Design and Implementation of Printed Monopole Antenna for Portable Devices

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Abstract— Ultra-wideband (UWB) has been identified as the future technology. Mostly, bandwidth critical applications such as sensor data collection and location tracking can benefit from the advantageous, highly wide bandwidth of the UWB technology. It is very challenging for the antenna engineers to reduce the size of the antenna while maintaining the performance parameters such as low voltage standing wave ratio (VSWR), wide bandwidth and symmetric radiation patterns. In this paper, a novel, compact printed monopole antenna has been proposed for the portable wireless communication devices. The operating frequency range of the proposed antenna spans from 3–12 GHz, covering the entire frequency range of the UWB spectrum whose range is from 3.1–10.6 GHz. The simulated results of proposed antenna shows good conformity with measured results. The antenna has been etched out in the middle of the radiating patch to form a slot. Moreover, the size of the ground plane has also been reduced. These techniques have been effective to widen the bandwidth of this compact antenna for UWB operation.

1. INTRODUCTION

The Federal Communication Commission (FCC) in 2002 allocated the frequency band from 3.1 to 10.6 GHz to Ultra-wide Band wireless communication [1]. This allocation motivated both the industrial and academic communities to develop compact antennas for UWB communication. The revolution of Wireless technology has changed our life for the last few decades. Today, people are using cell phones providing more freedom to communicate anywhere at any time. Internet by using Wireless Technology provided an opportunity to interconnect computers with each other without any cable.

Presently, a lot of research is being done on wireless personal area network (WPAN) throughout the world. Within a limited range, WPAN provides a consistent wireless connection between portable devices like laptops, computers and other electronic gadgets. In order, to have a reliable communication, fast exchange of data and storage is required between these devices.

The UWB antenna design requires extensive work in miniaturization with high efficiency and large impedance bandwidth. In order to reduce the size of UWB antenna three dimensional radiators have been replaced by planar versions given in [2, 3]. Printed antennas on PCB is a good option for portable devices because it can be easily embedded into wireless devices or integrated with many other RF circuits.

One of the drawbacks of microstrip patch antenna is their inherited narrow bandwidth. A lot of research has been carried out to increase the impedance bandwidth of patch antennas. Like, in [4] a ring shaped slot has been introduced to increase the bandwidth. While, in [5] a slot with a U-shape has been etched on the radiating patch for bandwidth enhancement.

Different techniques have been used to fabricate UWB antenna having small size, omni directional radiation and high efficiency. In [13] compact triple band planar monopole antenna has been proposed for WLAN and WiMAX applications. Similarly, printed UWB antenna has been proposed in [4] having frequency range of 3.1 GHz–5 GHz. Another printed antenna for portable devices is proposed in [5] having dimension of 50×100 mm. Similarly, other design with reduced size has been proposed in [6–10].

In this paper a new printed monopole design has been proposed for UWB portable device application. The design has been simulated in HFSS and its results have been tested experimentally. Maximum gain of 2.5 dBi has been achieved at 8.5 GHz and radiation efficiency of 85%–98% has been achieved throughout UWB range. By using partial ground plane and using slot in radiating plane overall size has been reduced with good radiating efficiency throughout UWB range. The overall antenna size of the proposed antenna is $27.5\,\text{mm} \times 29.5\,\text{mm}$. The outline of the paper is as follows. Section 2 describes the antenna design; Section 3 describes the results, and Section 4 summarizes the conclusion.

2. ANTENNA DESIGN

Figure 1 shows the geometry of proposed printed monopole antenna. Which is printed on FR4 substrate printed circuit board therefore it is easy to fabricate different RF circuits on the same substrate. Overall dimension of antenna is 27.5 mm × 29.5 mm. Thickness of substrate is 1.6 mm with relative permittivity of 4.8.

The antenna consists of a rectangular radiating element and a rectangular slot with width 2 mm and length 10 mm is cut inside radiating element for impedance matching. In order to increase impedance bandwidth partial ground plane has been used to achieve the complete UWB range. The length of the ground plane L_G is 8.9 mm. The radiating element is excited by 50 Ω coaxial probe at the end of micro stripfeed line of width 2.8 mm. The dimensions of radiating element and ground plane are given in Table 1.

Table 1: Parameters of the antenna.

Basic configuration	**Variable**	**Dimensions (mm)**
Substrate	W	**29.5**
	L	**27.5**
Patch Antenna	W_P	**14**
	L_P	**16**
	S_W	**10**
	S_L	**2**
	L_F	**9.5**
	W_F	**2.8**
Ground Plane	L_G	**8.9**

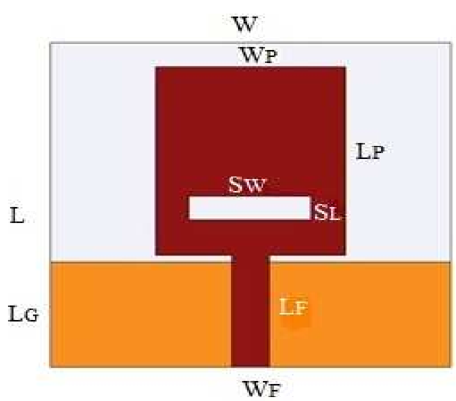

Figure 1: Geometry of patch antenna and ground plane.

