A proposal of a Compact Ultra-Wide Band Antenna works as a magnetic dipole

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***Abstract* - Recently, the Ultra-Wideband Multi-Input Multi-Output technique has draw the intention of many researchers as it is very promising for high data rate wireless communication systems. In this paper, a new ultra-wideband (UWB) antenna with the size of 15 mm × 26 mm × 1.6 mm is proposed. The antenna works as a magnetic dipole and has the working bandwidth from 3.1 GHz to 10.6 GHz with VSWR ≤ 2. The antenna parameters such as radiation pattern, maximal gain are also investigated.**

Keywords - Ultra-Wide Band (UWB), Ultra-Wide Band (UWB) antenna, printed antenna, planar antenna, slot antenna.

I. INTRODUCTION

Recently, a number of techniques have been developed to achieve high data rate in wireless communication systems. The Ultra-Wide Band Multi-Input Multi-Output (UWB-MIMO) transmission technique is one of the most promising technique as it can achieve a very high data rate of more than 1 Gbps. This technique combines the advantages of the UWB communication and that of MIMO transmission. It has a very wide working frequency band from 3.1 GHz to 10.6 GHz. In the UWB-MIMO devices, the antenna is normally required to be small and the mutual coupling between antenna elements must be very low. An approach to reduce the mutual coupling is using a combination of electric dipole and magnetic dipole.

There has been a number of ultra-wide band antennas with different structures and materials, including: defected ground structure plane radiator [1], UWB monopole antenna with semi-ellipse shaped patches [2], slot UWB antenna with half-wavelength and quarter-wavelength slot on the radiation plane [3], defected ground structure [4], dipole antennas [5], [6], printed antennas [7], printed antennas with defected ground structure [8], slot antennas [9]. The authors have also proposed an ultra-wide antenna with slotted rectangular radiation plane to achieve small-sized structure [10].

Some designs of the UWB antennas have been proposed, which used different structures and materials. In [11], Antoine Diet et. al. proposed an UWB antenna, whose dimensions were of 60 × 80 ×1,575 mm3 on FR4 dielectric substrate. Compared with this structure, the design of Mai A. R. Osman's group [12] had smaller size, where antenna dimensions were of 60 × 60 ×1 mm3. Furthermore, the design of Khalil H. Sayidmarie's group [13] had smaller size, where antenna dimensions were of 46 × 44 × 1,6 mm3 on FR4 dielectric substrate. Although this antenna achieved the technical requirements of the ultra-wide band antenna, the antenna structure was still large to be not really consistent with the general structure of UWB devices.

In this paper, an antenna structure that has a slotted reflection plane for UWB applications is proposed. The antenna is simple, compact (15 mm × 26 mm × 1.6 mm) and satisfies the bandwidth requirement of 3.1 GHz to 10.6 GHz.

II. ANTENNA DESIGN

The structure of the antenna is shown in Figure 1. The antenna is flat, small, thin and thus suitable for UWB applications. The antenna is made from FR4 material which has the dielectric permittivity of ε = 4.4 and dissipation factor of $tan\delta$ = 0.02.

The Ansoft HFSS software with finite element method was used to vary antenna dimensions to find the optimal structure for the antenna. The dimensions for the optimized antenna are shown in Table 1. The antenna is designed on FR4 substrate with the dimensions of 26 × 15 × 1.6 mm3. The feeding line has the dimensions of 17.6 × 3 × 0.035 mm3 and located on the radiation plane of the antenna. The ground plane takes the whole copper layer on the other side of the substrate. The layer is 0.035 mm thick and is etched as shown in Figure 1.

The purpose here is to design a simple and compact antenna that has a broad bandwidth of 3.1 GHz to 10.6 GHz with VSWR ≤ 2.

