ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome V (Year 2012). FASCICULE 4 [October–December]. ISSN 2067-3809

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SEMI CIRCULAR MICROSTRIP LINE FED PRINTED MONOPOLE ANTENNAS FOR UWB COMMUNICATION

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ABSTRACT: *In this paper we have investigated Microstrip line fed semi circular printed monopole antenna, which is basically printed microstrip antenna with etched ground plane for UWB applications. In particular we have simulated circular patch monopole antenna and then after etched some part of the radiating patch in order to make semi circular antenna with good performance for UWB communication. While doing simulation study, a simple rectangular microstrip line is used for feeding the printed monopole antenna. Finally the simulated antenna is having frequency bandwidth under -10dB return loss is ranging from 2.8 GHz to 15 GHz. This semi circular printed monopole antenna works well for the whole UWB frequency band 3.1-10.6GHz.*
KEYWORDS: UWB, semicircular, printed monopole antenna, Microstrip line

INTRODUCTION

Ultra-Wideband (UWB) commonly refers to signal or system that either has a large relative bandwidth (BW) or a large absolute bandwidth [1]-[4]. Such a large BW offers specific advantages with respect to signal robustness, information content and/or implementation simplicity. But such systems have some fundamental differences from the conventional narrowband systems. The Federal communications Commission (FCC) has designated the 3.1 to 10.6 GHz band with Effective Isotropic Radiated Power (EIRP) below -40dbm/kHz for UWB Communications [1]-[2].

Some UWB antennas are much more complex than other existing single band, dual band and multi-band antennas [5]-[6]. Most of the UWB monopole antennas are investigated till today is non-planar as in and due to its protruded structure they cannot be integrated with integrated circuits and they are fragile. Few researchers have also studied printed monopole Antennas [3]-[4].

Ansoft High Frequency Structure Simulator (HFSS) simulation software has been employed for obtaining the simulation results.

GEOMETRY OF PRINTED UWB MONOPOLE ANTENNAS AND SIMULATION RESULTS. MODIFIED CIRCULAR UWB-MONOPOLE ANTENNA

This modified UWB monopole antenna is designed directly from the circular Patch UWB-Monopole antenna with some modifications in the patch shape as shown in Fig. 1(a). This proposed UWB-monopole antenna is designed on a substrate with 4.4 relative permittivity and 1.6 mm thickness and with a semicircular patch. The simulated UWB antenna is illustrated with the dimensions using FR4 substrate. After doing an extensive simulation study, we have fixed the dimensions of UWB monopole antenna and the value of "g" is 0.8mm. The patch has been reshaped from a circular to semicircular to make the antenna compact [5]-[6]. By reducing the patch size the antenna impedance matching was affected, the impedance matching was restored my adjusting the value of 'g'. By reducing the size of the patch the antenna efficiency was reduced slightly but a large bandwidth has been obtained which greater than the UWB bandwidth. After extensive simulation the 'g' value has been fixed [7]-[8].

The final optimal dimensions of the UWB-monopole antenna are:

- *Dimensions of Patch: Radius =12mm &*
- *Thickness =0.035mm*
- *Dimensions of Substrate: W = 46 mm, L = 52mm & Thickness =1.6mm.*
- *Dimensions of Ground: W = 46mm, L = 26.2mm & Thickness =0.5mm.*
- *Dimensions of Microstrip line: W=2.6 mm, L = 27.5 mm & Thickness =0.035mm.*

where "g" is gap between the ground plane and patch.

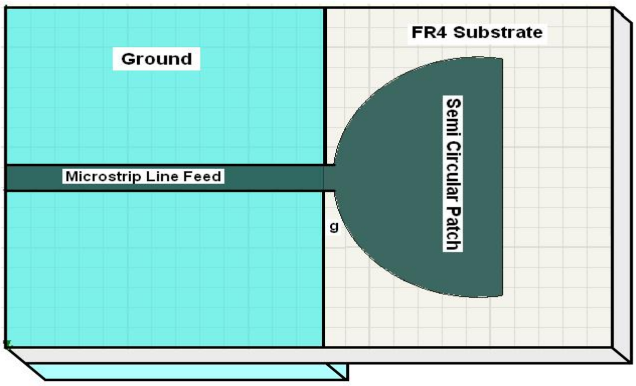


Fig. 1(a): Geometry of Semi circular Patch UWB Antenna.

