Progress In Electromagnetics Research C, Vol. 11, 1–10, 2009

DESIGN OF A PLANAR UWB DIPOLE ANTENNA WITH BAND-NOTCHED CHARACTERISTIC

C. F. Tseng

Department of Electronic Engineering
National United University
No. 1 Lien Da, Kung-Ching Li, Miao-Li 36003, Taiwan

C. H. Hsu

Department of Electrical Engineering
National United University
No. 1 Lien Da, Kung-Ching Li, Miao-Li 36003, Taiwan

Abstract—A compact planar ultra-wideband (UWB) dipole antenna having band-notched characteristic is presented. The dipole antenna has the shape of a modified annular ring and is fed by a 50-Ω microstrip line. Cutting a slot in each radiating annular ring improves the input impedance bandwidth. With the design, the return loss is lower than −10 dB in 3.1 GHz–10.6 GHz frequency range. In addition, band-notched filtering properties in the 5.15 GHz–5.825 GHz are achieved by etching four rectangular slits in the ground plane, and the radiation pattern is similar to a conventional dipole antenna. A good agreement is found between the simulation and the experiment. Details of the proposed antenna design and the experimental results are presented.

1. INTRODUCTION

With the development of modern wireless and mobile communication, ultra-wideband (UWB) systems have recently attracted attention owing to several advantages, including high-speed data rate, small size, and low power consumption. According to the Federal Communications Commission (FCC) document, the frequency band of the UWB (category of communications and measurement systems) should be between 3.1 and 10.6 GHz [1]. However, UWB antennas are also necessary for the rejection of an interference with the

Corresponding author: C.-F. Tseng (cftseng@nuu.edu.tw).

existing wireless networking technologies, such as IEEE 802.11a in the U.S. (5.15–5.35 GHz, 5.725–5.825 GHz) and HIPERLAN/2 in Europe (5.15–5.35 GHz, 5.47–5.725 GHz) [2]. This is because UWB transmitters should not cause any electromagnetic interference on nearby communication systems such as wireless LAN (WLAN) applications. To overcome this problem, UWB antennas with good band-rejection performance are desirable.

Many antennas with the band-rejection characteristic have been researched to utilize the advantages of composing simpler RF front-ends. The widely used methods are etching slots on the patch or on the ground plane, i.e., straight, triangular, C-shaped, H-shaped, U-shaped, and pie-shaped slot in [3–7]. Another way is putting parasitic elements near the printed monopole as filters to reject the limited band or introducing a parasitic open-circuit element, rather than modifying the structure of the antenna's tuning stub [8–10].

In this paper, a new type of UWB dipole antenna with band-notched characteristics at 5.15–5.825 GHz is proposed. A modified annular ring dipole antenna covering 2.6–10.61 GHz is first designed, then, etching of four rectangular slits in the ground plane is used to obtain the rejection of 5.15–5.825 GHz bands.

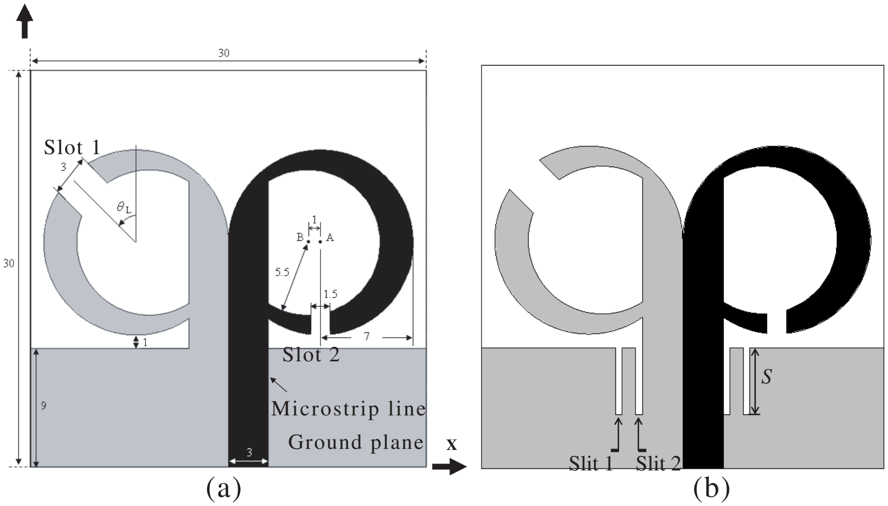

Figure 1. Geometry of (a) the planar UWB dipole antenna (Ant. 1) and (b) the band-notched UWB dipole antenna (Ant. 2) (unit: mm).

