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TECHNICAL PAPER

# Rectangular slotted microstrip line fed compact printed antenna with etched ground plane for UWB communications

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**Abstract** Now a days, Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. And these antenna structures useful for wireless and mobile communications domain and also we can manufacture with low cost and suitable for handheld devices such as mobiles and Laptops. In this paper we have designed and proposed printed monopole antenna and also we have mentioned extensive simulation study and how we have utilized the usage of broadband techniques but also how we have achieved the huge bandwidth. We have used simple microstrip line for feeding the antennas and also these proposed antennas are well suitable for UWB frequency band from 3.1 to 10.6 GHz.

## 1 Introduction

Day by day the technology is getting updated and advancing with various applications. There were a lot of achievements in the mobile and wireless communication domain like short distance communication via Bluetooth, Wi-Fi and the best example is wireless personal area networks (WPAN), which will work with UWB technology. The meaning of ultra-wideband (UWB) is the signal or system that either has a large relative bandwidth or a large absolute bandwidth (Allen et al. 2007; Schantz 2005). These large bandwidth antennas are having several advantages and several application area but these antennas have some fundamental differences from the conventional and traditional narrowband antennas (Aiello et al. 2003; Pozar 2005). The federal communications commission (FCC) has been defined and declared the frequency band from 3.1 to 10.6 GHz band with effective isotropic radiated power (EIRP) below −40 dbm/kHz for UWB communications.

We have designed UWB antenna directly from circular patch UWB antennas by doing some changes not only the changes but also after doing extensive simulation study with application of broadband techniques. While designing antennas we faced so many problems like improper frequency bandwidth and improper antenna impedance matching but we resolved these problems by using broadband techniques likes etching of ground planes, changing the width of substrate and ground plane and by increasing or decreasing the gap “g” between the radiating patch and ground plane. Finally we have fixed the dimensions of antenna and we can see the final antennas structure in the Fig. 1a (Pillalamarri et al. 2009a, b, 2010; Pillalamarri and Kshetrimayum 2007).

## 2 Design and structure of UWB antennas

The UWB monopole antenna is designed for UWB applications on a substrate with 4.4 relative permittivity and 1.6 mm thickness. Basic formulas and microwave

