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COMPACT OPEN-ENDED L-SHAPED SLOT ANTENNA WITH ASYMMETRICAL RECTANGULAR PATCH FOR UWB APPLICATIONS

K. Song, Y.-Z. Yin, S.-T. Fan, and B. Chen

National Key Laboratory of Science and Technology on Antennas and Microwaves, Xidian University, Xi'an, Shaanxi 710071, China

Abstract—A novel compact open-ended L-shaped slot antenna with asymmetrical rectangular patch is demonstrated and designed for UWB applications. With the open-ended L-shaped slot and an asymmetrical rectangular patch fed by the micro-strip line, multiple resonant frequencies are excited and merged to form a measured widen operating bandwidth of $3.01 \sim 11.30$ GHz with 10 dB return loss. The fractional bandwidth can be enhanced from previous 32% ($3 \sim 4.15$ GHz) to 112% ($3 \sim 10.66$ GHz) among three different antenna types in simulations. The details and vital parameters of the proposed slot antenna are also illustrated. In addition, the proposed slot antenna exhibits a small size of $25 \times 25\,\mathrm{mm}^2$, which makes it an excellent candidate for UWB systems and portable applications.

1. INTRODUCTION

To realize a high rate of wireless transmission, the widespread use of ultra-wideband (UWB) systems has attracted much public attention on the development of UWB antennas with good impedance match and radiation pattern over a wider $3.1 \sim 10.6$ GHz frequency range. Compared with the traditional wideband antennas such as vivaldis, log-periodics and spirals, slot antenna becomes an attractive candidate to realize a broadband and ultra-wideband characteristics due to its low profile, wide bandwidth, compact size, low cost, and ease of fabrication. Various wide slot antennas have been reported in [1–7]. With a variety of wide slots such as an additional quarter-wavelength line slot resonator [1], two different feed-slot combinations [2], square-slot [3], square-ring slot fed by a fork stub [4], asymmetrical CPW slot [5], a

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Corresponding author: Kun Song (kingsong2010@gmail.com).

circular slot [6], and a fractal-shaped slot [7], these wide slot antennas can achieve a good ultra-wideband characteristic. Unfortunately, these inchoate investigations on the ultra-wideband operation bandwidth and size reduction are not solved well because that the limited bandwidths in [1, 2, 5, 7] are not enough for ultra-wideband requirement and the sizes in [1–4, 6, 7] are too large for the portable systems.

Recently, some called open slot antennas are introduced and used for wideband applications [8–11]. These open slot antennas with open L-, T-slot [8, 9], three small slots [10], and ground notch [11] are designed with fractional bandwidths about 87% [8], 94% [9], 109% [10], and 105% [11], respectively. It's obvious that open slot antennas are superior in its wideband characteristic with a suitable small ground size in [9, 10]. Meanwhile, different latest designation techniques to enhance the operating bandwidth are also proposed efficiently in [12–16]. With a rotated slot [12], multiple resonant slots [13], a pair of parasitic elements [14], a multi-stub with multi-arms [15], and a self-similar slot [16], their operation bandwidths are increased greatly. However, their operation bandwidths [8–14] are still not available for continuously expanding ultra-wideband applications; what is more, large and complicated sizes [11–16] are an obvious deficiency in the application of the miniaturization.

In this article, a design of compact open-ended L-shaped slot antenna with asymmetrical rectangular patch is demonstrated for UWB applications. With the open-ended L-shaped slot and an asymmetrical rectangular patch fed by the micro-strip line, multiple resonant frequencies are excited and merged to form a measured widen operating bandwidth of $3.01 \sim 11.30$ GHz with 10 dB return loss. The details and vital parameters of the proposed slot antenna are also illustrated.

2. ANTENNA DESIGN

Figure 1 depicts the geometry of the proposed open-ended L-shaped slot antenna. By combining open-ended L-slot and asymmetrical rectangular patch fed by the micro-strip line, a novel compact UWB slot antenna is formed. Not only the printed open-ended L-slot on asymmetric ground plate produces wideband impedance characteristic just like [8–11], but also the ground plate is reduced greatly compared with Refs. [8, 10, 11]. The proposed UWB antenna with a smaller overall size of $25 \times 25\,\text{mm}^2$ is fabricated on a FR4 substrate with a thickness of 0.8 mm and a relative permittivity of 4.6. The vital parameters (l, w, g, d) about the asymmetrical rectangular patch fed by the $50\,\Omega$ micro-strip line can be well adjusted for a widen impedance

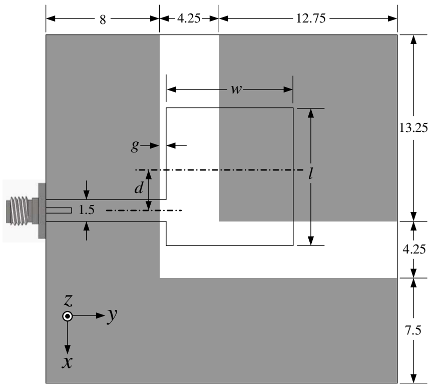

Figure 1. Geometry of the proposed open-ended L-slot UWB antenna.

