An ACS-fed Compact Antenna for UWB Applications

T. K. Roshna[1*], U. Deepak[1], V. R. Sajitha[1], and P. Mohanan[1]

[1] *Centre for Research in ElectroMagnetics and Antennas, Department of Electronics,*
Cochin University of Science and Technology, Cochin, Kerala, India,
**e-mail:* roshnatk03@gmail.com

Abstract. A novel Asymmetric Coplanar Strip (ACS) fed compact antenna for Ultra Wideband (UWB) application is proposed. The staircase-shaped radiator elements are used to obtain the UWB characteristics. The prototype is fabricated on a substrate, with Ų of 4.4 and thickness of 1.58 mm, having an overall size of 25 x 10 mm^2. The proposed antenna achieves a 2:1 VSWR bandwidth of 3 to 13 GHz (10 GHz), with an average gain and radiation efficiency of 3.6 dBi and 75%, respectively throughout the UWB band.

Keywords: UWB, Coplanar, ACS-fed, Compact, Antenna

1. Introduction

The UWB technology became a promising solution for future high-data rate short range wireless communications and peer-to-peer ultra-fast communications, since FCC (Federal Communications Commission) had allocated 3.1 to 10.6 GHz spectrum for unlicensed UWB communication. UWB is conventionally known as Impulse Radio, which transmits data in short pulses and this technology is mainly used for short-range applications, as the EIRP is less than -41.3 dBm/MHz [1]. UWB have attracted much attention due to its high speed data rate and excellent immunity to multipath interference. For many applications like WUSB (Wireless Universal Serial Bus), WBAN (Wireless Body Area Network) etc. small and miniaturized UWB antennas are needed. Wide research efforts have been made towards the design of small UWB antennas. Many compact UWB antennas such as beveled rectangular patch [2], two-step tapered monopole antenna [3], tapered slot with tuning patch [4] and Vivaldi antenna with extended ground plane stubs [5] are reported in the literature. Coplanar Waveguide (CPW) fed antennas are easy to integrate with microwave circuits and are used for developing various UWB antennas [6, 7]. To further minimize the overall size of the antenna, asymmetric coplanar strip feeding technique is efficiently utilized. Fei *et al*. discussed an asymmetric coplanar strip-fed half monopole antenna [8].

In this paper, a compact asymmetric coplanar strip fed compact UWB antenna is proposed and designed. It has achieved 8% reduction in the overall area and has a less group delay as compared to the one discussed in [8]. The proposed antenna offers a wide bandwidth of 10 GHz (3 to 13 GHz) with good impedance matching and stable gain. Simulated and measured results show that the proposed UWB antenna meets the requirements of the antenna for UWB radio systems, in spite of its small size which makes the antenna suitable for various portable devices

2. Antenna design and geometry

The proposed compact UWB antenna is depicted in Figure 1. The signal to ground gap (feeding gap, g) is optimized as 0.4 mm to have a proper impedance matching. This antenna consists of two staircase shaped patches. The left side patch has six steps and right side patch has five steps to achieve the broad bandwidth. Thus, the staircase shaped radiator elements along with the ACS feed are responsible for the UWB operation of this antenna. Here, the ultra-wide bandwidth is achieved by the overlapping of two or more resonant bands corresponding to its resonant portions in the staircase shaped elements. Electromagnetic simulator tool CST Microwave Studio is used to investigate numerically and optimize the proposed antenna configuration. The optimized dimensions of the proposed geometry are shown in Table I. The prototype is fabricated on a 25 x 10 x 1.6 mm^3 FR-4 substrate with relative permittivity (Ų) of 4.4 and loss tangent (tan ŭ) of 0.02.

