Progress In Electromagnetics Research Letters, Vol. 47, 103–109, 2014

Design of Compact Asymmetric Coplanar Strip-Fed UWB Antenna with Dual Band-Notched Characteristics

Long Chen*, Yuan-Fu Liu, and Pu-Chao Wu

Abstract—In this paper, a new design of asymmetric coplanar strip (ACS)-fed UWB planar monopole antenna with dual band-notched characteristics is presented and investigated. The proposed antenna is composed of an asymmetric ground plane, a semi-circular radiator, together with two open-ended half wavelength bow-shaped slots etched on the radiation patch. This leads to the desired dual notched bands of 3.12–3.69 GHz for WiMAX and 5.51–6.01 GHz for WLAN. Experimental results show that the designed antenna, with compact size of $29.5 \times 12\,\text{mm}^2$, has stable and omnidirectional radiation pattern, sharp reduction in gain and group delay at notched frequencies. The very simple feeding structure and compact uniplanar design make it easy to be integrated within the portable device for UWB communication systems.

1. INTRODUCTION

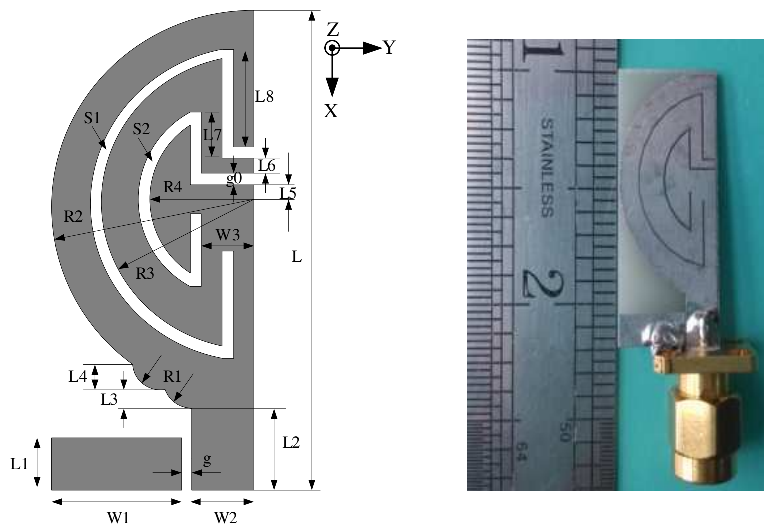
Since the Federal Communication Commission (FCC) permitted its civil application within the frequency band of 3.1–10.6 GHz [1], ultra-wideband (UWB) system has attracted both researchers and wireless industries' great attention for its advantage of large information capacity, high data transmission rate, low power consumption, constant gain and group delay over the entire operating frequency band. Because of these attractive features, planar monopole antennas have been good candidate for UWB communication systems, such as [2–5]. However, there are several narrow band wireless systems with work bands below 10 GHz that might become potential interferences of UWB systems, such as WiMAX (3.4–3.69 GHz), and WLAN (5.725–5.825 GHz). To improve the coexistence of UWB systems with other wireless standards, a considerable amount of research has been devoted to devising techniques to reject certain bands within the passband of the UWB. The most popular approach to achieve a notched band are cutting proper slot on the patch, such as W-shaped slot [6], SRR-shaped slot [7], or adding defected ground structure (DGS) in the ground plane [8]. Another way is to put parasitic elements near the printed monopole, playing a role as filters to reject the limited band [9]. These antennas can achieve good omnidirectional radiation patterns and good impedance bandwidth. However, most of the proposed notch-band antennas have large size, complex structures, and conventional feeding structure, which limit their applications. Coplanar waveguide (CPW) is easy to integrate with microwave circuits and has been used for developing various antennas [10, 11]. However, the CPW-fed antenna occupies a large ground plane. In order to further minimize the overall size of antenna, literature [12] presented an effective feeding (asymmetric coplanar strip (ACS) feeding) technique, unlike the traditional antennas using a larger ground plane or a coaxial line feed, the ACS-fed structure which only has half a ground plane. However, the proposed antenna only covers one notched band, namely for WLAN. The asymmetric coplanar strip feed used here has all the advantages of a uniplanar feed along with compactness and the feeding mechanism could be analogized to the coplanar wave guide feed.