2. ANTENNA STRUCTURE

The geometry and configuration of a UWB dipole antenna (called Ant. 1) is shown in Figure 1(a). This antenna is composed of a rectangular ground plane and a modified annular ring dipole. A big circle cuts a small circle to form the annular ring. The radius of the big circle and small circle is 7.0 mm and 5.5 mm respectively. Point A is the center of the big circle and point B is the center of the small circle. The distance between the two points is 1 mm. Additionally, the antenna performance can be further improved by cutting a slot on each annular ring. The dark part is placed on the front and the gray part is on the back plane. The antenna is printed on both sides of an FR4 substrate with a thickness of 1.6 mm, relative permittivity of 4.4, and loss tangent of 0.02. The total size of the antenna is $30 \times 30\,\text{mm}^2$, and is fed by a 50-Ω microstrip line. The optimized dimensions for the proposed antenna are shown in Figure 1. Furthermore, Figure 1(b) shows the proposed band-notched UWB dipole antenna (Ant. 2) configuration. We will discuss the detailed performances of the band-notched antenna later.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the measured and simulated return loss curves of Ant. 1. The measured results are found to agree reasonably well with

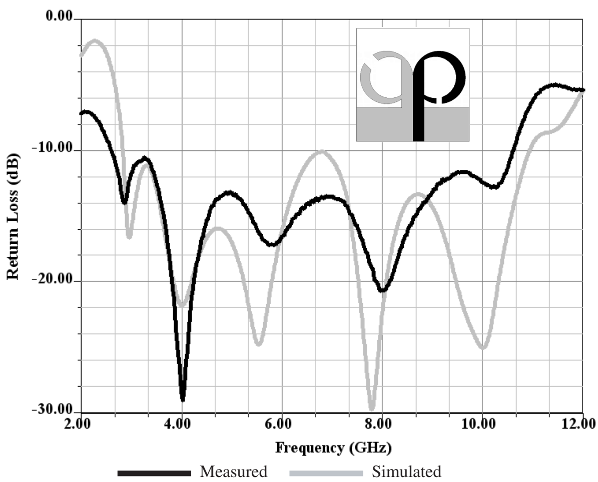

Figure 2. Measured and simulated return loss of the UWB dipole antenna.

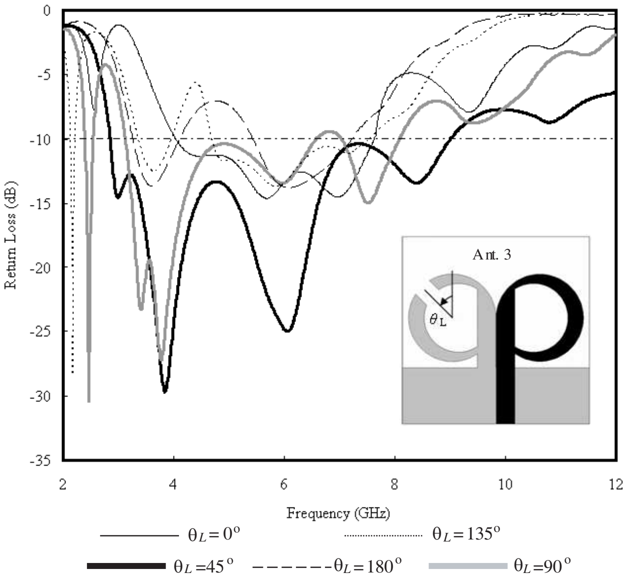

Figure 3. Effects of the θ_L on the simulated return loss of Ant. 3.

