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A NOVEL COMPACT ULTRA-WIDEBAND (UWB) WIDE SLOT ANTENNA WITH VIA HOLES

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Abstract—A novel compact ultra-wideband (UWB) wide slot antenna with via holes is presented for UWB applications. The antenna is composed of a trapezoidal slot on the ground plane, a rectangular patch in the center of the slot and three via holes connecting the rectangular patch and the microstrip feed-line. The antenna is successfully designed, implemented, and measured. The measured results show that the proposed antenna with compact size of $27.0\,\text{mm} \times 29.0\,\text{mm} \times 1.0\,\text{mm}$ achieves good performance, such as an impedance matching bandwidth of 111.7% ($|S_{11}| \leq -10\,\text{dB}$), constant gain and stable radiation patterns over its whole frequency range.

1. INTRODUCTION

Ultra-wideband (UWB) wireless communication technology has been receiving wide attention from both academy and industry since the Federal Communication Commission (FCC) released of the frequency band from 3.1 to 10.6 GHz for commercial communication applications in February 2002 [1]. In an UWB system, the UWB antenna is one of the most important passive components and has attracted significant research power in the recent years. However, there are more challenges in designing an UWB antenna. A feasible UWB antenna should possess a good performance in both the time and frequency domain. Furthermore, small and compact appearance of the antenna size is also required for portable UWB applications.

Because of its attractive features such as wide bandwidth performance, easy fabrication and bidirectional radiation patterns, the wide slot antenna has become one of the most promising candidates for

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UWB antennas design [2–11]. Previously in [2], a rectangular wide slot with cross-shaped microstrip-line-fed structure achieves an impedance bandwidth of 98.6% with $|S_{11}| \leq -10\,\text{dB}$. In [3, 4], rectangular wide slot antennas using fork-like microstrip fed line are proposed to broaden operating bandwidth. In [5], a semicircular slot with a square-patch feed and a triangular slot with a triangular-patch feed provide bandwidth of 120.0% and 110.0% respectively. Some other types of the microstrip wide slot antennas have been reported in [6–11].

In this paper, a novel UWB wide slot antenna with via holes is proposed. The design comprises a trapezoidal slot on the ground plane, a rectangular patch in the center of the slot and three via holes connecting the rectangular patch and the microstrip feed-line. By properly adding the three via holes, impedance matching can be accomplished over a very wide bandwidth.

The geometrical parameters of this antenna are experimentally optimized and the configurations are etched onto a piece of printed circuit board (PCB) with a very compact size of $27.0\,\text{mm} \times 29.0\,\text{mm} \times 1.0\,\text{mm}$. The results of simulations and measurements show that the antenna can easily provide a wideband impedance matching over the UWB frequency band. In addition, the gain and radiation patterns remain almost constant particularly across the frequency range. Details of the antenna design are presented and the measured results are given in order to demonstrate the performance of the proposed antenna.

2. ANTENNA CONFIGURATION AND PERFORMANCE

The geometry and configuration of the proposed wide slot antenna is shown in Figure 1. It can be observed that the antenna consists of a trapezoidal slot on the ground plane, a rectangular patch in the center of the slot and three via holes connecting the rectangular patch and the microstrip feed-line. All of these are mounted on a square substrate of a thickness of 1.0 mm and a relative permittivity of 2.65 with length and width of 29.0 mm and 27.0 mm respectively. The parameters of the trapezoidal slot are W_{s1}, W_{s2} and L_s. The length and width of the rectangular microstrip patch in the center of the slot are L_p and W_p respectively. The gap between the rectangular patch and the side of the slot is described by g. The microstrip feed-line connecting the rectangular patch by via holes is designed with the strip width of W_{m2} and the length of L_{m2}. It is characteristic that the rectangular patch and the microstrip feed line are connected by via holes in order to adjust the input impedance. By compromising between the fabrication cost and antenna performance, three via holes with the diameter of