Received 22 June 2014, Accepted 19 July 2014, Scheduled 5 August 2014
* Corresponding author: Long Chen (longchen409@163.com).
The authors are with the Research Institute of Electronic Science and Technology, University of Electronic Science and Technology of China, Chengdu 611731, China.

In this article, an ACS-fed UWB planar monopole antenna with dual band-notched characteristics is proposed. The notched bands are realized by etching two open-ended half wavelength bow-shaped slots on the radiation patch. The proposed antenna with compact size of $29.5 \times 12\,\text{mm}^2$, has a wide bandwidth covering the entire UWB frequency band, and exhibits two designed notched bands cover WiMAX (3.4–3.69 GHz) and WLAN (5.725–5.825 GHz) bands. Numerical and experimental studies are implemented, both of which show that the proposed antenna is a good candidate for UWB communication systems.

2. ANTENNA DESIGN AND PARAMETRIC STUDY

The electromagnetic simulation software Ansoft HFSS V13 is used to quicken the design. Figure 1(a) shows the geometry of the proposed antenna, the fabricated photograph is shown in Figure 1(b). The antenna is printed on the FR-4 substrate with dielectric constant of 4.4 and a thickness of 1.6 mm. In order to correspond to the 50-Ω characteristic impedance, the ACS-fed structure has a signal strip width of W_2 (= 3.8 mm) and a gap distance of g (= 0.2 mm). The geometries of the two small corrugate circular-arcs (R_1, L_3, L_4) on the edge of the radiating patch are critical to achieve broad bandwidth. As shown in Figure 2, the antenna with two corrugate circular-arcs performs well-matched from 10.1–10.6 GHz compared to the antenna without the two corrugate circular-arcs, it can be concluded that the corrugate circular-arcs on the edge are true important to improve the high frequency radiation performance. The two open-ended half wavelength bow-shaped slots (outer slot S_1 and inner slot S_2) etched on the radiating patch can realize two required notched bands. By optimizing the dimensions of the slots, the notched bands can be adjusted to cover WLAN and WiMAX bands. Details of the design procedure are as follows.



(a) (b)

Figure 1. (a) Geometry of the proposed ACS-fed monopole antenna ($W_1 = 8\,\text{mm}$, $W_2 = 3.8\,\text{mm}$, $W_3 = 2\,\text{mm}$, $L = 29.5\,\text{mm}$, $L_1 = 3.3\,\text{mm}$, $L_2 = 5.5\,\text{mm}$, $L_3 = 1.1\,\text{mm}$, $L_4 = 1\,\text{mm}$, $L_5 = 1\,\text{mm}$, $L_6 = 0.7\,\text{mm}$, $L_7 = 3.7\,\text{mm}$, $L_8 = 7.1\,\text{mm}$, $R_1 = 1.5\,\text{mm}$, $R_2 = 12\,\text{mm}$, $R_3 = 9.3\,\text{mm}$, $R_4 = 6.2\,\text{mm}$, $g = 0.2\,\text{mm}$, $g_0 = 0.3\,\text{mm}$). (b) Fabricated photograph of the proposed ACS-fed antenna.

Figure 3 shows the evolution of the proposed antenna and corresponding simulated reflection coefficient curves. Antenna 1 in Figure 3(a) is the original ACS-fed UWB monopole antenna, it consists of an asymmetric ground plane, a semi-circular radiator with two small corrugate circular-arcs on the edge, which are important to improve the input impedance bandwidth and the high frequency radiation performance of the UWB antenna. It can be seen from the Figure 3(b), Antenna 1 covers the operating band from 3.1 to 10.6 GHz, so the performance of the UWB antenna is achieved. To obtain the band-notched function, an open-ended bow-shaped half wavelength slot S_1 is inserted on the radiating patch (Antenna 2) to generate the first notched band of 3.21–3.85 GHz, but makes the lower and upper edge