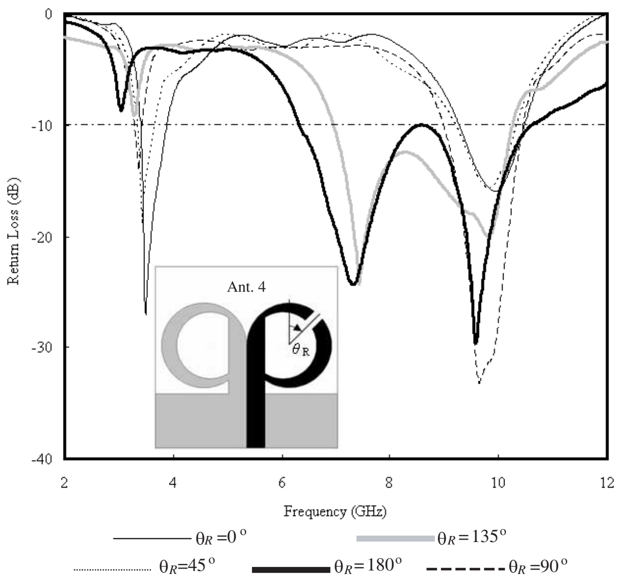

Figure 4. Effects of the θ_R on the simulated return loss of Ant. 4.

the simulated data obtained using Ansoft HFSS [11]. The obtained results indicate that the proposed antenna has UWB characteristics with an impedance bandwidth covering at least 3.1–10.6 GHz assuming a −10 dB return loss reference. As seen in Figure 2, the −10 dB return loss bandwidth for the measured result is found to be 2.6–10.61 GHz.

Effects of the locations of slot 1 and slot 2 are studied. The geometries are shown in Figure 3 and Figure 4, and called Ant. 3 and Ant. 4, respectively. The simulated return loss as a function of the θ_L is shown in Figure 3. The width of slot 1 is fixed at 3 mm; moreover, slot 2 does not exist in this study. For brevity, only simulated S_{11} values for $\theta_L = 0°$, 45°, 90°, 135°, and 180° are presented in Figure 3. It is shown that as θ_L increases from 0° to 180°, the impedance bandwidth increases and reaches its maximum at $\theta_L = 45°$ at which an impedance bandwidth ranging from 2.86 to 9 GHz is found. In this study, the optimal angle θ_L is determined to be 45° as shown in the figure. Figure 4 depicts that θ_R varies in a certain range with the same width (= 1.5 mm) of slot 2, but without slot 1. The

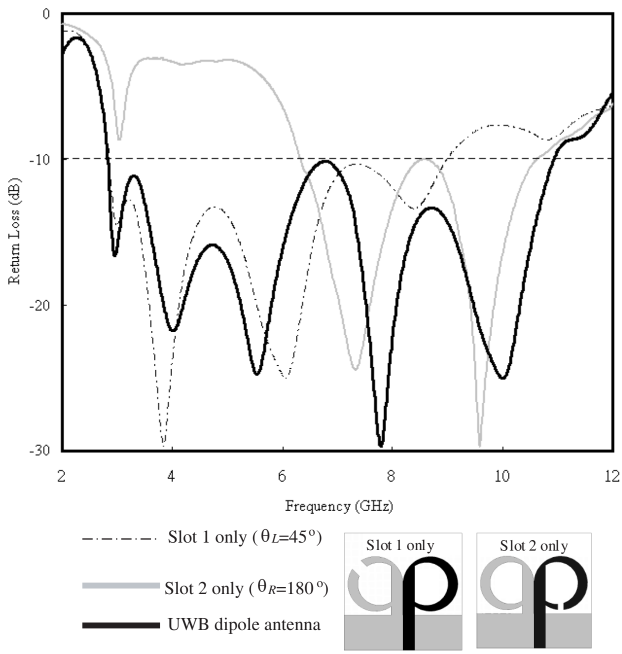

Figure 5. Simulated return loss for the UWB dipole antenna and the cases with slot 1 only or slot 2 only.

results show that all resonant modes shift toward lower frequencies as θ_R increases. Furthermore, it is also clearly seen that changing is θ_R is an efficient way to improve the input impedance matching, especially at high frequencies. For the case of the $\theta_R = 0°$, 45°, and 90°, the bandwidth is small. By properly choosing θ_R, a widest bandwidth can be obtained. From the simulated results in Figure 4, it occurs when $\theta_R = 180°$.

