

## Novel Printed Rectangular Patch Monopole Antennas with Slit Ground Plane for UWB Applications

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### Introduction

Ultra-Wideband (UWB) commonly refers to signal or system that either has a large relative bandwidth (BW) or a large absolute bandwidth<sup>1,4</sup>. 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.

Some UWB antennas are much more complex than other existing single band, dual band and multi-band antennas<sup>5,6</sup>. Most of the UWB monopole antennas investigated till today is non-planar as in<sup>2,4</sup> 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.

In this paper, we investigate rectangular patch UWB antenna with slit in the ground plane, which is basically a printed microstrip antenna with etched ground plane<sup>6,8</sup>. First we investigate in depth the rectangular disk printed monopole antenna with etched ground plane as shown in Fig. 1 for UWB applications. We have used conventional rectangular microstrip lines as feed lines for printed UWB antennas which are properly matched to the antenna impedance<sup>9,10</sup>. And we have maintained some gap "g" between the rectangular patch and the ground plane in order to get proper impedance matching as well as huge bandwidth, which was one of the design parameters of proposed antenna in order to meet UWB applications<sup>11</sup>. In future we propose to

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investigate other broadband matching techniques to further improve the UWB performance of the printed monopole antenna. The CAD-FEKO simulation software has been employed for obtaining the simulation results.<sup>12</sup>

### Geometry of Printed UWB Monopole Antennas and Simulation Results

#### A. UWB Antenna with Rectangular Patch and Slit in Ground Plane

The UWB monopole antenna is designed for UWB applications on a FR4 substrate with 4.4 relative permittivity and 1.6 mm thickness. Next, the input impedance of the patch at the edge was determined by placing a simple 50Ω rectangular microstrip line. The final dimensions of the UWB antenna after doing an extensive simulation study are:

The Patch: W=12 mm, L=16.5 mm and thickness=0.035 mm; the Substrate: W=30 mm and L=28 mm; the Ground: W=30 mm, L=10 mm and thickness=0.5 mm; the Microstrip line: W=3 mm and L=11.5 mm; the Slit: W=30 mm and L=4 mm.

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

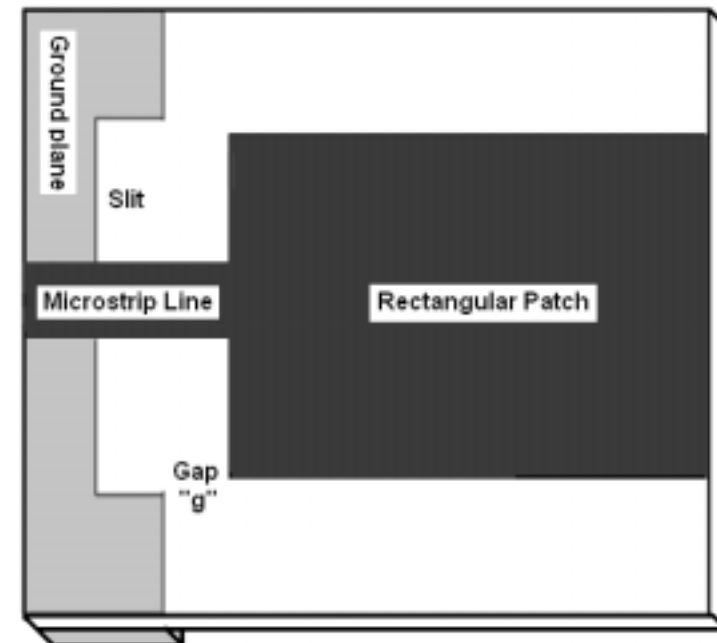


Fig.1. Geometry of Rectangular UWB Antenna

After doing extensive simulation study at particular values of “g”, the antenna impedance, the maximum radiation intensity (Max U) in watt per steradian, 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 the radiation efficiency are tabulated. Here the gap (g) between the rectangular patch and the ground plane below is the most crucial parameter for getting the broad BW, matching the antenna impedance to 50  $\Omega$  and maximize the antenna radiation efficiency.

Table 1: Various Parameters of the Antenna

g mm	F <sub>low</sub> GHz	F <sub>high</sub> GHz	Antenna Impedance $\Omega$	P <sub>acc</sub> w	P <sub>rad</sub> w	Max U W/Sr	Peak Gain	$\eta$ %
2.5	3.1	12	50	0.88	0.76	0.20	2.4	95

As we can see from Table 1, the value of ‘g’ is fixed at 2.5 mm. The ‘g’ value is a very crucial parameter for proper impedance matching and the slit in the ground plane results the broadband width. The width of the ground plane and the slit in the ground plane are important factors in determining the antenna impedance and consequently the frequency BW. The lower end of the frequency BW is 3.5GHz before making the slit in the ground plane. This is a serious limitation of the UWB regulations, and this can be solved and fixed by the slit in the ground plane. The lower end of the frequency BW is shifted from 3.5 GHz to 3.1 GHz after slit formation in the ground plane, the final dimensions of the slit are listed above. The UWB performance of the monopole antenna is due to such closely resonating fundamental and harmonic frequencies.