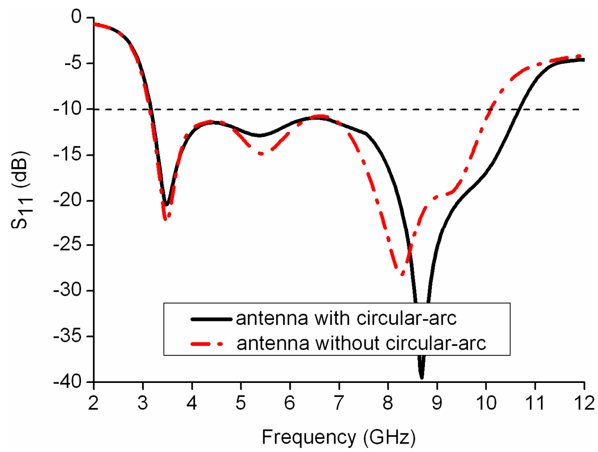


Figure 2. The reflection coefficient of the antenna with and without circular-arc.

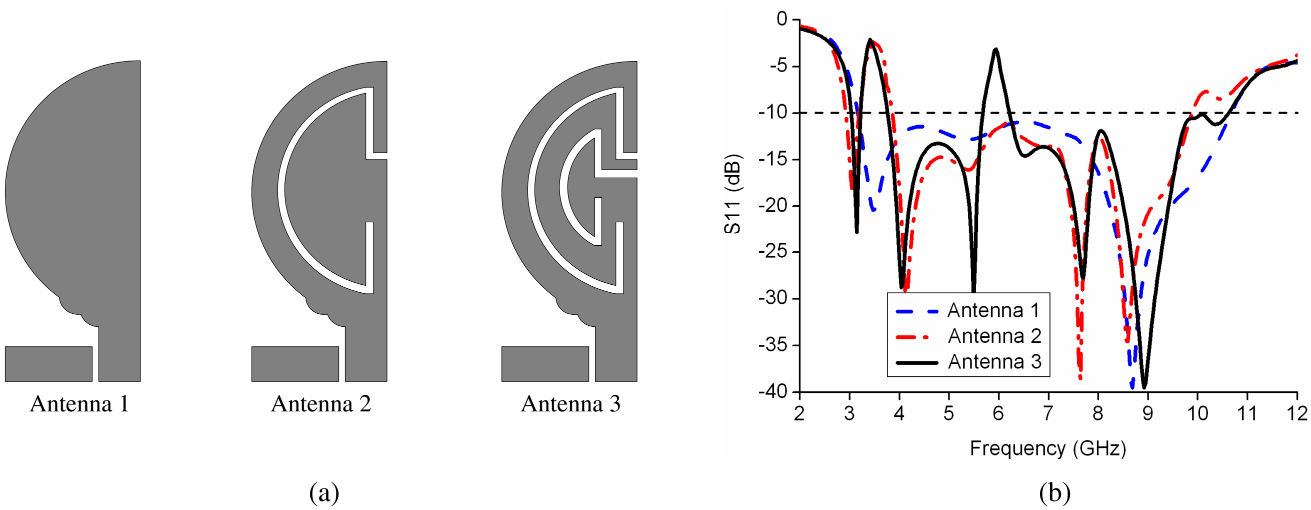


Figure 3. (a) Evolution of the proposed ACS-fed antenna. (b) The corresponding simulated reflection coefficient.

