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A STUDY OF A COMPACT MICROSTRIP-FED UWB ANTENNA WITH AN OPEN T-SLOT

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Abstract—In this paper, a compact and simple microstrip-fed slot antenna is proposed for ultra-wideband (UWB) applications, which consists of a circular patch and an open T-slot to realize the microstrip-line to slot transition well over a widened frequency range. The simulations and measurements show that this simple structure with the novel design generates a broadband impedance bandwidth of 10 dB return loss from 2.5 to 12.5 GHz (BW = 133.3%) adjustable by variation of its parameters. Details of the antenna design and experimental results of the constructed prototype are presented. In addition, a geometric parameters study of the proposed antenna is able to provide more useful information for antenna design.

1. INTRODUCTION

Today, microstrip (MS)-fed slot antenna is useful in many applications because of its numerous advantages such as low profile, low cost, lightweight, easy fabrication, etc. It naturally becomes an excellent candidate for the increasing demands of broadband antennas in modern wireless communication systems. For research on antenna characteristics for emerging UWB applications, operating bandwidth and small size are two key factors, besides effective radiation and radiation pattern.

In recent years, various slot antennas fed by microstrip-line have been seen in the literatures [1–5]. With different shapes such as cross-shaped slot [1], eccentric annular slot [2], triangular slot [3], square-slot [4], E-shaped slot [5], etc., wide bandwidth can be achieved well and also used for wideband and UWB communications. In addition,

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a new technique with multiple Z-like slots is proposed in [6], which is an effective method that creates several resonant paths for bandwidth enhancement. But a large size with complicated designs is a fatal defect for integrated, portable and smaller demands. In [7, 8], Latif et al. introduced a new type antenna with open L- and T-shaped slots for wideband applications and achieved about 52.8% [7] and 87% [8] operating bandwidth. Same as above, the problem was still not improved obviously. Recently, an open inverted-L MS-fed antenna with small size in [9–11] was investigated, which could overcome the aforementioned problem well. However, the operating impedance bandwidth [9–11] is still used in a limited frequency range of 2.2–6.1 GHz, which is not adequate for UWB applications.

In this article, the antenna employs a novel design to realize the microstrip-line to slot transition well over a widened frequency range. The circular structure is selected just like the small open-slot in [11], because it has the advantages of good impedance bandwidth, simple structure and ease in reducing size. Compared with [11], the microstrip-line to open T-slot transition structure has also been investigated and discussed, which can be used to excite an enhanced operation bandwidth over a UWB frequency range. Choosing the proper dimensions of the circular patch and the T-slot, we can obtain a wider operating bandwidth. From simulated and experimental results, the impedance bandwidth of the proposed antenna, defined by 10 dB return loss, can reach an operating bandwidth of 10 GHz (2.5–12.5 GHz), or about 133.3% with the center frequency operating at 7.5 GHz. A prototype antenna has been constructed, and performance results from simulation and measurement have been compared, including return losses, bandwidths, radiation patterns, and gains.

2. ANTENNA DESIGN

The antenna proposed in this study employs a MS-fed circular patch to excite an open T-slot on the opposite ground. Figure 1 shows the configuration of the proposed antenna. The novel design can achieve MS-to-slot transition well to excite a UWB characteristic. The proposed antenna is fabricated on a 0.8 mm thick FR4 substrate having a dielectric constant of $\varepsilon_r = 4.4$ and $\tan\delta$ of 0.02, and an overall size of $30 \times 35\,\mathrm{mm}^2$. The antenna is fed by a $50\,\Omega$ microstrip with a circular patch, which has a radius of R_a. In order to achieve the desired operating bandwidth, an open T-slot is etched on the ground plane. The dimensions: W_1, W_2, L, R_a, and R_b are carefully chosen in the process of bandwidth optimization. The relationship between W_2 and R_b is expressed by a simple equation: $W_2 = 2 \times R_b$,

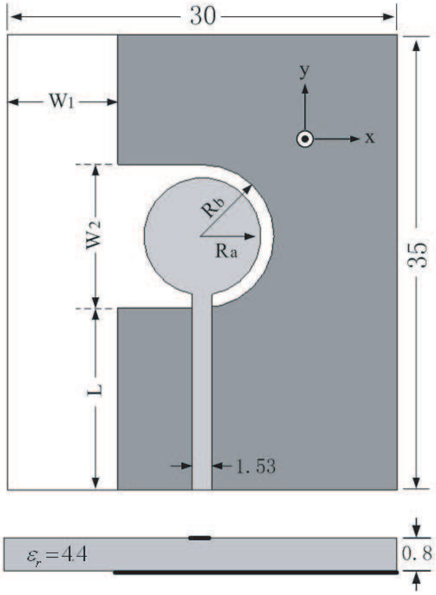


Figure 1. Geometry of the proposed antenna (Units: mm).