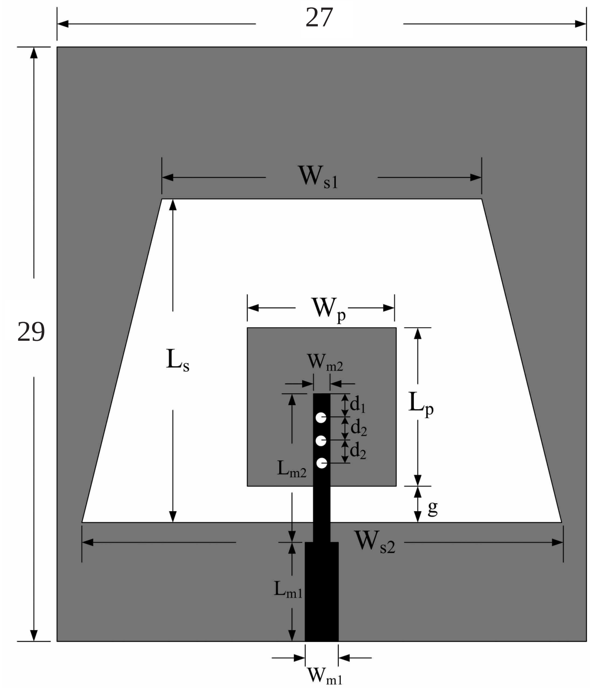

Figure 1. Configuration of the proposed wide slot antenna (unit: mm).

0.4 mm are utilized and the distance between adjacent via hole is d_2. The width of the microstrip line at the input of the antenna is 2.6 mm which is derived from 50 Ω characteristic impedance.

The simulation of the final design is then carried out using IE3D, a commercial electromagnetic simulator. After an extensive parametric study, the final geometry parameters are obtained as $W_{s1} = 17.2$ mm, $W_{s2} = 24.2$ mm, $L_s = 13.5$ mm, $W_p = 7.8$ mm, $L_p = 8.1$ mm, $W_{m1} = 2.6$ mm, $L_{m1} = 4.5$ mm, $L_{m2} = 11.1$ mm, $g = 1.5$ mm, $d_1 = 2.0$ mm, and $d_2 = 1.0$ mm. The antenna is fabricated and measured with Agilent's 8720ET vector network analyzer. Figure 2 illustrates the measured return loss of the designed antenna with a comparison with simulation results over the frequency rang from 2.0 to 12.0 GHz. Measured results of this structure reveal a return loss lower than −10 dB over the frequency band from 3.0 to 10.6 GHz, which means that the relative impedance bandwidth of the antenna is about 111.7% with respect to the center frequency of 6.8 GHz.

Moreover, Figure 3 shows the simulated S_{11}-parameters of the

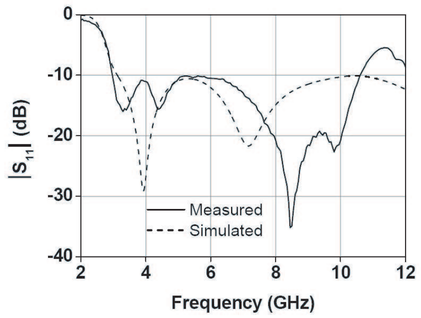

Figure 2. Simulated and measured performance of the UWB antenna.

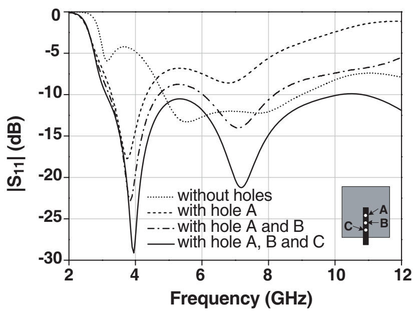

Figure 3. Simulated S_{11}-parameters of the UWB antennas with different numbers of via holes.

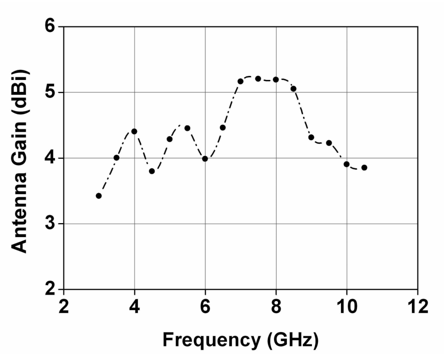

Figure 4. Measured peak gain of the UWB antenna.

UWB antennas with different numbers of via holes under all other parameters are fixed. It can be observed that the impedance bandwidth is broadened with an increase in the number of via holes. By utilizing three via holes, the return loss of the antenna is below -10 dB within the entire UWB frequency range.

The measurement for the antenna radiation was carried out in a chamber. The peak gain of the antenna remains constant throughout the band as indicated in Figure 4. Figure 5 depicts the measured radiation patterns in correspondence with three different representative frequency points within the band of operation ($f_1 = 4.0$ GHz, $f_2 = 7.0$ GHz, $f_3 = 9.0$ GHz). It can be seen from the figure that the antenna has relative stable radiation patterns at the three frequency points.