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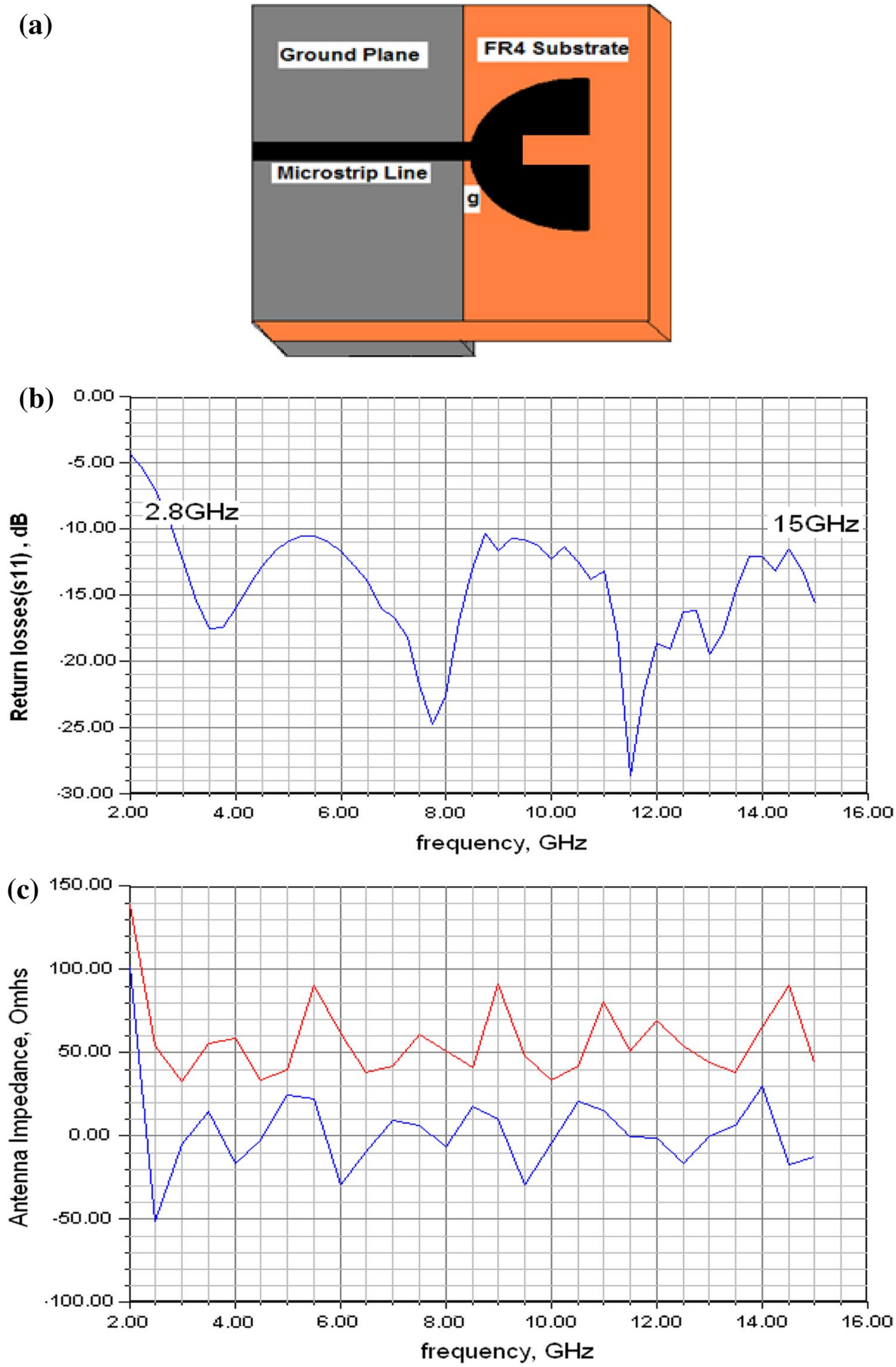


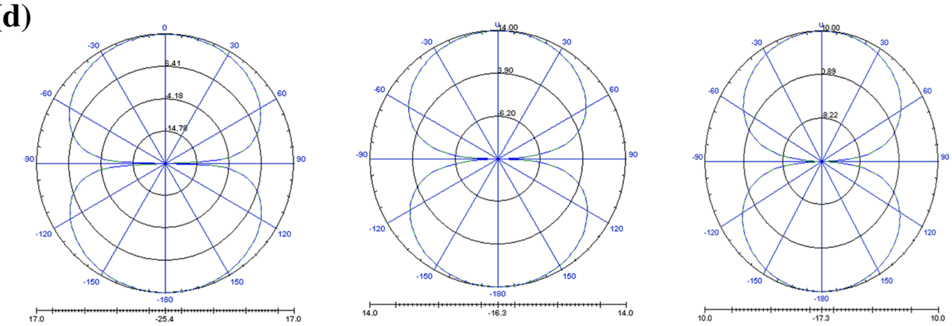

**Fig. 1** **a** Rectangular slotted UWB antenna. **b** $s_{11}$ vs. frequency plot (BW is from 2.8 to 15 GHz). **c** Antenna impedance versus frequency (real part *red color* and imaginary part *blue color*) of circular planar UWB monopole antenna. **d** E-plane radiation patterns at different frequencies. **e** H-plane radiation patterns at different frequencies. **f** 3D radiation plots at different frequencies (color figure online)

calculator were used in order to determine the approximated values of antenna structure like width (W) and length (L) of substrate, radius (R) of circular patch and microstrip line. Next, the input impedance of the patch at the edge was determined by placing a length of 50 Ω transmission lines to the patch antenna. The final dimensions of the entire UWB monopole antenna are given below and these dimensions may not same as what we have got the dimensions from basic microwave calculator because of application of broadband techniques while making compact antennas this is only an achievement:

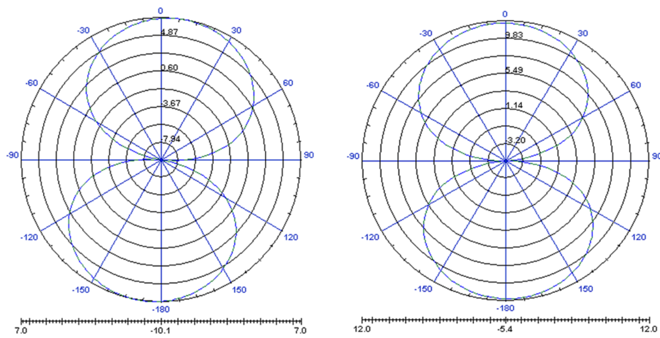
This rectangular slotted UWB monopole antenna is designed directly from the circular disc UWB-monopole antenna with some modifications in the patch shape as

**Fig. 1** continued

**(d)**

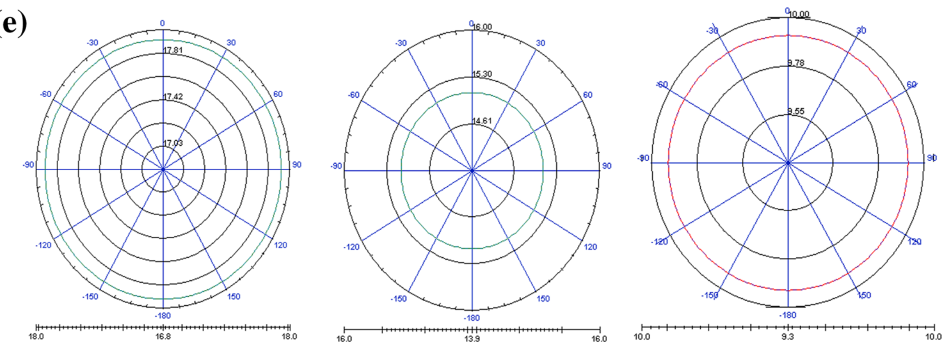


(i) At 3GHz (ii) At 5 GHz (iii) At 7.5GHz

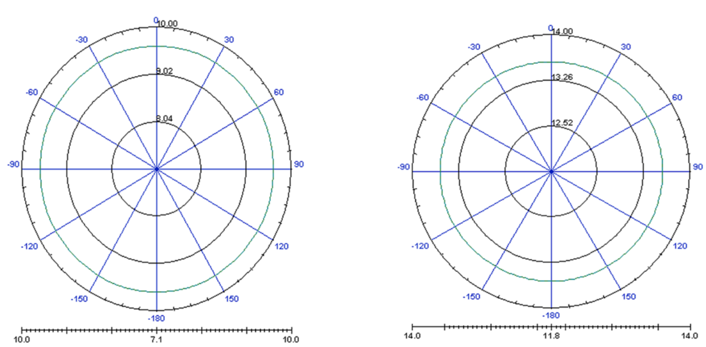


(iv) At 10.6 GHz (v) At 12 GHz

**(e)**



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



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

**Fig. 1** continued

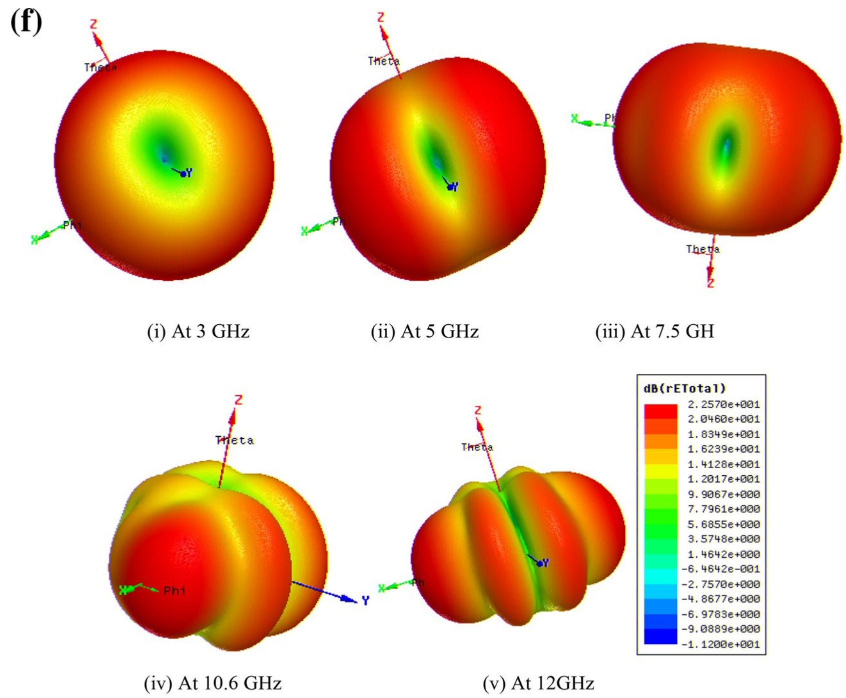



**Table 1** Various antenna parameters of rectangular slotted UWB antenna

| 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 |

shown in Fig. 1a. The final dimensions of the UWB-monopole antenna are:

Patch radius = 12 mm and thickness = 0.035 mm.
Substrate: W = 46 mm, L = 52 mm and thickness = 1.6 mm.
Ground plane: W = 46 mm, L = 26.2 mm and thickness = 0.5 mm.
Microstrip line: W = 2.6 mm, L = 27.5 mm and thickness = 0.035 mm.

Where the "g" is gap between the ground plane and radiating patch. At the values of g are 1 and 0.8 mm, the antenna impedance, % BW and antenna radiation efficiency are tabulated. ($f_{low}$ is the lower cut of frequency and $f_{high}$ is the higher cut of frequency of the UWB antenna BW and generally antenna BW is considered for those frequency range where the $s_{11}$ is below −10 dB).

Here the values of gap "g" are most crucial parameter for getting broad BW and impedance matching in order to get the antenna impedance to be 50 Ω and for maximum radiation efficiency. After an extensive simulation study, the final dimensions are fixed as listed above for antenna. The various antenna parameters have been calculated and when the gap between the ground plane and patch was 1 mm and tabulated in Table 1.