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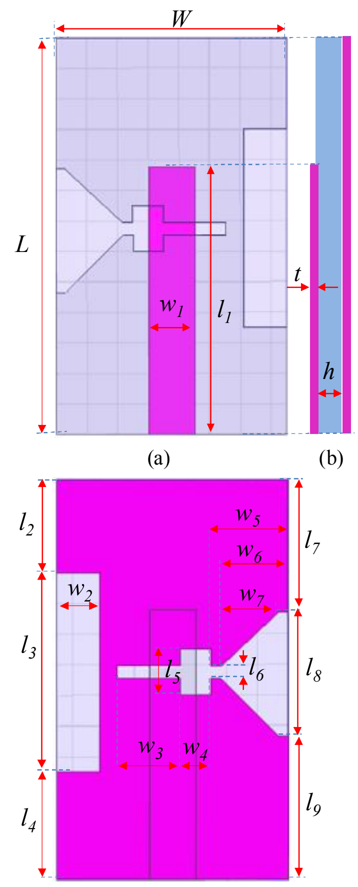


Fig. 1. Configuration of the UWB antenna.
(a) top view, (b) side view and (c) bottom view.

TABLE 1

THE OPTIMUM GEOMETRICAL PARAMETERS (MM)

Parameters	Values	Parameters	Values	Parameters	Values
L	26	w_4	2	l_4	7
W	15	w_5	5	l_5	3
h	1.6	w_6	4.4	l_6	0.8
t	0.035	w_7	3.8	l_7	8.6
w_1	3	l_1	17.6	l_8	7.1
w_2	2.8	l_2	6	l_9	9.3
w_3	4.1	l_3	13		

III. RESULTS

The antenna proposed in Figure 1 was simulated and its parameters are investigated in the frequency band from 3.0 GHz to 11.0 GHz using simulation software. The VSWR of the antenna is shown in Figure 2. From the figure 1, one can see that the VSWR is less than 2 within the frequency band of 3.0 GHz to 10.8 GHz. Thus the antenna is performing well in the working bandwidth of UWB devices.

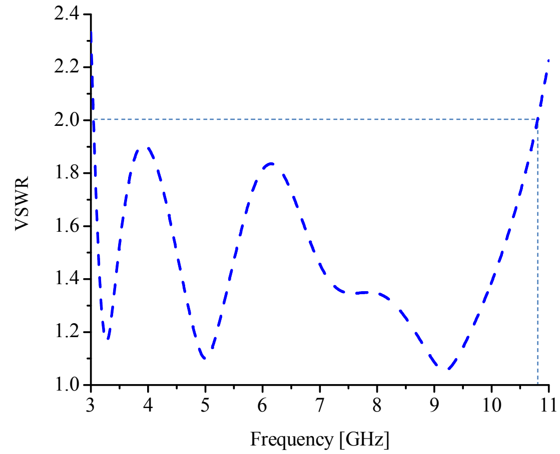
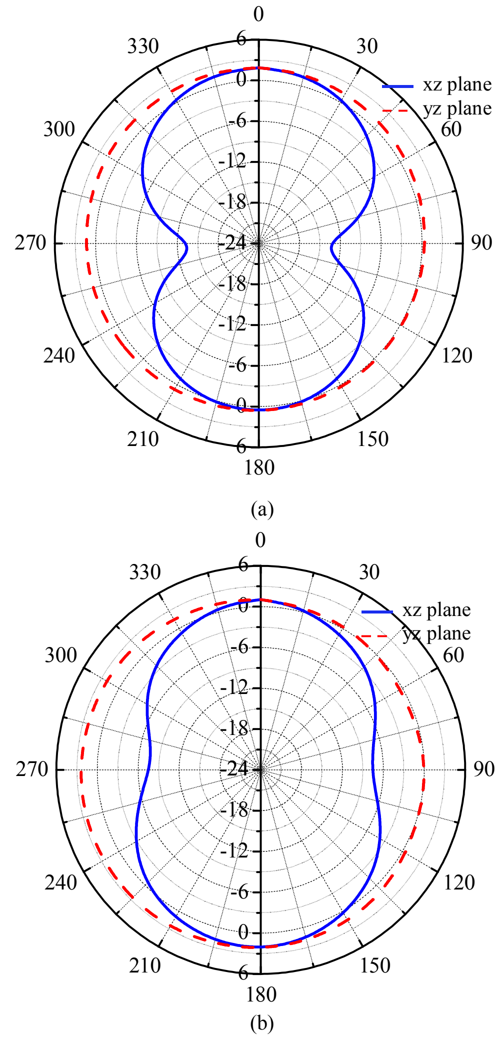
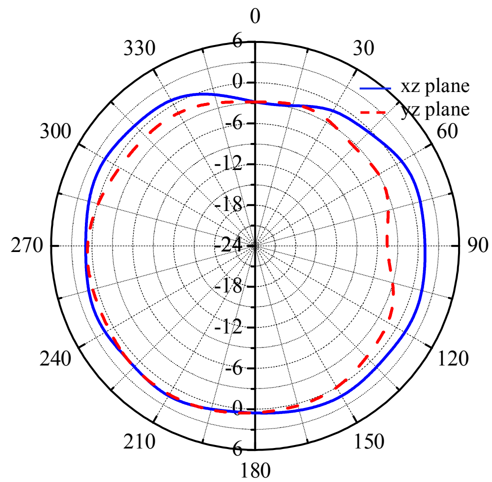
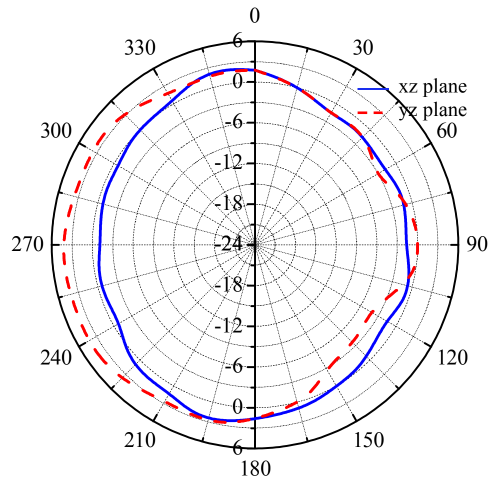