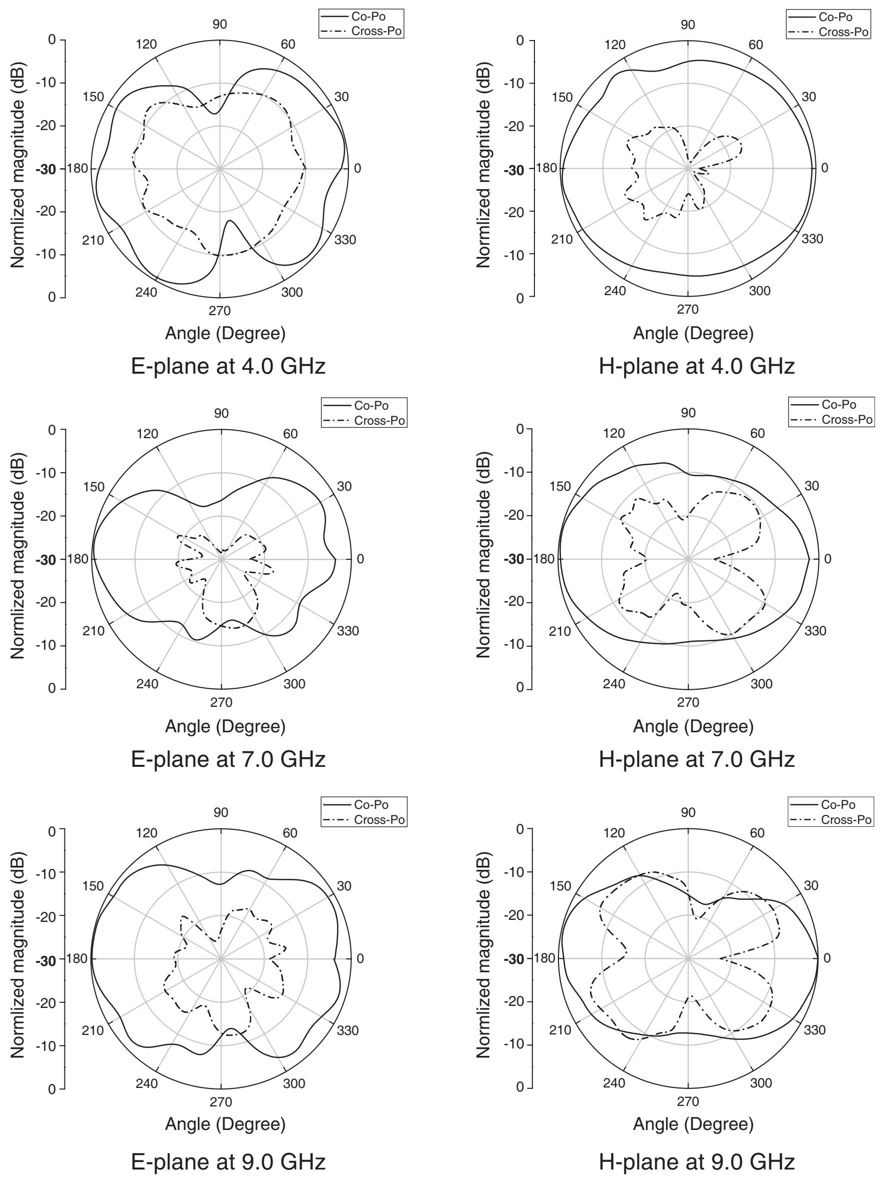

Figure 5. Measured radiation patterns of the UWB antenna at different frequencies.

3. CONCLUSION

A novel UWB wide slot antenna with via holes for UWB applications is illustrated in this paper. It consists of a trapezoidal slot on the ground plane, a rectangular microstrip patch in the center of the slot and three via holes connecting the rectangular patch and the microstrip feed-line. The antenna is successfully designed, constructed, and measured. The measured results show that the proposed antenna possesses an impedance matching bandwidth of 111.7% ($|S_{11}| \leq -10\,\text{dB}$) at the center frequency of 6.8 GHz, constant gain and stable radiation patterns over its whole frequency band. In addition, the compact size of the antenna further confirms its suitability for portable UWB devices.

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