.1-2005, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs), **(2005)** June 14.
[22] Institute of Electrical and Electronics Engineers. IEEE Std 802.15.4-2006, Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifi-cations for Low-Rate Wireless Personal Area Networks WPANs), **(2006)**.
[23] IEEE P802.15 Study Group Medical Body Area Networks (SG-MBAN). SG BAN Montreal Interim Meeting Minutes, ftp://ieee:wireless@ftp.802wirelessworld.com/15/07/15-07-0748-00-0ban-mban-meeting-minute-montreal-may-2007.doc, **(2007)** May 20.
[24] IEEE P802.15 Study Group Medical Body Area Networks (SG-MBAN). SG BAN San Francisco Plenary Meeting Minutes, ftp://ieee:wireless@ftp.802wirelessworld.com/15/07/15-07-0820-00-0ban-ban-sessions-minute-sanfrancisco-july-2007.doc, **(2007)** August 16.
[25] http://www.ieee802.org/15/pub/.
[26] S. K. Mishra, R. K. Gupta, A. R. Vaidya and J. Mukherjee, "Printed fork shaped dual band antenna for Bluetooth and UWB applications with 5.5 GHz WLAN band notched characteristics", Progress In Electromagnetics Research C, vol. 22, **(2011)**, pp. 195-210.
[27] I. Oppermann, M. Hamalainen and J. Iinatti, "UWB Theory and Applications", John Wiley & Sons Ltd., **(2004)**.
[28] S. K. Mishra, R. K. Gupta and J. Mukherjee, "Parallel metal plated tuning fork shaped omnidirectional monopole antenna for UWB appli-cations", Microw. Opt. Technol. Lett., **(2011)** March, pp. 601–604.
[29] Z. N. Chen, T. S. P. See and X. M. Qing, "Ultra-wideband antennas with miniaturized size, reduced ground plane reliance, and enhanced diversity (Invited)", Proceedings of iWAT 2008, Chiba, Japan, **(2008)** March.
[30] Z. N. Chen, T. S. P. See and X. M. Qing, "Small printed ultra-wideband antenna with reduced ground plane effect", IEEE Trans. Antennas and Propagat., vol. 55, no. 2, **(2007)** February, pp. 383−388.
[31] G. -P. Gao, M. Li, S. -F. Niu, X. -J. Li, B. -N. Li and J. -S. Zhang, "Study of a novel wideband circular slot antenna having frequency band-notched function", Progress In Electromagnetics Research,vol. 96, (2009), pp. 141-154.

Authors

Dr. Chandrasekhar G. Dethe received his M.Tech. Degree in Electronics Engineering from VNIT, Nagpur. ,and Ph.D. degree from Amravati University, Amravati.His Ph.D. Thesis titled "***IP NETWORK TRAFIC MEASUREMENT, ANALYSIS AND MODELING"***. He worked as an Assistant Professor at SSGM, College of Engineering Shegaon from 1999 to 2005, later on he joined a professor and in charge of research and development activity at YCCE, Nagpur. He is currently working as a principal of PIET, Nagpur. His field of specialization includes digital Communication, Data network, Signal Processing. His papers are published in National and International Journals including IEEE proceedings. He is a fellow of IE and IETE and Life member of ISTE.

Mr. Pankaj S. Ashtankar obtained his Bachelor's and master's Degree in Electronics Engineering from RTM, Nagpur University. He is Pursuing Ph.D. in the field of UWB antenna design. He is Asst. Prof. in ECE Dept. KITS; Ramtek He attended and presented several papers in National, international conferences and symposium. He has been closely Associated with various continuing education programmes in the area of communication Engineering conducted by K.I.T.S, Ramtek. His area of interest is Ultra wide band and RF antenna design. He is member of IETE, Member of IE (India), Member of International Association of Engineers, Member of Antenna test and measurement society of India, Member of System society of India and Life member of ISTE.