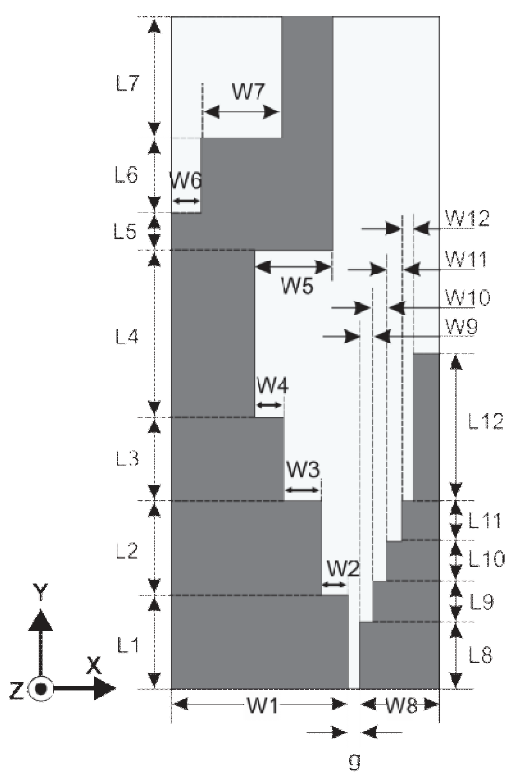
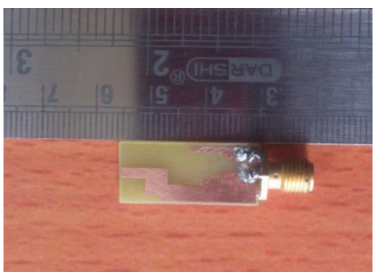


Fig.1. Geometry of the proposed antenna

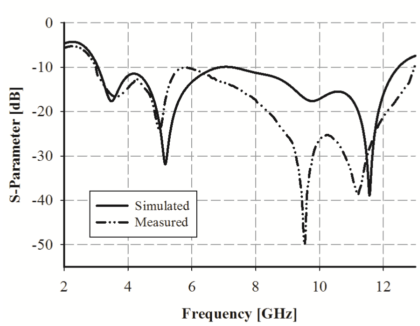
3. Results and discussion

The Agilent PNA E8362B Network Analyzer is used to monitor the experimental results of the proposed antenna and anechoic chamber is utilized for the far-field measurements. A photograph of the fabricated antenna is shown in Figure 2(a). Simulated and measured reflection characteristics of the proposed antenna with optimized parameters are shown in Figure 2(b). Both the simulated and measured results are in good agreement. The slight discrepancies are due to the effect of SMA connector soldering and fabrication tolerances. As observed from the figure, the proposed antenna offers a 2:1 VSWR bandwidth covering the essential bandwidth criteria for UWB communication systems as specified by FCC. This wide bandwidth is predominantly due to the overlapping of four resonances at 3.5, 5, 9.5 & 11.5 GHz.

Figure 3 (a), (b), (c) & (d) depicts the surface current distribution for the four resonant frequencies, i.e., at 3.5, 5, 9.5 and 11.5 GHz, respectively. Figure 4 shows the effect of WX, L7 and L12 on the reflection coefficient, where, WX=W1-(W2+W3+W4), by keeping all the other parameters intact as in Table I. These three parameters have a critical role in the UWB characteristics of this antenna. From Figure 4(a), it is interesting to notice that when WX is either too wide or too narrow, the -10 dB bandwidth is reduced. As the WX increases, the impedance matching at 6-8 GHz deteriorated whereas it improves at 3.5 - 4.5 GHz. As in Figure 4(b), the -10 dB bandwidth of the antenna varies significantly with the change of L7. An increase in L7 increases the impedance matching at 3 - 5.5 GHz, but decreases the matching at 5.5 - 8 GHz. Looking at the whole spectrum, it seems that the variation in WX and L7 does not affect the first two resonances very much, but has a larger impact on the higher harmonics. L12 has a critical role in determining both impedance matching and resonant frequencies in the entire UWB band, as shown in Figure 4(c). It can be seen that the variation of the L12 shifts all the resonance modes across the spectrum. When L12 varies from its optimal value the current flows along the length. This allows to increase or decrease of the inductance of the antenna, which causes the first resonance mode either to be