Fig. 2.  $s_{11}$  versus Frequency Plot

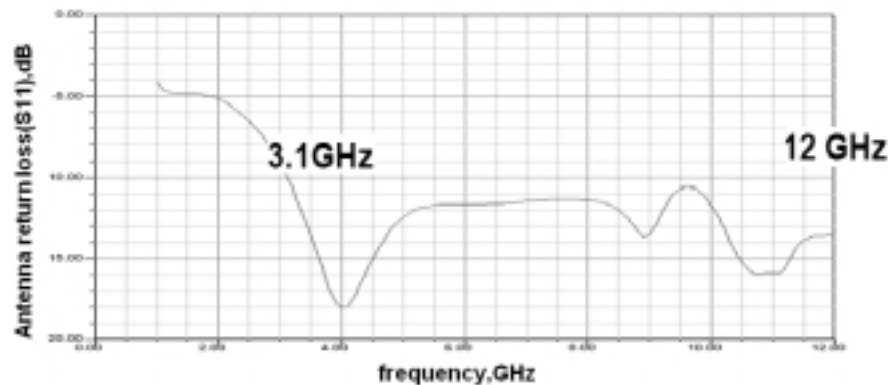
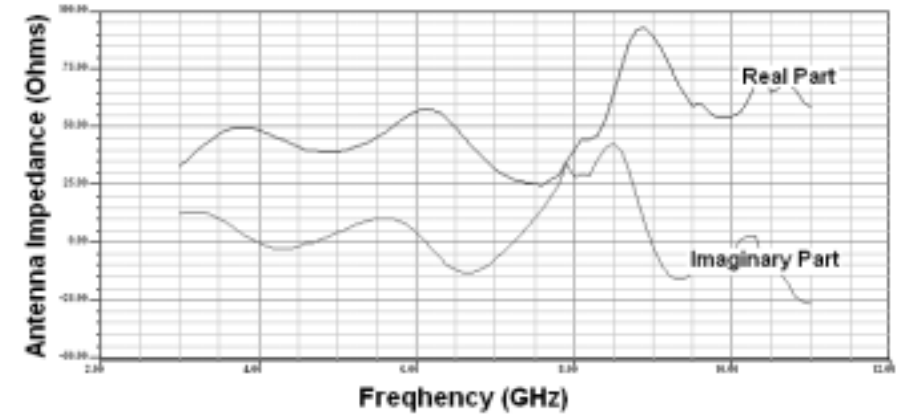


Fig. 3. Antenna Impedance versus Frequency



The antenna impedance versus frequency plot tells us that “the real part of antenna impedance is exactly 50  $\Omega$  at 6 GHz and 8 GHz where the imaginary part of the antenna impedance equals zero as depicted in Fig.3. Throughout the bandwidth of the UWB antenna, the real part of the antenna impedance varies from 40  $\Omega$  to 60  $\Omega$  whereas the imaginary part of the antenna impedance is in the range of -30  $\Omega$  to +30  $\Omega$ , which is not a major variation of the antenna impedance. The E-plane (i.e. vertical cut of 3D radiation pattern) and the H-plane (i.e. horizontal cut of 3D radiation pattern) radiation patterns of the rectangular patch UWB monopole antenna at 3.1, 7.2, 9 and 10.6 GHz are shown in Fig. 4 and Fig. 5. It can be observed that the E-plane radiation pattern is in the shape of figure “8” at 3 GHz and the higher frequencies. It has maximum directivity at - 15<sup>o</sup> and - 180<sup>o</sup> at 3 GHz and at the frequency 10.6 GHz. It has been tilted to 9<sup>o</sup> and -16<sup>o</sup>. As frequency increases it is slightly tilted with 5<sup>o</sup> to 10<sup>o</sup>. The H-plane radiation pattern on the other hand is purely omni-directional pattern throughout ultra wideband.