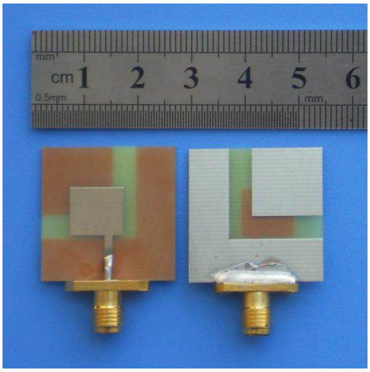

Figure 2. Photograph of the proposed open-ended L-slot UWB antenna.

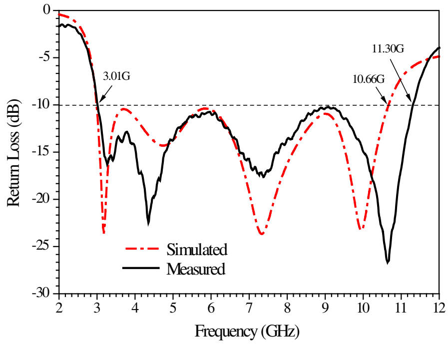

Figure 3. Simulated and measured return losses of the proposed open-ended L-slot UWB antenna with $l = 10\,\text{mm}$, $w = 9\,\text{mm}$, $d = 2.25\,\text{mm}$ and $g = 0.35\,\text{mm}$.

matching over UWB frequency range. After a thorough parametric study, the optimum design parameters are set as follows: $l = 10\,\text{mm}$, $w = 9\,\text{mm}$, $g = 0.35\,\text{mm}$ and $d = 2.25\,\text{mm}$. A prototype of the proposed antenna is fabricated and measured as shown in Figure 2 and Figure 3, respectively, according to the aforementioned design results. With the aid of Ansoft's High Frequency Structure Simulator (HFSS) software, the expected UWB antenna performance can be thoroughly investigated.

In our design procedure, the evolution of three mentioned L-slot antennas and their corresponding simulated return losses diagram are presented in Figures 4(a) and (b). It begins with the design of Antenna Type A, which is an open-ended L-slot modified version without extra large ground different with Refs. [8, 9]. In this case, a slightly narrow resonant frequency range over $3 \sim 4.15$ GHz at around lower edge can be excited by selecting suitable values of the length of the micro-strip feed line, the width and position of open-end L-slot. For a wider bandwidth, Antenna Type B with a rectangular patch ($l = 10$ mm, $w = 9$ mm, $d = 0$ mm, $g = 0$ mm) symmetrically fed by the $50\,\Omega$ micro-strip line can excite an enhanced operation range from 3 to 7.05 GHz, which is still unable to fulfill the UWB 7.5 GHz bandwidth requirement. Interestingly, the complete UWB band can be realized when the rectangular patch of the proposed antenna is asymmetrically fed by the $50\,\Omega$ micro-strip line like some reported asymmetrical structures [3, 5]. By carefully tuning the parameters ($d = 2.25$ mm, $g = 0.35$ mm), an approximate 112% impedance bandwidth from 3 to 10.66 GHz can be obtained, and is also much wider than those that have been reported for broadband open slot antennas [8–11].