We can see the plot of antenna return loss vs frequency from the Fig. 1b, it can be seen that the bandwidth below −10 dB ranges from 3 to 11.6 GHz which includes the UWB bandwidth i.e. from 3.1 to 10.6 GHz and from the Fig. 1c, the plot of antenna impedance vs frequency, we can observe the real part of antenna impedance is exactly 50 Ω at different resonant frequencies in the entire bandwidth of antennas where the imaginary part of the antenna impedance equals zero.

We can see the simulated E-plane radiation patterns and H-plane radiation patterns of the UWB antenna with a circular patch at different frequencies are shown in the Fig. 1d, e. It can be observed that the E-plane pattern is like a doughnut or '8' shaped at lower frequency range of UWB band and is almost same with a little distortion at higher frequency end of UWB band and the antenna radiation patterns has gone though slight transition from a simple doughnut at the first resonance to the higher resonances but had omni-directionality with a tilt (slightly from 5 to 10°), this was possible because of the partial ground plane.

The simulated H-plane radiation patterns (horizontal plane) of the UWB antenna with a circular patch, with a 'g' value 1 mm is purely omni-directional pattern throughout UWB frequency range.

We can see the simulated 3D radiation patterns of the proposed antenna in the Fig. 1f at different frequencies at 3, 5, 7.5, 10.6 and 12 GHz. The radiation pattern is like a doughnut at lower frequencies and somewhat distorted as it reaches higher frequencies (i.e. 10.6 and 12 GHz).

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 planar 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 0.8 mm.

## 3 Conclusion

In this paper, we have investigated printed rectangular slotted disc 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 very compact UWB monopole antenna and it has higher efficiency. The E-plane radiation patterns of the printed monopole antenna are 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 and the proposed antennas are analyzed and designed from Ansoft High Frequency Structure Simulator (Ansoft, v 9.0).

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