At a particular values of g, the antenna impedance, bandwidth (f_{low} is the lower start frequency of the antenna BW, f_{high} is the higher end frequency of the antenna BW and antenna BW is considered for those frequency range where the s_{11} is below -10dB) and radiation efficiency are tabulated. Here the gap (g) between the circular patch and the ground plane below is the most crucial parameters for getting a huge BW. Mainly this "g" is served as a proper *impedance matching technique in order to get the antenna impedance equal to 50Ω and maximize the antenna radiation efficiency, as we can see from Table-I. And all other antenna parameters like Antenna accepted and radiated power, Maximum radiation intensity and peak gain are tabulated.*

Table I

g, mm	F_{low}, GHz	F_{high}, GHz	Antenna Impedance, Ω	P_{acc}, W	P_{rad}, W	Max U, W/Sr	Peak Gain	η, %
0.5	2.8	12.4	50	0.92	0.81	0.11	1.51	88.23
0.8	2.7	17.2	50	0.91	0.80	0.12	1.55	87.88

Note that modified Semi-circular Patch UWB-Monopole antenna is having better performance and good Bandwidth than the conventional circular Patch UWB-monopole antennas. The H-plane radiation pattern and E-plane radiation pattern on the other hand is purely omni-directional pattern throughout the Band of frequencies.

The simulated plot of Antenna return losses Vs frequency of antenna is shown in Fig. 1(b). , it can be seen that the bandwidth below -10dB ranges from 2.8 GHz to 15 GHz which includes the UWB bandwidth i.e. from 3.1GHz to 10.6 GHz .So this antenna operates as UWB antenna.

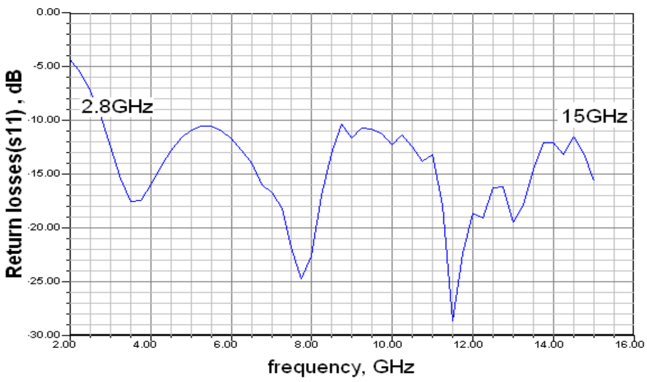


Fig. 1(b): s_{11} versus frequency plot (BW is from 2.8GHz to 15 GHz).

From the Fig.1(c) (i.e. the plot of antenna impedance Vs frequency), we can see the real part of antenna impedance is exactly 50 Ω at 3.1GHz and 7.9GHz where the imaginary part of the antenna impedance equals zero. Throughout the bandwidth of the UWB antenna, the real part of the antenna impedance varies from 25 Ω to 90 Ω whereas the imaginary part of the antenna impedance is in the range -32 Ω to +25 Ω that is not a major variation of the antenna impedance.

The simulated E-Plane radiation patterns(vertical plane or vertical cut of 3D radiation pattern) of the UWB antenna with a circular patch, with a 'g' value 1mm i.e. the separation between the ground plane and the patch at different frequencies are shown in the figure below. The radiation pattern is a function of (ϑ,φ) of electric field vector and E-planes are measured at fixed value of "ϑ" ,varying the value of "φ" from 0 degrees to 360 degrees.