Fig. 2. Simulated VSWR versus frequency.

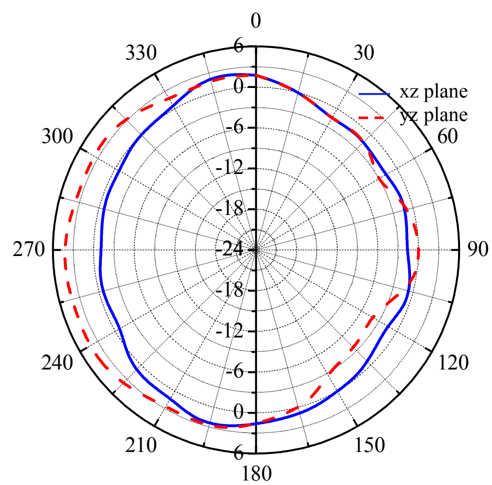




(c)



(d)



(e)

Fig. 3.Radiation patterns of the antenna: (a) at 3.1 GHz; (b) at 5.0 GHz; (c) at 7.0 GHz; (d) at 9.0 GHz; (e) at 10.6 GHz.

Since the frequency band for UWB applications is very wide, the radiation pattern of the antenna need to be investigated at different frequencies in the whole bandwidth. Antenna radiation pattern at the frequencies of 3.1 GHz, 5.0 GHz, 7.0 GHz, 9.0 GHz and 10.6 GHz are shown in Figure 3. (a), (b), (c), (d), (e), respectively. The solid line shows the pattern in the xoz plane and the dashed line shows the pattern in the xoy plane.

From Figure 3 one can see that at low frequencies, the antenna isotropically radiates. At high frequencies, the radiation pattern slightly changes but it is still rather equal. Thus, it satisfies the requirement for UWB antenna.

Figure 4 shows the peak gain of the antenna in the whole bandwidth. The peak gain can reach its maximum of 5.7 dBi at 10.3 GHz. At low frequencies, antenna peak gain is reduced. Thus, the proposed antenna meets the requirements for a UWB antenna.

The proposed UWB antenna has the bandwidth that covers frequencies from 3.1 GHz to 10.6 GHz, small size (15 mm × 26 mm × 1.6 mm) and simple structure. Therefore, it is appropriate for the applications in UWB devices. Thank to its small size and simple structure, the antenna itself can be used in UWB MIMO antennas.