Fig. 4. E-plane Radiation Patterns at (i) 3.1 GHz, (ii) 7.2 GHz, (iii) 9 GHz and (iv) 10.6 GHz

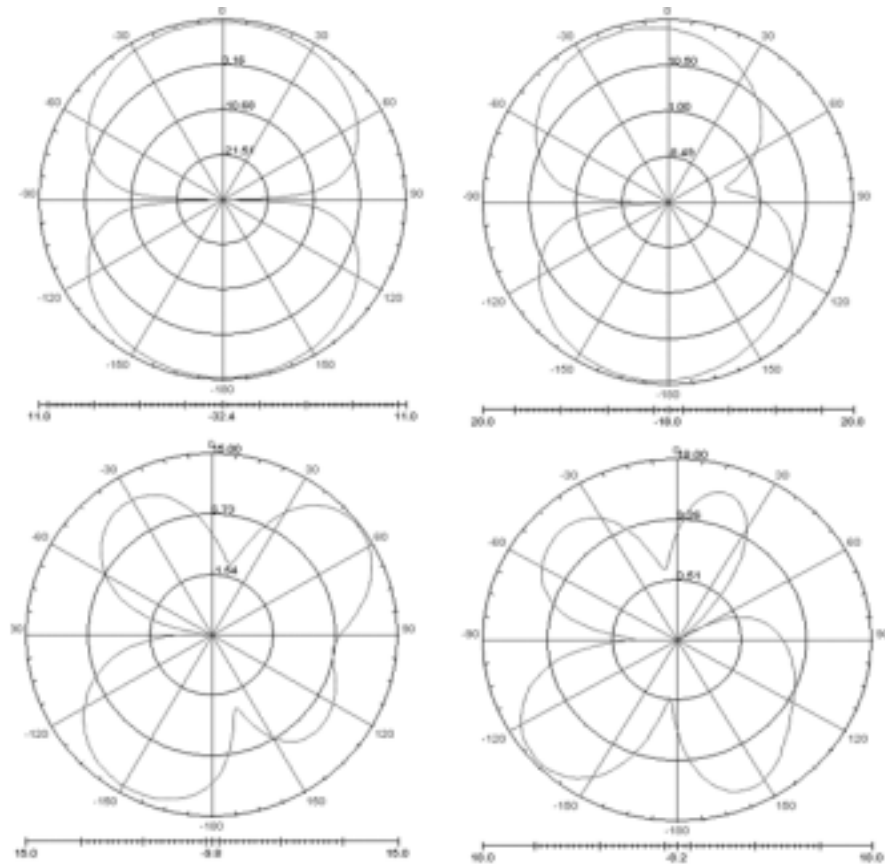
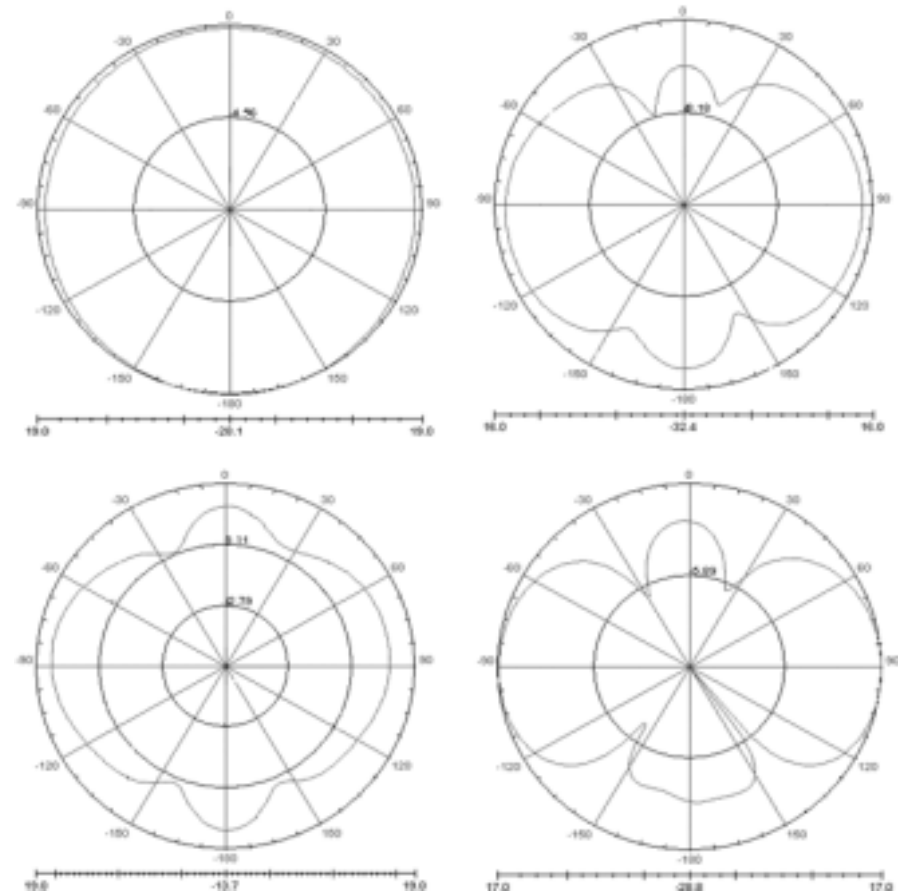
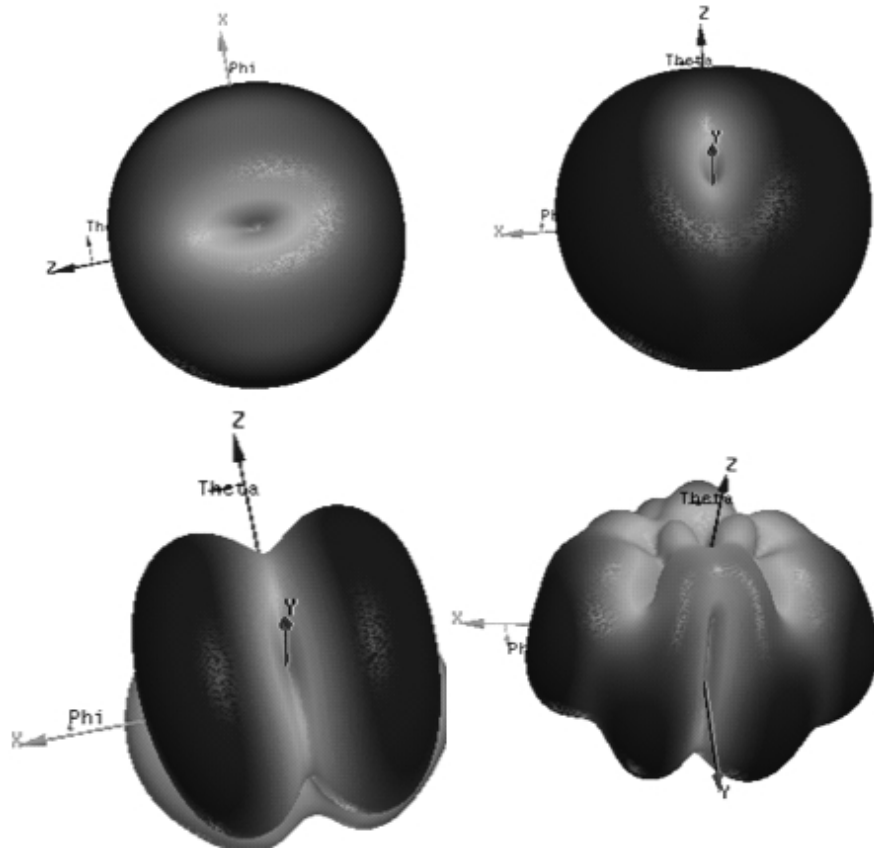