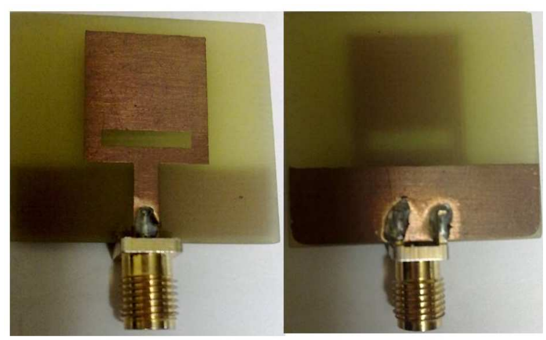

Figure 2: Prototype of the proposed antenna.

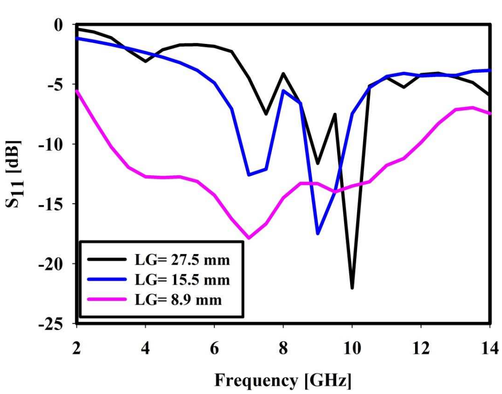

Figure 3: Parametric study of the reflection coefficient magnitudes over the length of the ground plane.

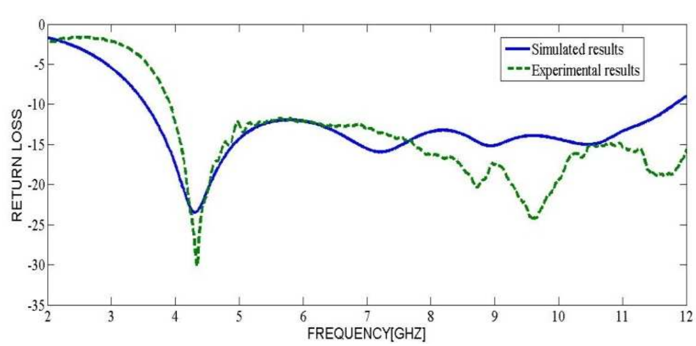

Figure 4: Simulated and measured reflection coefficient magnitudes.

3. RESULTS AND DISCUSSIONS

Based on the dimensions given in Section 2, the antenna is simulated and then the antenna prototype has been fabricated as shown in Figure 2.

3.1. Parametric Study

In order to optimize the antenna design, parametric study has been conducted. The parametric study is important as it helps in giving an approximation measure before the antenna is fabricated. The Figure 3 shows the antenna reflection coefficient plotted against various values of ground length L_G. As clear from Figure 3 that for $L_G = 27.5$ mm the antenna is able to operate only over a narrow band. As the length of the ground is decreased the bandwidth improves and a best result is obtained when the length of the ground L_G becomes 8.9 mm.