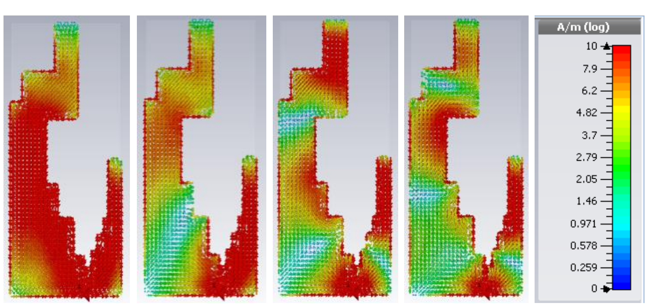


(a)



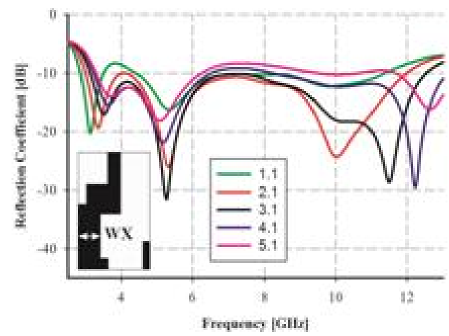
(b)

Fig. 2.(a) Photograph of the fabricated antenna (b) Simulated and measured reflection characteristics.

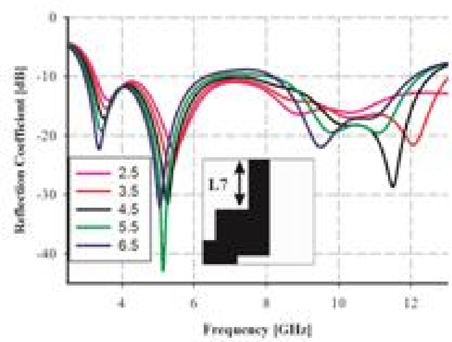


(a) (b) (c) (d)

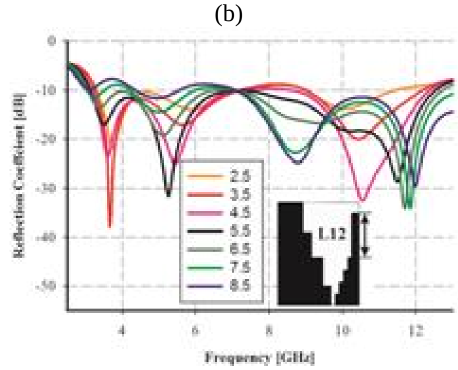
Fig.3. Surface current distribution at (a) 3.5 GHz (b) 5 GHz (c) 9.5 GHz (d) 11.5 GHz



(a)



(b)



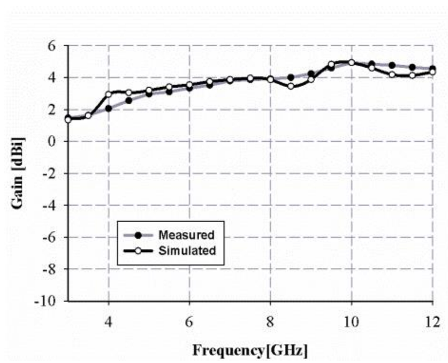
(c)

Fig.4. Simulated reflection coefficient for different values of (a) WX (b) L7 (c) L12

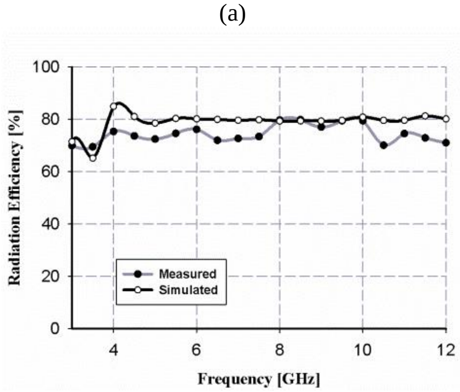
up-shifted or down-shifted in the spectrum. This change of inductance causes the frequencies of the higher harmonics to be unevenly shifted and thus makes some resonances not closely spaced across the spectrum and reduces the overlapping between them. As a result, the impedance matching becomes worse in these frequency ranges. After a rigorous parametric analysis the optimized values of WX=3.1 mm, L7=4.5 mm and L12=5.5 mm are taken for the overall UWB antenna performance.