Fig. 5. H-plane Radiation Patterns at (i) 3.1 GHz, (ii) 7.2 GHz, (iii) 9 GHz and (iv) 10.6 GHz



The simulated 3D radiation patterns of the proposed antenna are at 3.1, 7.2, 9 and 10.6 GHz are shown in Fig.6. Throughout the Ultra Wide Band the radiation pattern resembles a doughnut at the resonant frequencies, i.e., 3.1 GHz and 7.2 GHz similar to that of a dipole pattern. The radiation pattern is somewhat like a pinched doughnut (i.e., omni directional) at the higher resonant frequencies, i.e., at 10.6 GHz. The radiation pattern becomes somewhat distorted as it reaches higher frequencies (i.e. beyond 10.6 GHz).

Fig. 6. 3D Radiation Plots at (i) 3.1 GHz, (ii) 7.2 GHz, (iii) 9 GHz and (iv) 10.6 GHz



The radiation pattern variation from a simple doughnut at the lower frequencies to slightly distorted doughnut pattern at the higher resonances indicate that this antenna must have gone through major changes in its behaviour, yet has omni-directionality. The antenna has very less reflections and maximum radiation efficiency due to proper impedance matching. It has been observed that such monopole antennas are suitable for UWB operations from the CAD-FEKO simulation results.

### Conclusion

In this paper, we have investigated rectangular patch UWB monopole antenna with slit in the ground plane, 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 compact UWB monopole antenna namely rectangular disk printed monopole antenna. The proposed antenna is compact and has higher efficiency as well as broad BW. The E-plane radiation patterns of the monopole antenna are in figure 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.

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