and the distance from the center of the circular patch to the feed is the sum of L and R_b. By optimizing the parameters of W_1, $W_2(R_b)$, L, and R_a, the UWB characteristic can be excited with good impedance matching. To investigate the performance of the proposed antenna configuration, a commercially available simulation software was used for the required numerical analysis and obtaining the proper geometrical parameters. After a thorough parametric study of the open T-slot antenna, the optimum design parameters were set as shown in Table 1. A prototype of the proposed antenna was fabricated according to the aforementioned design result, as shown in Figure 2.

Table 1. The optimum design parameters.

Parameters	W_1	W_2	L	R_a	R_b
Values (mm)	8.5	11	14	4.5	5.5

3. RESULTS AND DISCUSSION

The antenna was simulated using Ansoft high-frequency structure simulator (HFSS) software, and the return loss of the antenna was

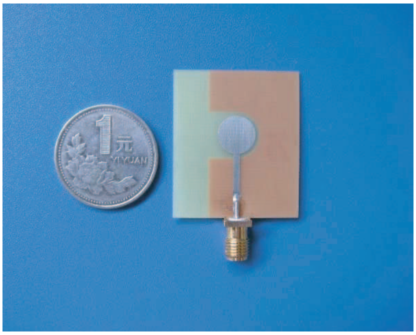


Figure 2. A photograph of the proposed antenna.

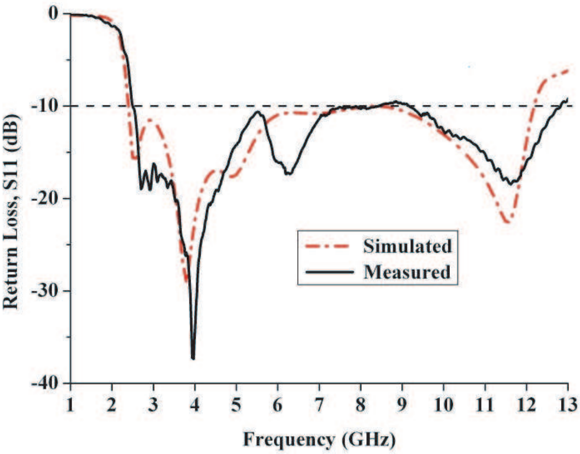


Figure 3. Simulated and measured and return losses of the proposed antenna with optimum design parameters.

measured using a calibrated vector network analyzer. Figure 3 shows the simulation and measurement frequency responses of return loss for the proposed antenna. From simulated and experimental results, the impedance bandwidth of the proposed antenna, defined by 10 dB return loss, can reach an operating bandwidth of 10 GHz (2.5–12.5 GHz), or about 133.3% with the center frequency operating at 7.5 GHz.

Figures 4, 5, 6, and 7 show the simulated return loss curves for the proposed antenna with various parameters. From these simulation results, the parameters W_1, $W_2\,(R_b)$, L, and R_a profusely affect the impedance bandwidth. W_1, W_2, and L in Figures 4, 5, and 7 show that

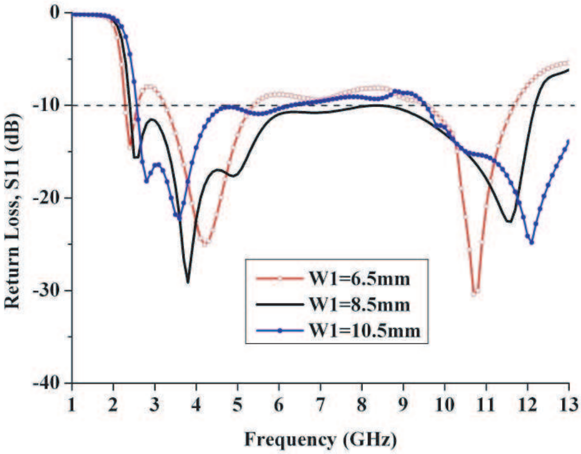


Figure 4. Simulated return loss for different vales of W_1. (Other parameters: $W_2 = 11\,\mathrm{mm}$ ($R_b = 5.5\,\mathrm{mm}$), $L = 14\,\mathrm{mm}$, and $R_a = 4.5\,\mathrm{mm}$.)