The proposed UWB antenna provides an average gain of 3.6 dBi, with a peak gain of 5 dBi at 10 GHz, in the direction of maximum radiation, within the UWB band, as shown in Figure 5(a). Also, this antenna provides good radiation efficiency in the operating band. Figure 5(b) shows the measured radiation efficiency using the Wheeler Cap method by Schantz [9]. Figure 6(a) & (b) show the 2-D far-field radiation patterns at 3.5, 5 & 9.5 GHz resonant frequencies in the H-plane and E-plane, respectively. The antenna provides nearly omnidirectional coverage in the H-plane and bi-directional coverage in the E-plane, with relatively stable radiation patterns in the operating band. It is seen that the radiation pattern deteriorates slightly at the higher frequencies; this is due to the propagation of higher-order resonant modes at these frequencies.

The measurement of group delay and transmission characteristics of the UWB antenna is important to have knowledge about the phase linearity of the transmitted signals. This measurement is accomplished by placing two identical prototypes of the antenna at a distance of 15 cm. It is evident from Figure 7 that, the group delay remains constant throughout the UWB band with variation less than 1ns, for face-to-face and side-to-side orientation tested.

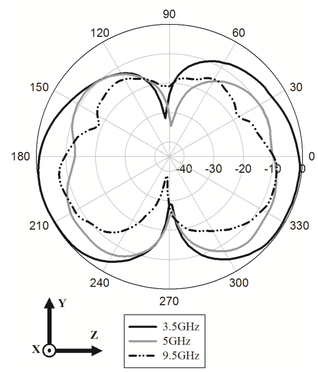


(a)

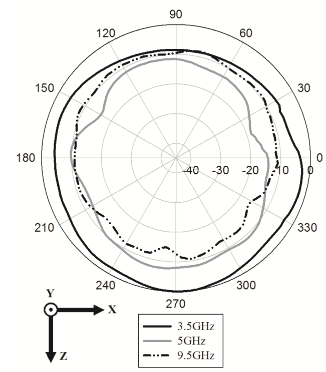


(b)

Fig.5. Measured and Simulated (a) gain (b) radiation efficiency



(a)



(b)

Fig.6. Measured radiation patterns at various resonance frequencies (a) E-Plane (y-z plane) (b) H-Plane (x-z plane).

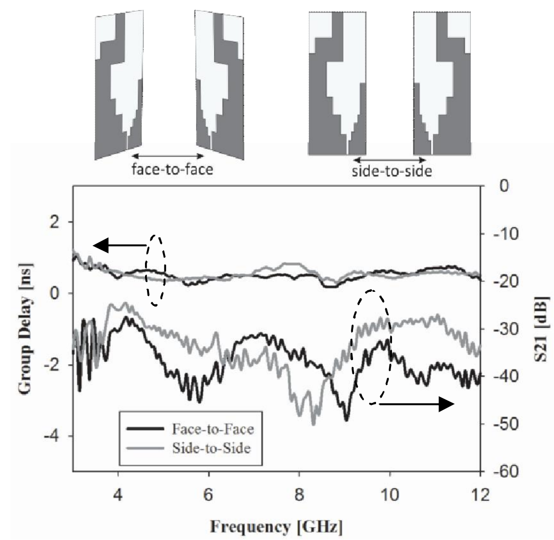


Fig.7. Measured group delay and transmission characteristics of the proposed antenna

4. Conclusion

A very compact and novel asymmetric coplanar strip fed antenna for UWB applications was presented and discussed. The antenna has a wide bandwidth and satisfied the essential criteria for UWB radio systems, in spite of its small size. It exhibited stable gain, good radiation efficiency and less group delay throughout the UWB band. The compactness, simple feeding technique and coplanar design will make the integration of this antenna easier on to the circuit boards.

Acknowledgement

The authors are thankful to University Grant Commission (UGC), Department of Science & Technology (DST) and Council of Scientific & Industrial Research (CSIR), Government of India, for their financial support.

References

[1] J. Hu and J. Yang, The adaptabilities of different UWB technologies to the FCC UWB emission limit, Int. Conf. Communications Software Networks (ICCSN–2009), Macau, China, February 2009, 358–361.