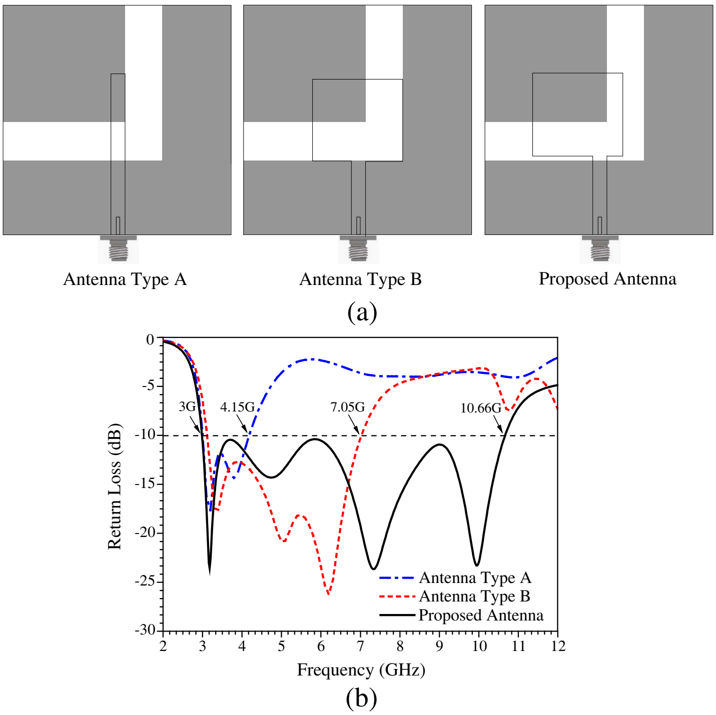

Figure 4. Design evolution of the open-ended L-slot antennas. (a) Three mentioned slot antennas. (b) Their corresponding return losses.

3. RESULTS AND DISCUSSIONS

The proposed antenna has been constructed and experimentally studied with the help of the HFSS and WILTRON37269A vector network analyzer. From Figure 3, it is obvious that the proposed UWB slot antenna can reach a wider operating bandwidth of about 116% from 3.01 to 11.30 GHz with 10 dB return loss in practice. Furthermore, with the open-ended L-slot and an asymmetrical rectangular patch fed by the micro-strip line, multiple resonant frequencies are excited at

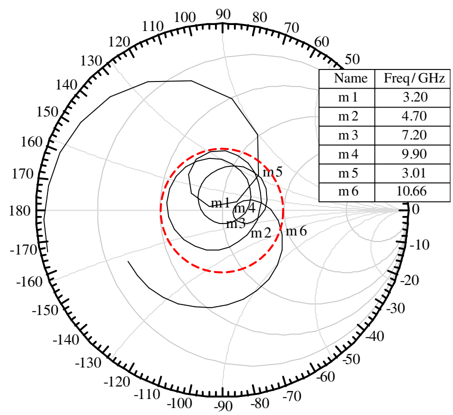

Figure 5. Widen impedance match of the proposed UWB antenna.

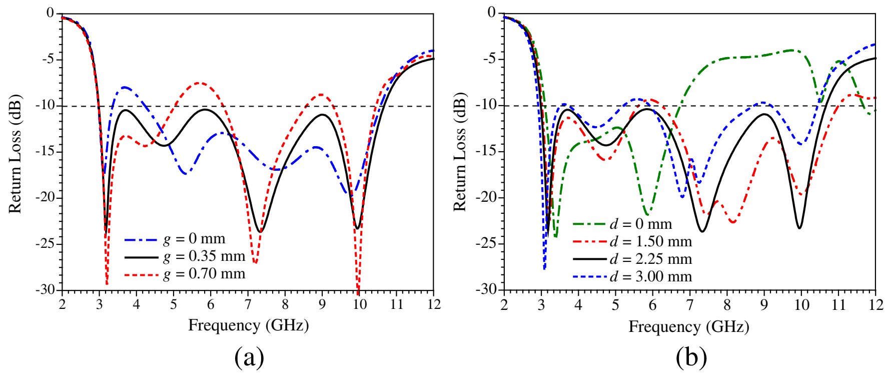

Figure 6. Vital parameters effect on the UWB performances of proposed open-ended slot antenna. (a) Simulated return losses for different vales of g. ($d = 2.25$ mm). (b) Simulated return losses for different vales of d. ($g = 0.35$ mm).

upper UWB band.

From Figure 4, the fractional bandwidth can also be enhanced from previous 32% (3 $\sim$ 4.15 GHz) to 112% (3 $\sim$ 10.66 GHz) among three different antenna types in simulations. A widen UWB impedance bandwidth can be achieved with more different resonant loops are close to the center of the Smith chart in Figure 5. With the four resonant frequencies (m1, m2, m3, m4), the same tightest resonant loops can form a great enhancement bandwidth for UWB applications.

Figures 6(a) and (b) show the simulated return losses with vital parameters of the proposed antenna for UWB performances. From these simulation results, it is obvious that the rectangular patch asymmetrically fed by the 50 Ω micro-strip line have a significant effect on the antenna's impedance bandwidth. The poor matching condition at upper UWB band can be obviously improved by the offset distance d from Figure 6(b).