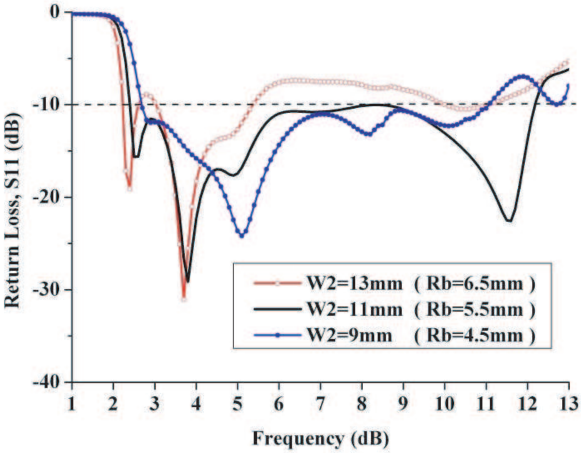


Figure 5. Simulated return loss for different vales of W_2 (R_b). (Other parameters: $W_1 = 8.5\,\mathrm{mm}$, $L = 14\,\mathrm{mm}$, and $R_a = 4.5\,\mathrm{mm}$.)

the T-slot has an effective improvement on the impedance bandwidth at high frequency. Especially, Figure 7 demonstrates that the position L of the horizontal part of T-slot can obviously improve the matching situation over 7 GHz. In addition, Figures 5 and 6 prove that the

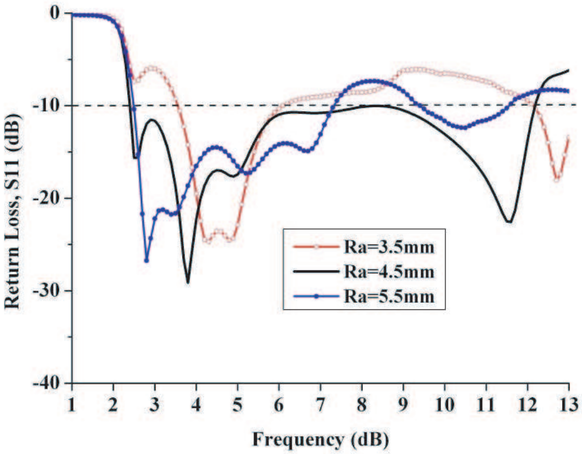


Figure 6. Simulated return loss for different vales of R_a. (Other parameters: $W_1 = 8.5\,\text{mm}$, $W_2 = 11\,\text{mm}$ ($R_b = 5.5\,\text{mm}$), and $L = 14\,\text{mm}$.)