Figure 5 shows the results of simulated return loss for the case having slot 1 section only ($\theta_L = 45°$), the case having slot 2 only ($\theta_R = 180°$), and the proposed UWB dipole antenna (Ant. 1). The corresponding dimensions of the three cases are all same as given in Figure 1. These results clearly indicate that the antenna's lower band is mainly contributed from the slot 1 section. For the case having slot 2 section only, it generates a wide operating band to form the antenna's upper band.

Since the 5.15–5.825 GHz frequency band has been allocated for WLAN systems, the UWB transmitters should not cause any interference on the nearby WLAN systems. Therefore, the UWB antenna with a band-notched characteristic is required. To minimize the potential interferences between UWB system and WLAN systems, in this paper, a kind of band-notched design is presented to

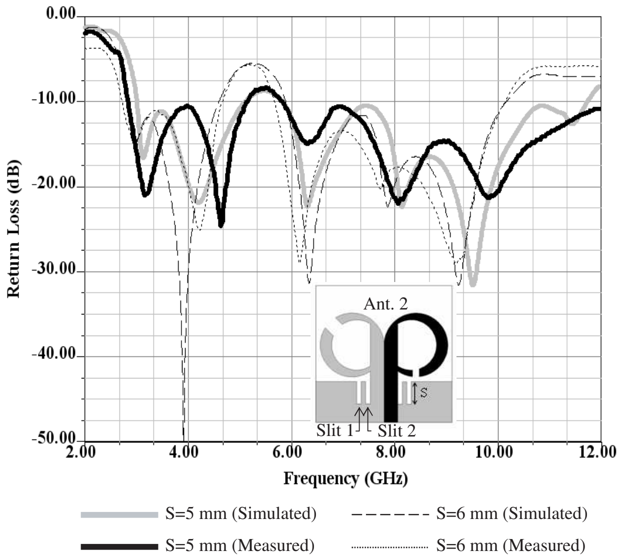

Figure 6. Measured and simulated return loss curves of the band-notched UWB dipole antenna for different values of S.