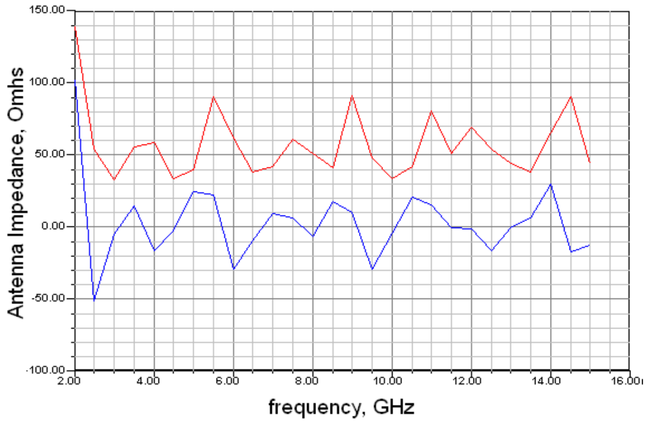
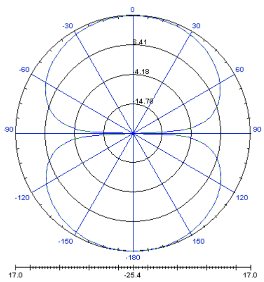
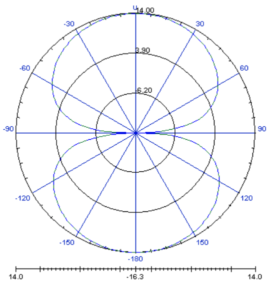


Fig. 1(c) : Antenna impedance versus frequency (real part → red color and imaginary part → blue color) of circular Patch UWB monopole Antenna.

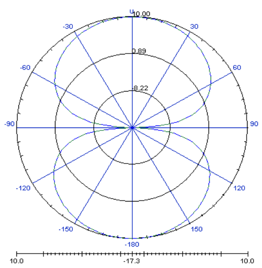
The E-Plane radiation patterns of the UWB antenna with a circular patch and with a separation of 1mm between the ground plane and the patch at different frequencies are shown in the above figure. It can be observed that the E-Plane pattern is like a doughnut or '8' shaped at 3GHz frequency and is almost same with a little distortion at 5GHz, 7.5 GHz, 10.6 GHz and 12 GHz frequencies.



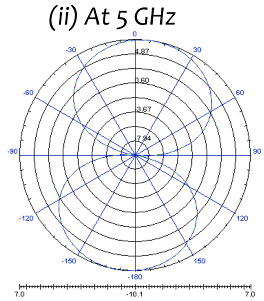
(i) At 3GHz



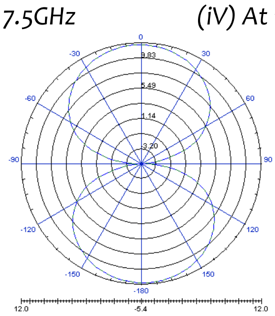
(ii) At 5 GHz



(iii) At 7.5GHz



(iV) At 10.6 GHz

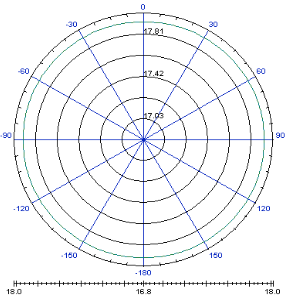


(V) At 12 GHz

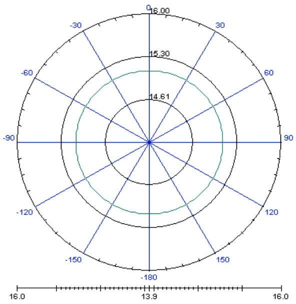
Fig. 1(d): E-plane radiation patterns at different frequencies.