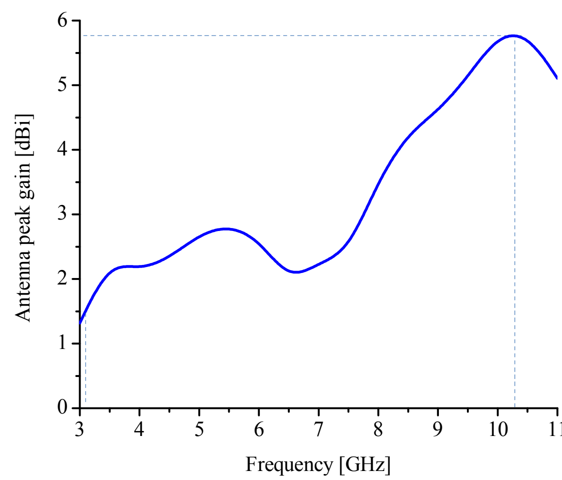
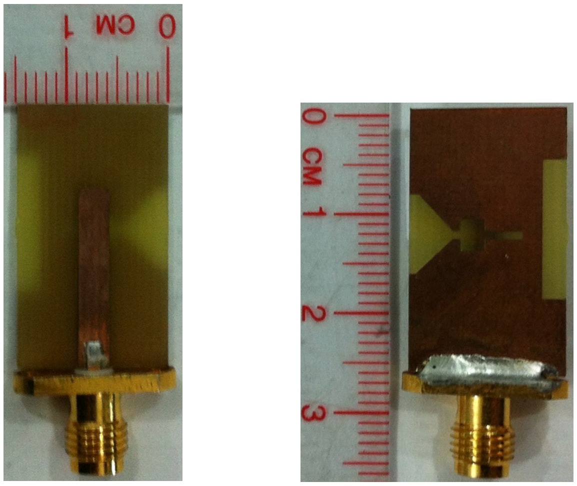


Fig.4. Antenna peak gain versus frequency.

IV. MEASURED RESULTS AND DISCUSSIONS

Based on the simulated results, a prototype was fabricated and shown in Figure 5.

The VSWR of antenna was measured and compared with simulation results as shown in Figures 6. From this figure, one can see that actual VSWR is similar to the simulation result and is less than 2 in the whole investigated frequency range. This shows that the proposed antenna satisfies the requirements of antenna.



(a) (b)

Fig.5. Photograph of the fabricated antenna.
(a) top view; (b) bottom view.

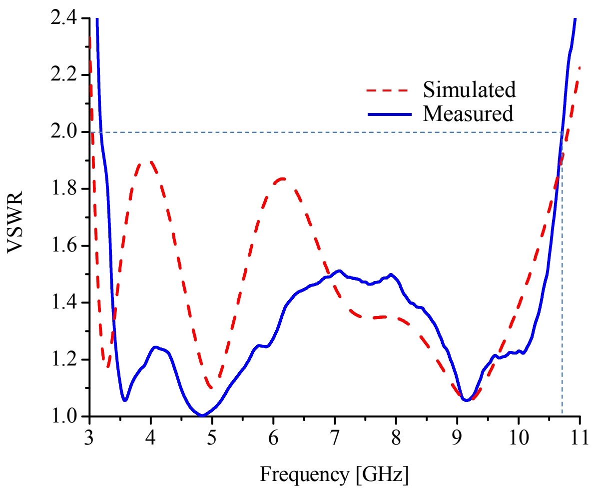


Fig.6. Comparison between measurement results and simulation results of antenna (VSWR).

To sum up, measurement results of the prototype of proposed UWB antenna agree well with the simulation results. This affirms that the parameters of proposed antenna satisfies the technical requirements for an UWB antenna with small size.

V. CONCLUSION

The paper proposed a new ultra wideband antenna design and has achieved some results as follows:

i) The antenna has small size of 15 mm × 26 mm × 1.6 mm.

ii) The proposed antenna has small and simple structure. Therefore, it is easy to be manufactured as printed antenna.

iii) The antenna has VSWR ≤ 2 in the whole bandwidth from 3.0 GHz to 10.7 GHz corresponding to 110% of the center frequency.

iv) Antenna radiation pattern is relatively equal in the working bandwidth. The peak gain varies from 1.5 dBi to 5.7 dBi.

v) Measurement results of proposed antenna prototype are similar to simulation results, which show that the proposed antenna meets the requirements for a MIMO UWB antenna.

The future work will focus on designing UWB antenna that works as electric dipole and then designing a UWB-MIMO antenna that uses the combination of electric dipoles and magnetic dipoles to reduce the mutual coupling between antenna elements.

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