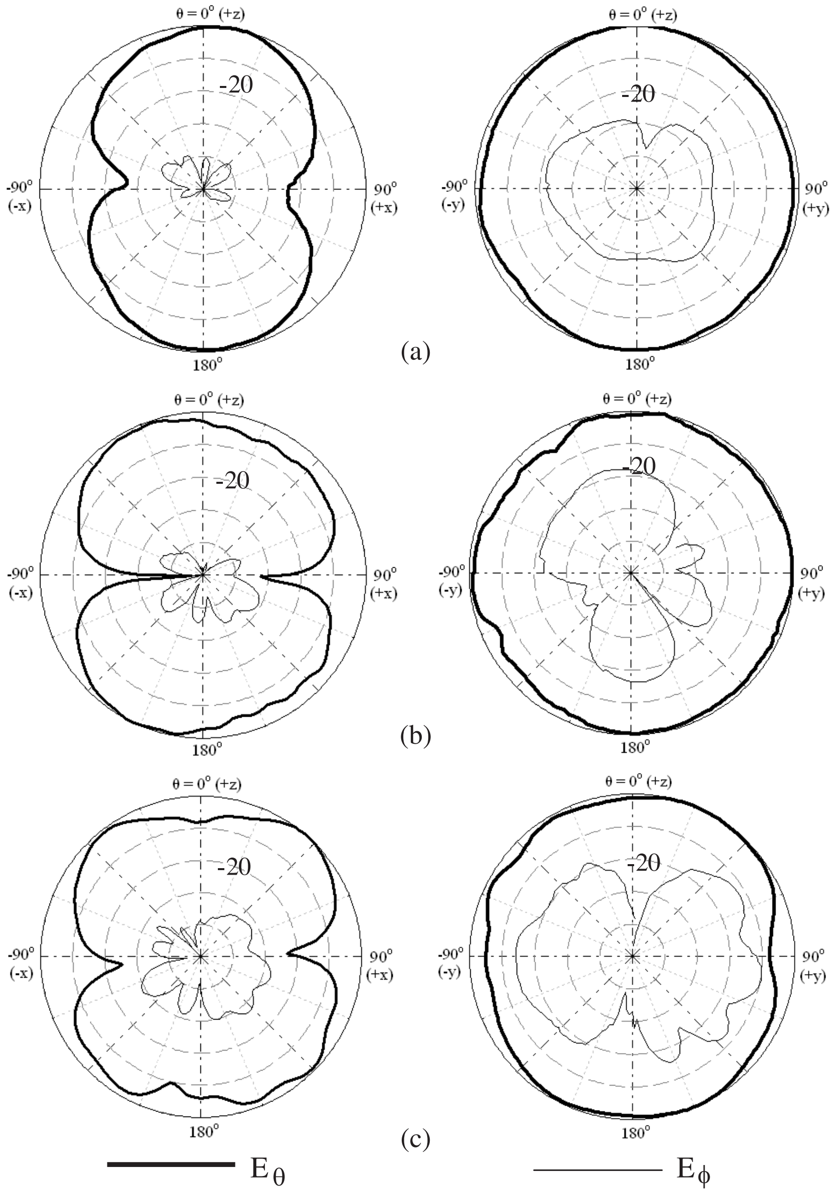

Figure 7. Measured far-field radiation patterns of the band-notched UWB dipole antenna in the x-z and y-z planes at (a) 3 GHz, (b) 6.5 GHz, and (c) 10 GHz.

demonstrate the superior features. The technique is to etch four rectangular slits in ground plane of the Ant. 1. The dimension of the slit is $1 \times S\,\mathrm{mm}^2$ as shown in Figure 6. The distance between slit 1 and slit 2 is 1 mm. Figure 6 shows the simulated return loss curves of the band-notched UWB dipole antennas (called Ant. 2) for two different values of S, i.e., 5 mm and 6 mm, whose corresponding notched bands were simulated to be 5.14 GHz–5.82 GHz and 4.6 GHz–5.87 GHz, respectively. The bandwidth of the notch band is mainly determined by the length of the slits. Obviously, the main features of return loss curves slightly move toward low frequency as the length of the slits increases. The reason might be explained by increased electric length. The measured result is also shown in Figure 6, and is almost the same as that obtained from simulation. With the measured result, the bandwidth is from 2.83 GHz to more than 12 GHz, and the antenna has a rejection frequency band of 5.15 to 5.825 GHz, where the wireless LAN service is allocated, when cutting four rectangular slits in the ground plane.

Figure 7 shows the radiation patterns of the band-notched UWB dipole antenna (Ant. 2), which have been measured at sampling frequencies of 3 GHz, 6.5 GHz, and 10 GHz, respectively. From the

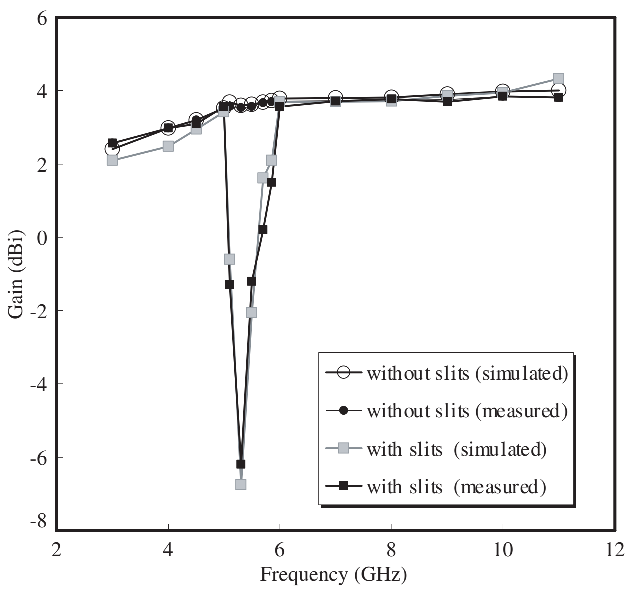

Figure 8. Measured and simulated antenna gain of UWB dipole antenna with and without four rectangular slits.

results, similar dipole-like radiation patterns at 3, 6.5, and 10 GHz are obtained. The x–z plane radiation patterns exhibit the typical nulls on the dipole axis (x-axis), at θ angles 90° and -90°. Similar radiation patterns for other frequencies over the desired UWB bands have also been observed. The proposed antenna has an acceptable approximate omnidirectional radiation pattern. This result agrees with a characteristic of UWB systems, which should be able to receive information signals from all directions.