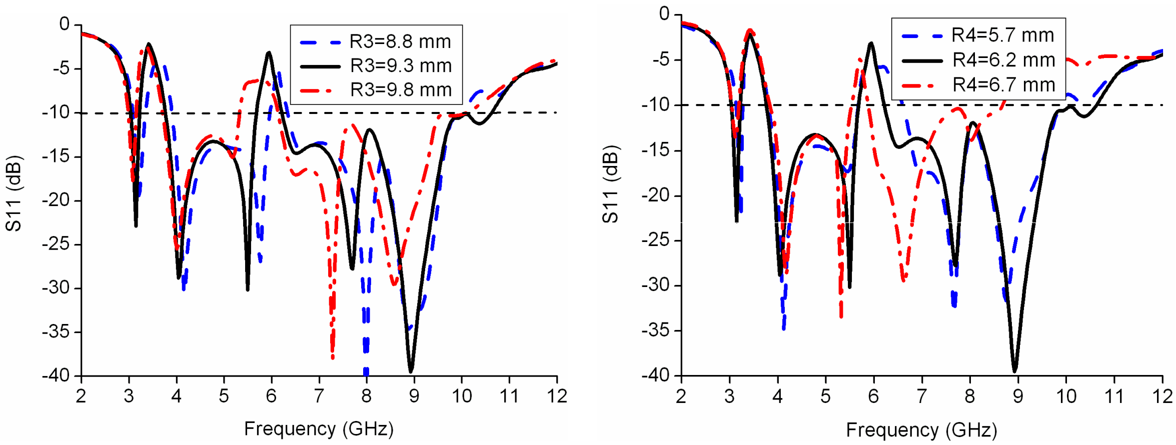
of the bandwidth all slightly shift to lower. Then a smaller alike slot S_2 is inserted on the radiating patch (Antenna 3) to generate the second notched band of 5.68–6.24 GHz. It can be seen from the Figure 3(b), by introducing the slot S_2 not only has no effect on the first notched band but also improves the performance of the bandwidth. Therefore, the UWB antenna with dual band-notched characteristics is obtained.

Furthermore, the notch-band frequency (f_{notch}) of the inserted open-ended half wavelength slot resonator is given by Eq. (1).

$$f_{notch} \approx \frac{c}{2l_S\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

where c is the speed of light, l_S the length of the slot, and ε_r the dielectric constant.

Figure 4(a) shows the reflection coefficient when the value of R_3 varies from 8.8 mm to 9.8 mm with $R_4 = 6.2$ mm. As the R_3 increases (equal to the length of slot S_1 increases), the two notched bands all shift to the lower frequencies. It is found that the outer slot S_1 not only dominates the lower notched band but also affects the upper notched band. The reason is that the outer slot is close to the edge of the patch, the change of slot's radius will not only affect the coupling between the slots but also change the current distributions on the two slots. Figure 4(b) describes the reflection coefficient for different



(a) (b)

Figure 4. Simulated reflection coefficient of the proposed antenna. (a) When R_3 changes with $R_4 = 6.2\,\text{mm}$, (b) when R_4 changes with $R_3 = 9.3\,\text{mm}$.

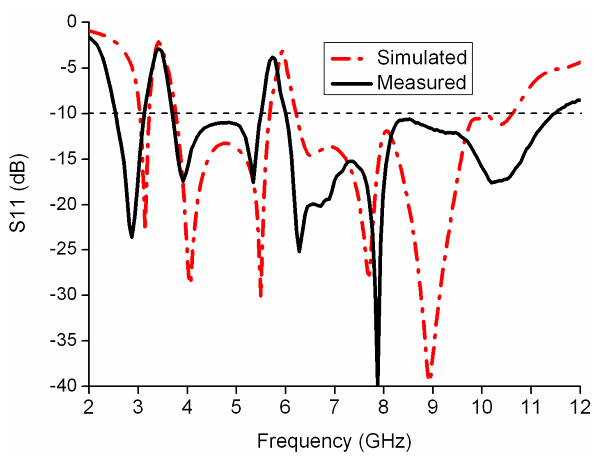
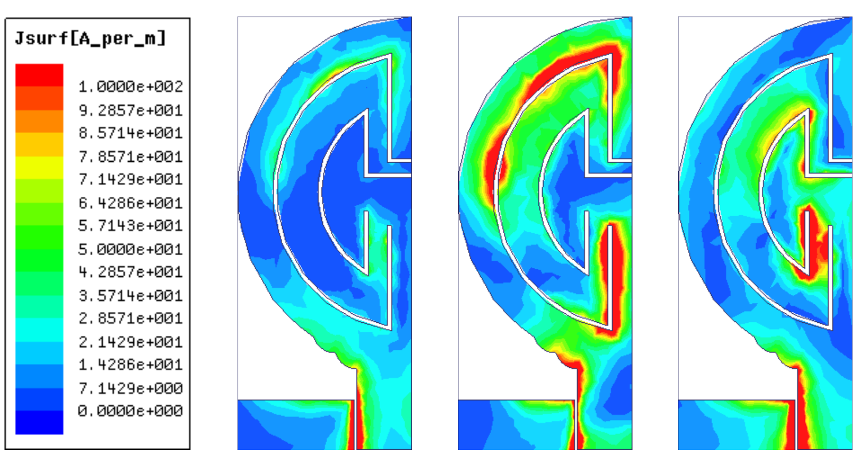


Figure 5. Simulated and measured reflection coefficient against frequency.