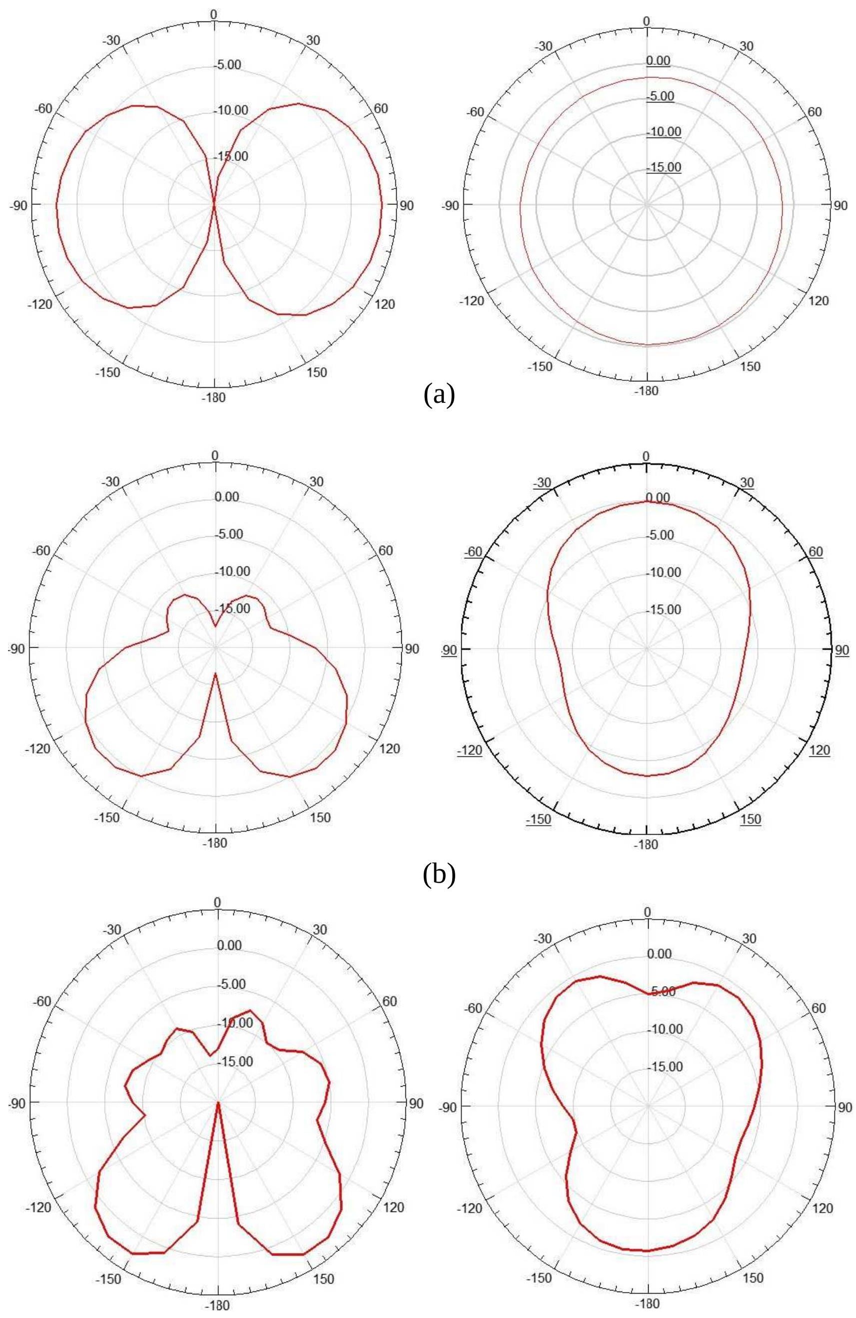

Figure 5: Simulated radiation pattern. (a) E-plane and H-plane pattern at 4 GHz. (b) E-plane and H-plane pattern at 7.5 GHz. (c) E-plane and H-plane pattern at 10 GHz.

3.2. Study of Input Performances

The proposed antenna has been simulated in HFSS V.14 and based upon its simulation results the antenna is optimized which leads to the development of its prototype which is then tested using network analyzer. Figure 4 shows the comparison of simulated and measured reflection coefficient magnitude $|S_{11}|$. It is observed from the figure that the impedance bandwidth is from 3.9 GHz to 12 GHz and the simulated and measured results shows close conformity with each other.

In [11] it is shown that the creation of a rectangular slot on the active zone of the patch increases the bandwidth of the antenna. The introduction of the slot on the patch has created a capacitive reactance that cancels out the inductive reactance of the feed line [12].

3.3. Radiation Pattern

The radiation patterns, both E and H plane of the proposed antenna are shown in Figure 5 at 4.5 GHz, 7 GHz and 10 GHz respectively.

It can be observed from the Figure 5 that the radiation pattern at 7 GHz in x-y plane is like donut shape while at 10 GHz donut shape gets many side lobes. Similarly the radiation pattern at 4 GHz in H-plane is omnidirectional as compared to the radiation pattern at 10 GHz which is more like directional. It is observed that the radiation pattern shows good performance in impedance bandwidth.

3.4. Simulated Gain and Efficiency

The simulated results show that average antenna gain is above 2 dB between 3.5 GHz to 6 GHz. Which shows uniform gain in this frequency range, whereas antenna gain decreases below 2 dB from 6 GHz to 7.2 GHz and gradually increases from 2 dB to 2.5 dB at 8.5 GHz frequency. It is observed that the maximum gain of antenna is 2.5 dB at 8.5 GHz frequency. The maximum simulated efficiency of the antenna is 95% at 3.2 GHz and the lowest efficiency is 88% at 9 GHz.

4. CONCLUSION

In this paper, a new design of printed monopole antenna has been proposed for portable devices. The design has been simulated in HFSS version 14 and the results have been analyzed. The proposed model has been fabricated and S_{11} parameter has been measured experimentally. The maximum gain of antenna is about 2.5 dB and the bandwidth of the proposed antenna is between 3.9 GHz to 11 GHz. It can be used for ultra wide band applications and printed structure is suitable for portable applications. The maximum efficiency of 95% has been achieved for the proposed design. The total size of antenna is 27.5 mm × 29.5 mm.

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