Figure 8 shows the measured antenna gains of the UWB dipole antenna with and without the four rectangular slits in the ground plane. It can be found that the band-notched UWB dipole antenna obviously results in the very low gain in the 5.15–5.825 GHz band otherwise the gains are almost the same as those of the UWB dipole antenna for their similar structures.

4. CONCLUSION

A compact microstrip-fed planar UWB dipole antenna with the band-notched characteristic at 5.15–5.825 GHz has been proposed and implemented. The total antenna size is $30\,\text{mm} \times 30\,\text{mm} \times 1.6\,\text{mm}$. By cutting a slot in each radiating annular ring, the impedance matching can be improved. Adding four rectangular slits in the ground plane is realized to obtain the band-notched function, and the notch band can be adjusted by choosing the lengths of these slits. From the measured results it is seen that the proposed dipole antenna has omnidirectional radiation patterns and rather flat gain variation over the full UWB band expected in the notched band. Therefore, the proposed dipole antenna is not only suitable for UWB communication application, but also prevents interference with WLAN systems.

ACKNOWLEDGMENT

This work was sponsored by the National Science Council of the Republic of China under grant NSC 97-2221-E-239-006-MY2.

REFERENCES

1. FCC, “Ultra-Wideband Operation FCC Report and Order,” Tech. Rep. US 47 CFR Part15, 2002.
2. Kerkhoff, A. and H. Ling, “Design of a planar monopole antenna for use with ultra-wideband (UWB) having a band-notched characteristic,” *Proc. IEEE Antennas and Propag. Soc. Int. Symp.*, 830–833, Columbus, OH, Jun. 2003.

3. Chair, R., A. A. Kishk, and K. F. Lee, "Ultrawide-band coplanar waveguide-fed rectangular slot antenna," *Antennas Wireless Propag. Lett.*, Vol. 3, No. 1, 227–229, 2004.
4. Hsu, S. H. and K. Chang, "Ultra-thin CPW-fed rectangular slot antenna for UWB applications," *Proc. IEEE AP-S Int. Symp.*, 2587–2590, Jul. 2006.
5. Liang, J., C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Trans. Antennas Propag.*, Vol. 53, No. 11, 3500–3504, Nov. 2005.
6. Huang, C. Y., W. C. Hsia, and J. S. Kuo, "Planar ultra-wideband antenna with a band-notched characteristic," *Microw. Opt. Technol. Lett.*, Vol. 48, No. 1, 99–101, Jan. 2006.
7. Huang, C. Y. and W. C. Hsia, "Planar ultra-wideband antenna with a frequency notch characteristic," *Microw. Opt. Technol. Lett.*, Vol. 49, No. 2, 316–320, Feb. 2007.
8. Lui, W. J., C. H. Cheng, and H. B. Zhu, "Frequency notched printed slot antenna with parasitic open-circuit stub," *Electron. Lett.*, Vol. 41, No. 20, 1094–1095, Sep. 2005.
9. Lee, S. H., J. W. Baik, and Y. S. Kim, "A coplanar waveguide fed monopole ultra-wideband antenna having band-notched frequency function by two folded-striplines," *Microw. Opt. Technol. Lett.*, Vol. 49, No. 11, 2747–2750, Nov. 2007.
10. Kim, K. H. and S. O. Park, "Design of the band-rejected UWB antenna with the ring shaped parasitic patch," *Microw. Opt. Technol. Lett.*, Vol. 48, No. 7, 1310–1313, Jul. 2006.
11. Ansoft Corporation HFSS [Online]. Available: http://www.anso -ft.com/products/hf/hfss/.