(a) (b) (c)

Figure 6. Surface current distributions on the radiating patch at (a) a passband frequency of 4.5 GHz, (b) the first notched band at 3.5 GHz, (c) the second notched band at 5.8 GHz.

value of R_4 with $R_3 = 9.3$ mm, equal to change the length of the slot S_2. It can be concluded that with the increase of R_4, the upper notched band shifts to lower, while the lower notched band is nearly not influenced. It is because that the inner slot is far from the edge of the patch, the inner slot's radius change nearly has no effect of the current distributions on the outer slot. The results discussed above indicate that the two notched band can be controlled effectively and tuned independently by adjusting the value of R_3 and R_4. The final dimensions of the proposed antenna are optimized and shown in Figure 1.

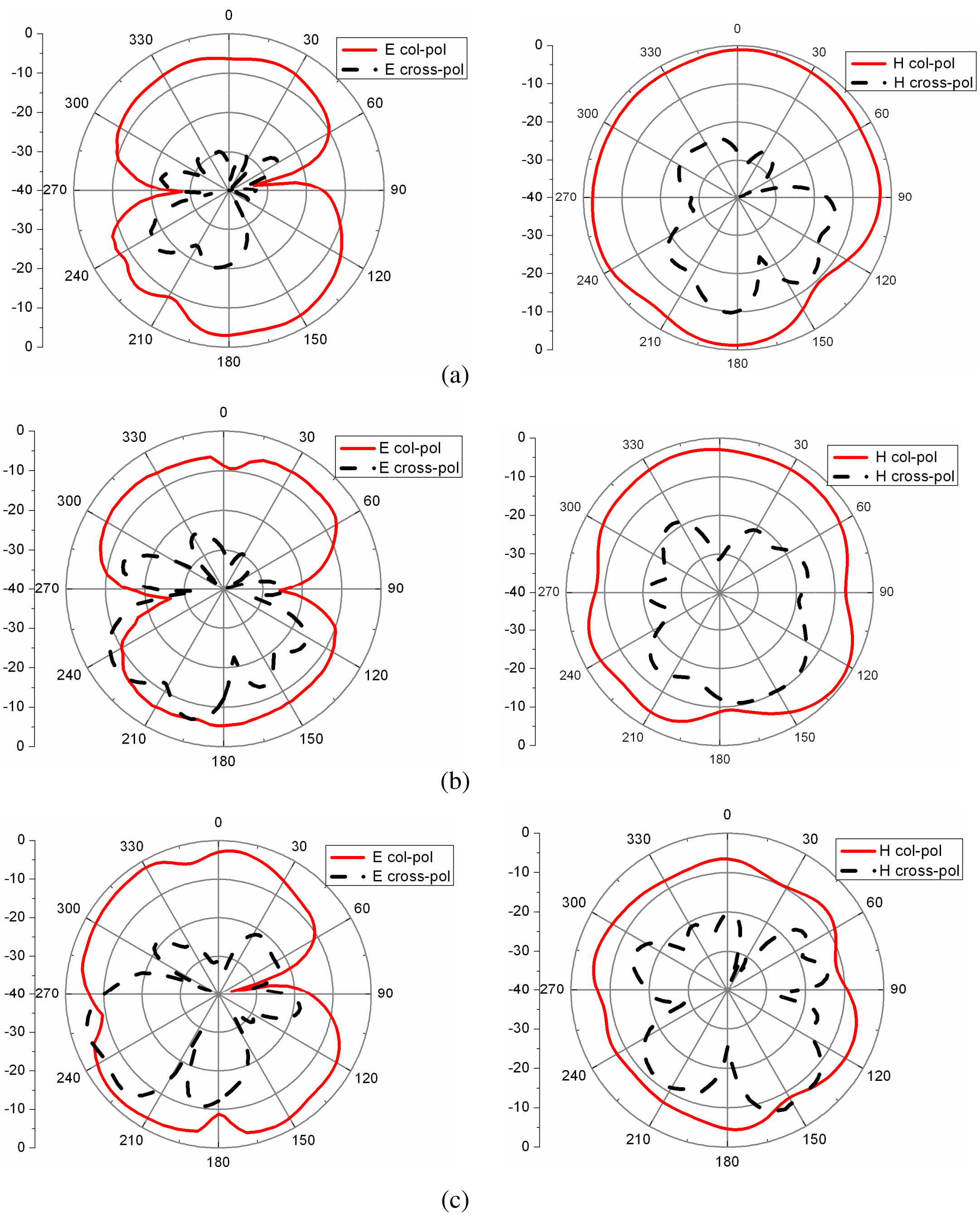


Figure 7. Measured radiation patterns of the proposed antenna at the passband frequencies (a) 4.5 GHz, (b) 7.5 GHz, (c) 9.5 GHz.

3. RESULTS AND DISCUSSION

The proposed antenna is fabricated and measured, the simulated and measured reflection coefficient are given in Figure 5. The proposed antenna is fed with a 50-Ω SMA connector at the end of the ACS-fed structure. The reflection coefficient of the proposed antenna is measured by the Agilent E8363B vector network analyzer. From the figure, measured data shows good agreement with the simulation, but still there are some differences, except the fabrication error, the tin solder distribute uneven may be another factor. It can be seen that the antenna with two open-ended half wavelength slots successfully exhibits two designed notched bands ranging from 3.12 to 3.69 GHz and 5.51 to 6.01 GHz, the center frequencies of the notched bands are 3.42 and 5.73 GHz, respectively. Which can cover WiMAX (3.4–3.69 GHz) and WLAN (5.725–5.825 GHz). Otherwise making certain broadband performance from 2.65 to 11.45 GHz with return loss more than 10 dB covering the entire UWB frequency band.