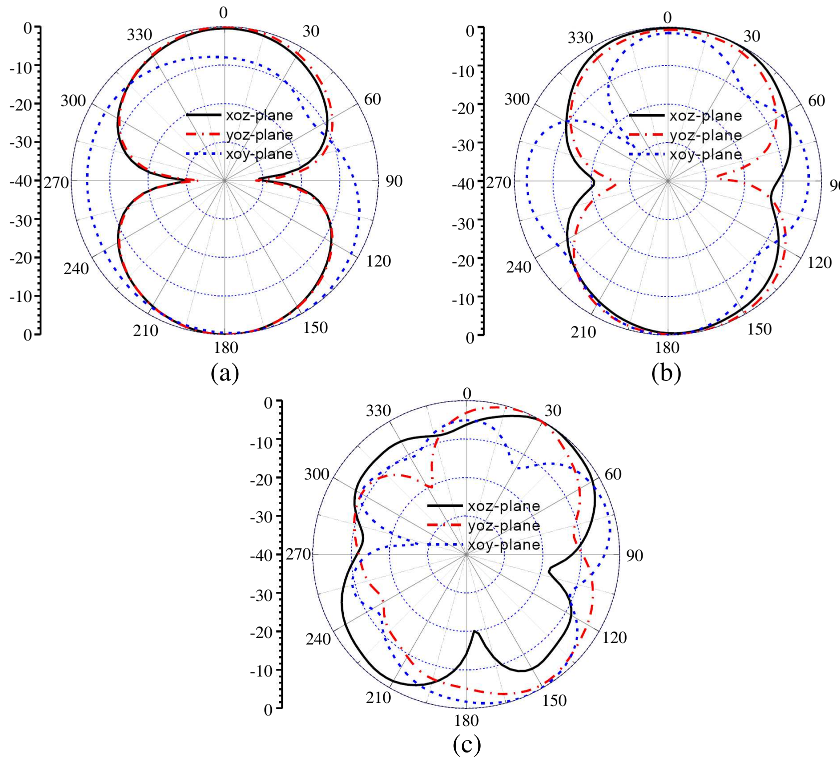

Figure 7. Far-field radiation patterns of the proposed antenna at (a) 3.5 GHz, (b) 6 GHz, (c) 9 GHz, respectively.

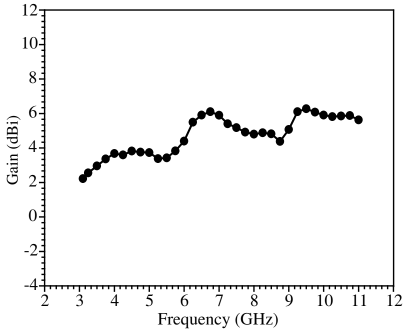

Figure 8. Peak gain of the proposed UWB antenna.

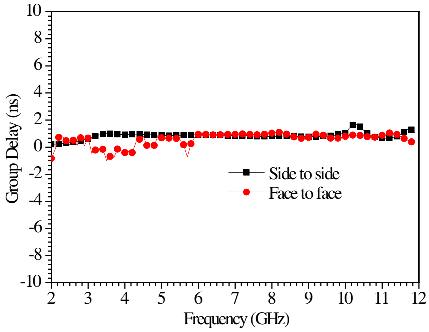

Figure 9. Group delay of proposed UWB antenna system.

The simulated far-field radiation patterns of proposed antenna at 3.5, 6, and 9 GHz are also shown in Figure 7. Based on these results of radiation patterns at xoz-plane, yoz-plane, and xoy-plane, respectively, it can be seen that the proposed UWB slot antenna has the asymmetric radiation characteristics at H-plane (xoy-plane) mainly because of its inherent asymmetric structure similar like [8, 9]. The peak gain of the proposed antenna is shown in Figure 8, as we can see that its gain is about 2.22–6.1 dBi in most of its impedance bandwidth. It has a peak value of 6.1 dBi at 6.75 GHz. Finally, the group delays of proposed UWB antenna system are presented with a distance of 15 cm in Figure 9, which proves that the antenna has a good time-domain characteristic varying within 2 ns as a small pulse distortion.

4. CONCLUSIONS

In this article, a compact open-ended L-shaped slot antenna with an asymmetrical rectangular patch for bandwidth enhancement is proposed and investigated. Using the simple open-ended L-shaped slot and an asymmetrical rectangular patch fed by the 50 Ω micro-strip line, the proposed antenna can achieve an enhanced operating bandwidth of 3.01 $\sim$ 11.30 GHz with 10 dB return loss. This UWB slot antenna also exhibits a small area of $25 \times 25\,\text{mm}^2$. The experimental results show that this antenna is an excellent candidate for the emerging UWB systems and portable applications.

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