The simulated H-Plane radiation patterns(horizontal plane or horizontal cut of 3D radiation pattern) of the UWB antenna with a circular patch, with a 'g' value 1mm i.e. the separation between the ground plane and the patch at different frequencies are shown in Fig. 1(e). The radiation pattern is a function of (ϑ,φ) *of electric field vector and H-planes are measured at fixed value of "φ" ,varying the value of "ϑ" from 0 degrees to 180 degrees in both clock wise and counter clock wise directions.*

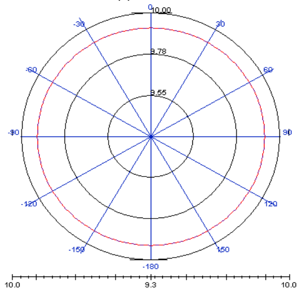
The H-Plane radiation patterns for the UWB antenna with a circular patch and a separation of 1mm between the ground plane and patch are shown in the above figure. It is observed that the H-plane patterns are almost omni directional at 3.1 GHz, 5 GHz, 7.5 GHz, 10.6 GHz and 12 GHzs. Finally the 'g' value was fixed at 1mm after extensive simulation meanwhile the antenna impedance was perfectly matched. The H-plane radiation was omni directional (circular) throughout the band of frequencies.



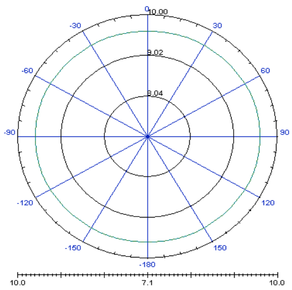
(i) At 3 GHz



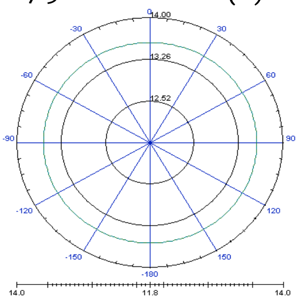
(ii) At 5 GHz



(iii) At 7.5 GHz



(iv) At 10.6 GHz

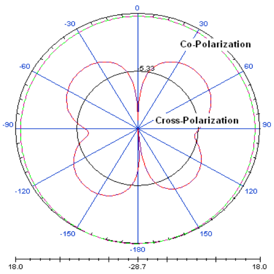


(v) At 12GHz

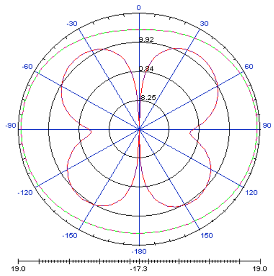
Fig. 1(e): H-plane radiation patterns at different frequencies.

The simulated polarization plots of the UWB antenna with a circular patch at different frequencies within the band of frequencies are show the Fig. 1(f), basically polarization is the orientation of the lines of electric flux in an electromagnetic field (EM field).

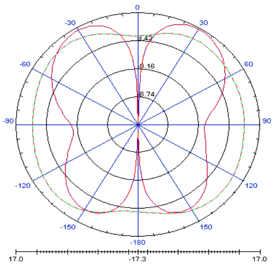
The polarization pattern is a function of (ϑ,φ) of electric field vector, in the above plots indicates co-polarization (dashed lines) and cross polarization in solid line (pink). Initially co-polarization was high at the lower resonant frequencies i.e. from 3GHz to 5 GHz and the cross polarization was slightly less, as the frequency increases i.e. from 7.5 GHz the cross polarization is increasing to a considerable extent at 10.6GHz and 12GHz.



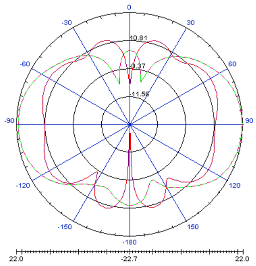
(i) At 3GHz



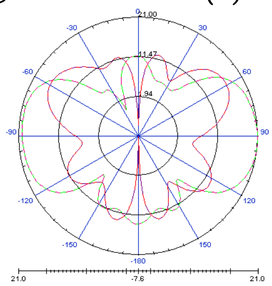
(ii) At 5 GHz



(iii) At 7.5 GHz

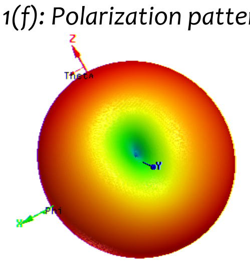


(iv) At 10.6 GHz

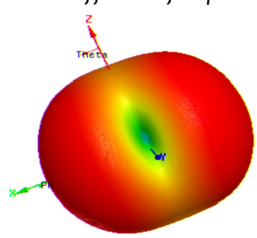


(v) At 12 GHz

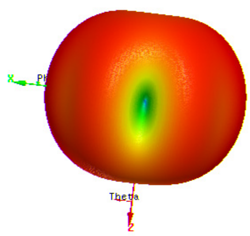
Fig. 1(f): Polarization patterns at different frequencies.