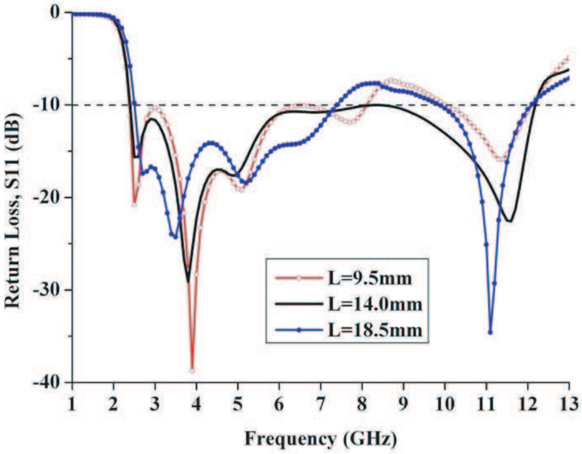
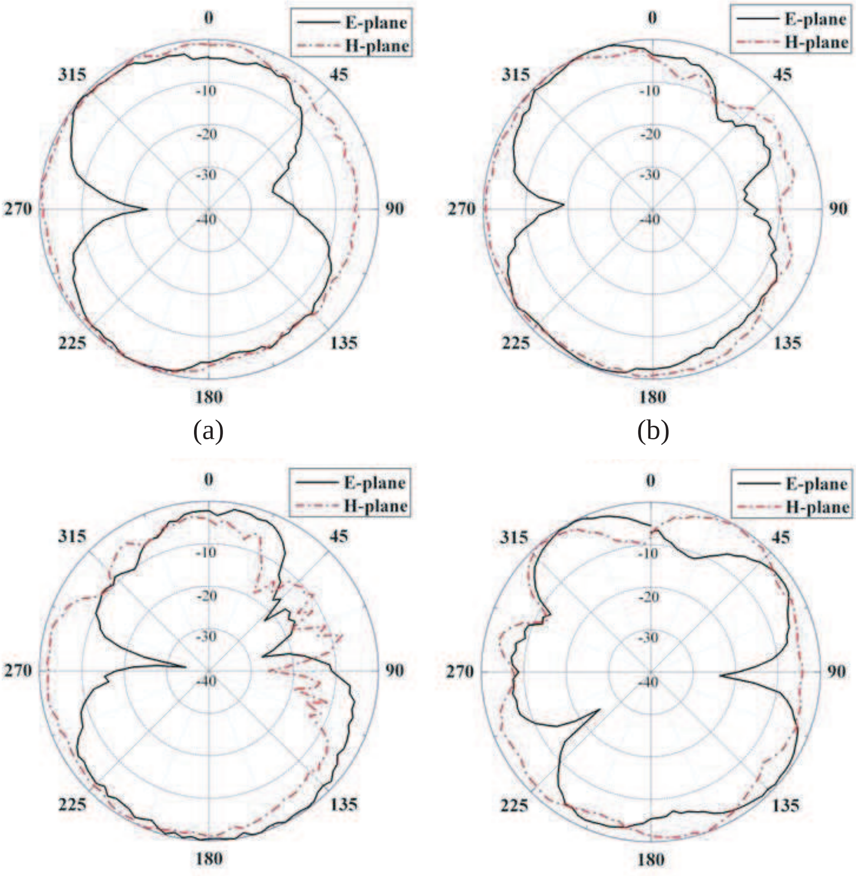


Figure 7. Simulated return loss for different vales of L. (Other parameters: $W_1 = 8.5\,\text{mm}$, $W_2 = 11\,\text{mm}$ ($R_b = 5.5\,\text{mm}$), and $R_a = 4.5\,\text{mm}$.)

operation bandwidth is not adequate for UWB applications if the gap between radiator and the slot is nonexistence just as in [11] or excessive. Therefore, using the optimized results can realize the microstrip-line to slot transition well over a widened frequency range.

Measured radiation patterns of the antenna in E-plane (y-z) and H-plane (x-z) at three different frequencies are shown in Figure 8. It shows an approximately omni-directional radiation characteristic in H-plane. From (c), it is obvious that the radiation pattern of H-plane is asymmetric because of its fringing through the open T-slot. The measured gain of E-plane against frequency is shown in Figure 9. It has a maximum value of about 4.1 dBi at 10 GHz.



(a) (b)

(c) (d)

Figure 8. Measured radiation far-field patterns for the proposed antenna operation at (a) 3 GHz, (b) 6 GHz, (c) 9 GHz, and (d) 12 GHz.

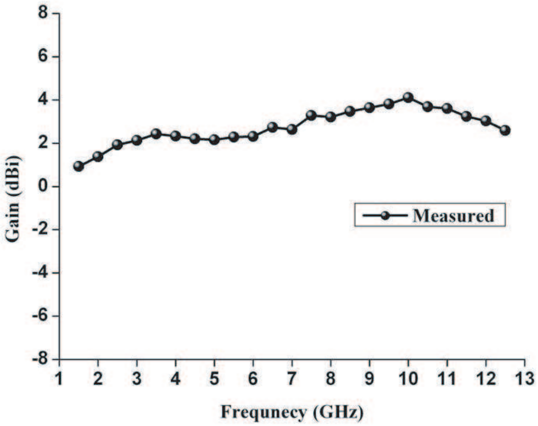


Figure 9. Measured gain of E-plane against frequency.

4. CONCLUSION

It has been demonstrated that the UWB operating bandwidth can be realized with a circular patch to open T-slot transition design excited by a MS-feeder. By optimizing the microstrip-line to slot structure and parameters, the proposed antenna generates a wider impedance bandwidth for UWB applications. A parametric investigation of the different variables, which can provide more useful information for antenna design, has been presented in this paper, and the obtained results show that the proposed antenna could produce a broad bandwidth of 10 GHz (2.5–12.5 GHz), or about 133.3% with the center frequency operating at 7.5 GHz. Also, measurements of the constructed prototype verify that the compact, small, and simple design is suitable for portable UWB applications.

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