In order to observe the effects of the outer and inner slots in getting the notched bands, the surface current distributions on the radiating patch of the proposed antenna at three different frequencies are shown in Figure 6. At a passband frequency of 4.5 GHz (outside the notched bands), the distribution of the surface current is uniform [Figure 6(a)]. Meanwhile, in Figures 6(b)–(c), we can see stronger current distributions concentrated near the edges of the outer and inner slots at the center frequency of the first notched band 3.5 GHz, and the second notched band 5.8 GHz, respectively. Because the currents along the modified slots are in the opposite direction, the radiation field generated by them are neutralized. So the antenna cannot radiate at these two notched frequencies. These clearly show the positive effects of the slots upon obtaining the band-notched characteristics.

Figure 7 shows the measured radiation patterns in the E- (XZ-) and the H- (YZ-) planes at the passband frequencies at 4.5, 7.5, and 9.5 GHz. The proposed antenna has nearly omnidirectional patterns in the H-plane and figure-eight radiation patterns in the E-plane. All the obtained radiation patterns accord with those of the conventional printed UWB monopole antennas. It can be seen that the radiation pattern deteriorates slightly at the higher resonant frequency. This may be due to the fact that the asymmetric ground plane of the presented design is half of the CPW-fed antennas. The measured peak gains and group delay (face to face) of the antenna are shown in Figure 8. Two sharp reductions at the two notched bands clearly confirm the signal-rejection capability of the proposed antenna.

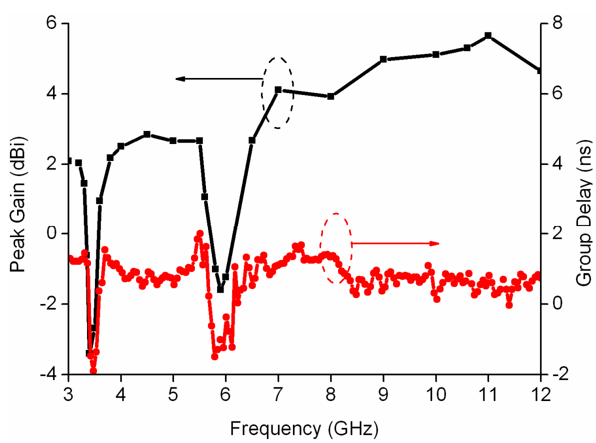


Figure 8. Measured peak gains and group delay (face to face) of the proposed antenna.