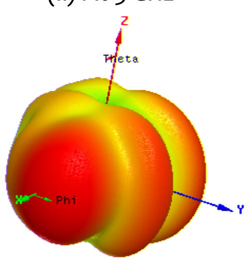
(i) At 3 GHz



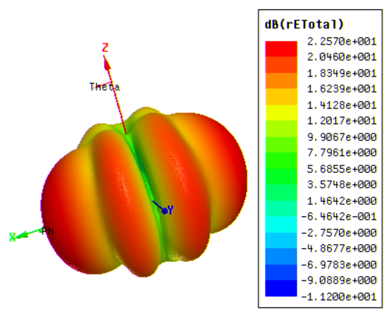
(ii) At 5 GHz



(iii) At 7.5 GH



(iv) At 10.6 GHz

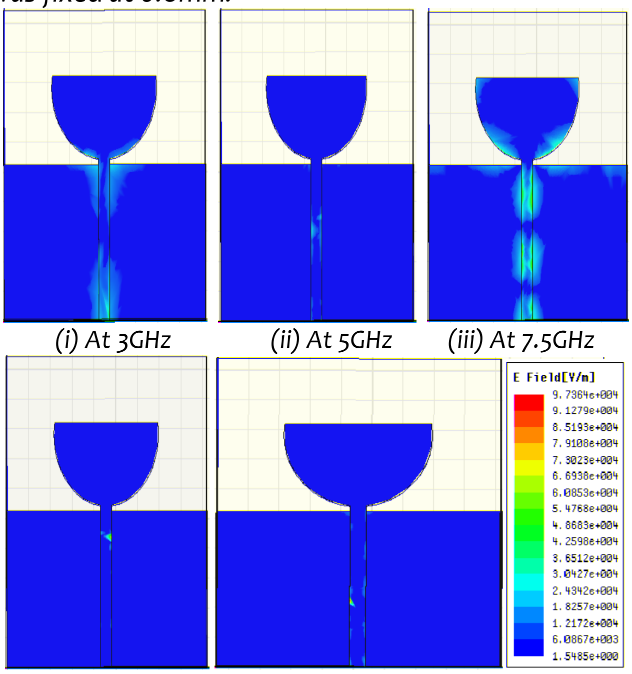


(v) At 12GHz

Fig. 1(g): 3D Radiation Plots at different frequencies.

The simulated 3D radiation patterns of the proposed antenna at 3, 5, 7.5, 9, 10.6 and 12 GHz are shown in the Fig. 1(g). The radiation pattern looks like a doughnut, similar to that of a dipole pattern, at the first resonant frequency i.e. 3GHz. At the second resonant frequency i.e. at 5GHz and the third resonance frequency i.e. at 7.5GHz the radiation pattern is somewhat like pinched doughnut (i.e. omni directional). As the frequency moves toward the upper end of the bandwidth the radiation pattern is some what slightly distorted as it reaches higher frequencies (i.e.10.6GHz and above)

The transition of the radiation patterns from a simple doughnut at the first resonance to the complicated radiation patterns at the higher resonances indicates that this antenna must have gone through major changes in its behavior but it had omni directionality, this was possible because of the partial ground plane i.e. 'g' the gap between the ground plane and the patch which was a major factor for perfect impedance matching of the antenna, due to the proper impedance matching the antenna has very less reflections. As the impedance matching was good the radiation power and radiation intensity were very high. After extensive simulation study the 'g' value was fixed at 0.8mm.