[2] L. N. Zhang, S. S. Zhong, X. L. Liang and C. Z. Du, Compact omnidirectional band-notch ultra-wideband antenna, Electron. Lett., 45(2009), 659ï 660.

[3] R. Zaker, Ch. Ghobadi and J. Nourinia, A modified microstrip-fed two-step tapered monopole antenna for UWB and WLAN applications, Progress In Electromagnetics Research, 77(2007), 137-148.

[4] R. Azim, M. T. Islam and N. Misran, Compact tapered shape slot antenna for UWB applications, IEEE Antennas Wireless Propag. Lett., 10(2011), 1190ï 1193.

[5] Jiangniu Wu, Zhiqin Zhao and Qing-Huo Liu, A novel vivaldi antenna with extended ground plane stubs for ultrawideband applications, Microwave Opt Technol Lett., 57(2015), 983-987.

[6] A. K. Gautam, Swati Yadav and Binod Kr Kanaujia, A CPW-fed compact inverted L-strip UWB microstrip antenna, Microwave Opt Technol Lett., 55(2013), 1584-1589.

[7] Amir Siahcheshm, Javad Nourinia, Yashar Zehforoosh, and Bahman Mohammadi, A compact modified triangular CPW-fed antenna with multioctave bandwidth, Microwave Opt Technol Lett., 57(2015), 69-72.

[8] Peng Fei, Yong-Chang Jiao, Yang Zhu, and Fu-Shun Zhan, Compact CPW-fed monopole antenna and miniaturized ACS-fed half monopole antenna for UWB applications, Microwave Opt Technol Lett., 54(2012), 1605-1609.

[9] H. Schantz, Radiation efficiency of UWB antennas, IEEE Conf. Ultra-Wideband Systems and Technologies (UWBST©2002), Baltimore, MD, USA, 2002, 350-355.

Biography of the authors

T K Roshna : She received the B.Sc degree in Electronics from Calicut University, Kerala, India, and M.Sc. degree in Electronics from Cochin University of Science And Technology (CUSAT), India, in 2009 and 2011, respectively. She is currently working towards her Ph.D. degree at Cochin University of Science and Technology (CUSAT), India. Her research interests include designing of MIMO antennas multiband antennas,ZOR antenna, electrically small antennas, inductive tuned antennas, Chip less RFIDs and UWB antennas.

U Deepak : He received the B.Sc degree in Electronics from Calicut University, Kerala, India, and M.Sc. degree in Applied Electronics from National Institute of Technology Tiruchirappalli (NITT), India, in 2003 and 2005, respectively. He is currently working towards his Ph.D. degree at Cochin University of Science and Technology (CUSAT), India. His research interests include dielectric measurements, designing of multiband antennas, ZOR antenna, Chip less RFIDs MIMO antennas and UWB antennas.

V R Sajitha : She received the M.Sc. degree in Electronics from Cochin University of Science And Technology(CUSAT), India, in 2011. She is currently working towards her Ph.D. degree at Cochin University of Science and Technology (CUSAT), India. Her research interests include designing of multiband antennas, inductive tuned antennas, Chip less RFIDs and UWB antennas.

P. Mohanan : He received the Ph.D. degree in microwave antennas from Cochin University of Science and Technology (CUSAT), Cochin,India, in 1985. He worked as an Engineer in the Antenna Research and Development Laboratory, Bharat Electronics, Ghaziabad, India. Currently, he is a Professor in the Department of Electronics,CUSAT. He has published more than 250 referred journal articles and numerous conference articles. He also holds several patents in the areas of antennas and material science. His research areas include microstrip antennas, uniplanar antennas, ultra wideband antennas dielectric resonator antennas, superconducting microwave antennas, reduction of radar cross sections, Chipless RFID, Dilectric Diplexer and polarization agile antennas. Dr. P.Mohanan received the Dr.S .Vasudev Award 2011 from Kerala Sate Council for Science, Technology and Environment Government of Kerala, in 2012 and Career Award from the University Grants Commissionin Engineering and Technology, Government of India, in1994.