4. CONCLUSION

A compact ACS-fed printed UWB monopole antenna with two open-ended half-wavelength slots for achieving dual band-notched characteristics was proposed, fabricated, and measured. The simple fed structure reduces the overall size of the proposed antenna largely. The effects of the dimensions of the slots in the radiating patch were discussed in detail. Surface current distributions were used to show the effect of these slots in generating the notched bands. Measured results testify that the proposed antenna can achieve a wide bandwidth from 2.65 to 11.45 GHz and two intended notched bands, has good omnidirectional radiation characteristics, reasonable gains and group delay at the passband. Therefore, the proposed antenna is suitable for UWB communication systems applications.

REFERENCES

1. Federal Communications Commission, "Federal communications commission revision of Part 15 of the commission's rules regarding ultra-wideband transmission system from 3.1 to 10.6 GHz," FCC, Washington, DC, ET-Docket, 98–153, 2002.
2. Lu, J.-H. and C. H. Yeh, "Planar broadband arc-shaped monopole antenna for UWB system," *IEEE Trans. Antennas Propagat.*, Vol. 60, No. 7, 3091–3095, 2012.
3. Barbarino, S. and F. Consoli, "Study on super-wideband planar asymmetrical dipole antennas of circular shape," *IEEE Trans. Antennas Propagat.*, Vol. 58, No. 12, 4074–4078, 2010.
4. Zhou, D., S. C. S. Gao, F. Zhu, R. A. Abd-Alhameed, and J. D. Xu, "A simple and compact planar ultra wideband antenna with single or dual band-notched characteristics," *Progress In Electromagnetics Research*, Vol. 123, 47–65, 2012.
5. Gao, G.-P., M. Li, S.-F. Niu, X.-J. Li, B.-N. Li, and J.-S. Zhang, "Study of a novel wideband circular slot antenna having frequency band-notched function," *Progress In Electromagnetics Research*, Vol. 96, 141–154, 2009.
6. Cai, L.-Y., G. Zeng, and H. C. Yang, "Compact wideband antenna with double-fed structure having band-notched characteristics," *Electron. Lett.*, Vol. 46, No. 23, 1534–1536, 2010.
7. Zhang, Y., W. Y. Hong, Z. Q. Kuai, Y. D. Don, and J. Y. Zhou, "Planar ultra-wideband antennas with multiple notched bands based on etched slots on the patch and/or split ring resonators on the feed line," *IEEE Trans. Antennas Propagat.*, Vol. 56, No. 9, 3063–3068, 2008.
8. Soltani, S., M. Azarmanesh, P. Lotfi, and G. Dadashzadeh, "Two novel very small monopole antennas having frequency band notch function using DGS for UWB application," *Int. J. Electron. Commun. (AEÜ)*, Vol. 65, 87–94, 2011.
9. Barbarino, S. and F. Consoli, "UWB circular slot antenna provided with an inverted-L notch filter for the 5 GHz WLAN band," *Progress In Electromagnetics Research*, Vol. 104, 1–13, 2010.
10. Moghadasi, M.-N., R. A. Sadeghzadeh, T. Sedghi, T. Aribi, and B. S. Virdee, "UWB CPW-fed fractal patch antenna with band-notched function employing folded T-shaped element," *IEEE Antennas Wireless Propag. Lett.*, Vol. 12, 507–507, 2013.
11. Danesfahani, R., L. Asadpor, and S. Soltani, "A small UWB CPW-fed monopole antenna with variable notched bandwidth," *Journal of Electromagnetic Waves and Applications*, Vol. 23, Nos. 8–9, 1067–1076, 2009.
12. Soltani, S., M. N. Azarmanesh, and P. Lotfi, "Design of small ACS-fed band-notch UWB monopole antenna using particle swarm optimization," *Microwave Opt. Technol. Lett.*, Vol. 52, No. 7, 1510–1513, 2010.