(i) At 3GHz (ii) At 5GHz (iii) At 7.5GHz

(iv) At 10.6GHz (v) At 12GHz

Fig. 1(h): Current distribution plots at different frequencies

The simulated current distribution patterns of the UWB antenna at different resonances are depicted in the Fig.1(h). It can be observed from the figure that the current distribution at 3GHz is indicating a first order harmonic, at 5GHz its indicating second harmonic. As frequency increases the current distribution becomes more complicated indicating to a third order harmonic at 10.6GHz and fourth order harmonic at 12GHz.

At the first resonance the current is oscillating and having a pure standing wave pattern along most part of the edges of the patch. So the patch acts as oscillating monopole, but the variation of current becomes more complicated at higher frequencies. The antenna operates in a hybrid mode of traveling waves and standing waves at higher frequencies, but the ground plane on the other side of the substrate cannot form good slot with the patch to support traveling waves. Therefore the impedance matching becomes worse for the traveling wave dependent modes at higher frequencies.

CONCLUSIONS

In this paper, we have investigated semicircular printed UWB monopole antenna with huge bandwidth, which is basically a printed microstrip antenna with the etched ground plane. Printed UWB monopole antennas are less fragile, planar and can be integrated with the integrated circuits unlike monopole antennas which have non-planar or protruded structures above the ground plane. In particular, we have simulated semicircular UWB monopole antenna directly from the circular printed UWB antenna and it has higher efficiency. The E-plane radiation the printed monopole antenna is in the form of 8 shapes and it is slightly tilted at higher frequencies. The H-plane radiation pattern has omni-directional patterns throughout the frequencies of the BW. It has been observed that such monopole antennas are suitable for UWB operations.

ACKNOWLEDGMENT

The First author is grateful to Dr. Kshetrimayum Rakhesh Singh forintroducing him design of broadband planar antennas for wireless and UWB Communication during his Postgraduate studies at the Indian Institute of Technology, Guwahati, India. As well as grateful to present Research guides, Dr. G Sasi Bhushana Rao, Andhra University, India and Prof. S Srinivasa Kumar, JNTU Kakinada, India, towards the Research Degree.

REFERENCES

[1] H. Schantz, "The Art and Science of Ultra wideband Antennas", Artech House Inc., 2005.
[2] G. R. Aiello and G. D. Rogerson, "Ultra-wideband Wireless Systems", IEEE Microwave Magazine, June, 2003, pp. 36-47.
[3] B. Allen, M. Dohler, E. E. Okon, W. Q. Malik, A. K. Brown, D. J. Edwards "Ultra-Wideband Antennas and Propagation for Communications, Radar and Imaging", John Wiley & Sons, 2007.
[4] D. M. Pozar, Microwave Engineering, John Wiley & Sons Inc., NJ, 2005
[5] Ramu Pillalamarri and R. S. Kshetrimayum, "Printed UWB Circular and Modified Circular Patch Monopole Antennas," accepted for IEEE Applied Electromagnetics Conference, Kolkatta, India, December 2007.
[6] Ramu Pillalamarri, SasiBhushana Rao G and Srinivara kumar S , "Novel Printed Circular Disc Microstrip Line Fed Monopole Antennas for UWB Applications" in The Journal of Acta Electrotehnica (ISSN 1841-3323), Volume 50, Number 3, pp. 205-209, 2009 Technical University of Cluj-Napoca, Romania.
[7] Ramu Pillalamarri, SasiBhushana Rao G and Srinivara kumar S, "A Novel Approach for Efficiency Enhancement and Size Miniaturization of UWB Printed Antennas" in Annals – International Journal Of Engineering" (ISSN 1584-2665), Tome VIII, Year 2010, Fascicule 1, pp. 67-72.
[8] Ramu Pillalamarri, Sasi Bhushana Rao G and Srinivara kumar S, "Compact Printed Semicircular Disc Microstrip Line Fed Monopole Antennas for UWB Applications" in The Journal of Physical Sciences, (ISSN:0972-8791) Volume 13, 2009, India.
[9] Ansoft High Frequency Structure Simulator Corporation, V 9.0, USA.