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DESIGNS ON CPW-FED APERTURE ANTENNA FOR ULTRA-WIDEBAND APPLICATIONS

Z. Li, C.-X. Zhang, G.-M. Wang, and W.-R. Su

Radar Engineering Department
Missile Institute of Air Force Engineering University
Sanyuan, Shanxi 713800, China

Abstract—A novel co-planar waveguide (CPW) ultra-wideband (UWB) aperture antenna is presented. The antenna consists of a rectangular aperture on a printed circuit board ground plane and a mushroom-shaped exciting stub. The mushroom-shaped stub is simple and has less parameter, which is convenient to analyze and optimize. The antenna has a compact aperture size $22 \times 13\,\text{mm}^2$, fabricated on FR4 substrate with dielectric constant of 4.3, thickness of 1.5 mm. The antenna is successfully implemented and measured, which has 8.3 GHz match bandwidth (VSWR < 2), and stable radiation patterns.

1. INTRODUCTION

Ultra-wideband (UWB) technology is one of the most promising solutions for future communication systems due to its high-speed data rate and excellent immunity to multi-path interference. As the key components of UWB system, the feasible UWB antenna design face some challenges including the ultra wideband performances of the impedance matching and radiation stability, the compact antenna size, and the low manufacturing cost for consumer electronics applications. Because the CPW fed planar slot antennas have the advantages of wide bandwidth, low cost, and easy integration with the radio frequency (RF) front end circuitry, the designs on the CPW-fed wide slot antennas have recently received much attention [1–8]. In [1, 2], the achieved bandwidths of these antennas is about 60%, which can not cover the whole FCC defined UWB frequency band (3.1–10.6 GHz). Besides, the size of the antenna is not very small. The circular slot antenna with rectangular CPW-fed structures has good match bandwidth (2.762–10.985 GHz), but it has great circular aperture and not stable directivity pattern [3]. In [4, 5], the ultra wideband characteristic of these antennas is fine, however, the design of using U-shaped tuning stub and tapering the feed line contains many added parameters for the complex geometry.

In this paper, a novel CPW-fed UWB rectangular aperture antenna with simple geometry is presented. The compact rectangular aperture antenna is fed by a 50 Ω CPW transmission line, where the end is terminated by a semicircle tuning stub. The whole feeding structure looks like a mushroom shape, which has a simpler geometry structure and fewer parameters. Details of the antenna design are discussed, and experimental results of the proposed antenna are presented and analyzed.

2. ANTENNA DESIGN

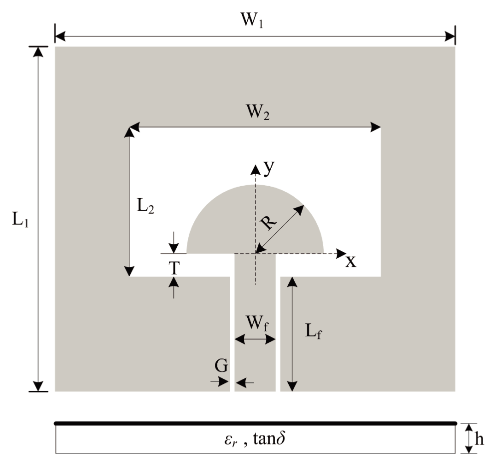

Figure 1. Layout of the proposed antenna.

The layout of the proposed UWB antenna is shown in Fig. 1. The antenna consists of a rectangular aperture etched out from the ground plane of a PCB and a CPW-fed mushroom-shaped stub for excitation. The developed antenna is fabricated on a low-cost FR4 substrate with dielectric constant $\varepsilon_r = 4.3$, loss tangent $\tan\delta = 0.02$, thickness $h = 1.5$ mm. The ground plane dimensions are $W_1 = 34$ mm by $L_1 = 29$ mm, and the rectangular aperture dimensions are $W_2 = 22$ mm by $L_2 = 13$ mm. A 50 Ω CPW feed line, having a metal strip of width $W_f = 3.6$ mm, gap of distance $G = 0.4$ mm and length $L_f = 10$ mm. The semicircle terminal of radius R is connected to the end of the CPW feed line. The spacing between the semicircle terminal and edge of the ground plane is T. The mushroom-shaped stub has only two parameters: the radius R and the extrusion depth T, which is convenient to optimize and design.

For the aperture antenna, the mushroom-shaped tuning stub is introduced to enhance the coupling between the slot and the feed line so as to achieve the ultra wideband property of the antenna. Thus the radius R and extrusion depth T are the most important design parameters which affect the antenna performance and need to study [6]. The commercial simulation software Ansoft HFSS 10.0 based on the finite element method (FEM) is employed to perform the design and optimization process. The final stub dimensions is $R = 6\,\text{mm}$, $T = 2\,\text{mm}$.

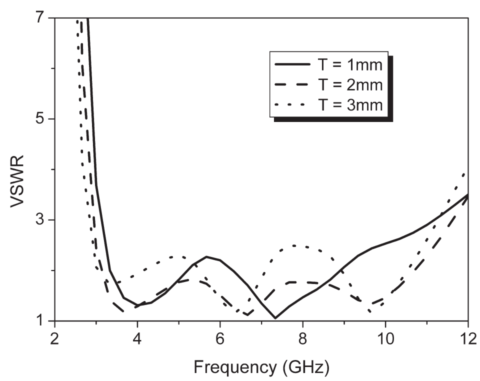

Figure 2. Simulated VSWR curve under different extrusion depth T.

The simulated voltage standing wave ratio (VSWR) of the UWB aperture antenna in Fig. 1 with respect to different radius R and extrusion depth T is shown in Fig. 2 and Fig. 3, respectively. Fig. 2 shows that the T parameter may influences the impedance both middle and high bands. Fig. 3 shows that the match curve varies lightly with the parameter R changing, and the resonant frequency is decreased as the parameter R increases. Compared to the parameter R, the extrusion depth T is relatively sensitive to the input impedance over the entire operation frequency band.

3. EXPERIMENTAL RESULTS AND ANALYSIS

The measurement result of VSWR is shown in Fig. 4. The fabricated antenna can approach an impedance bandwidth from 3.2 to 11.5 GHz for VSWR < 2. Comparing with the simulation curve ($R = 6\,\text{mm}$, $T = 2\,\text{mm}$) in the Fig. 2, a relative good agreement between simulation and measurement is achieved. Discrepancy between measured and simulated results may be caused by the fabrication inaccuracy, the nonuniform dielectric substrate and so on.

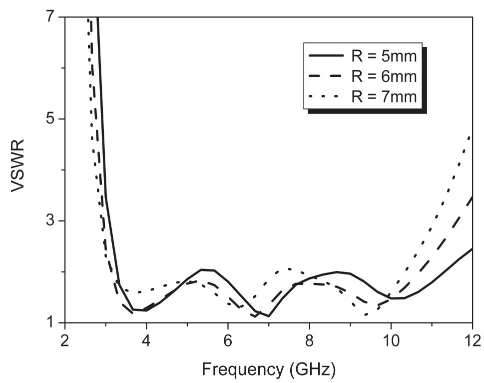

Figure 3. Simulated VSWR curve under different radius R.

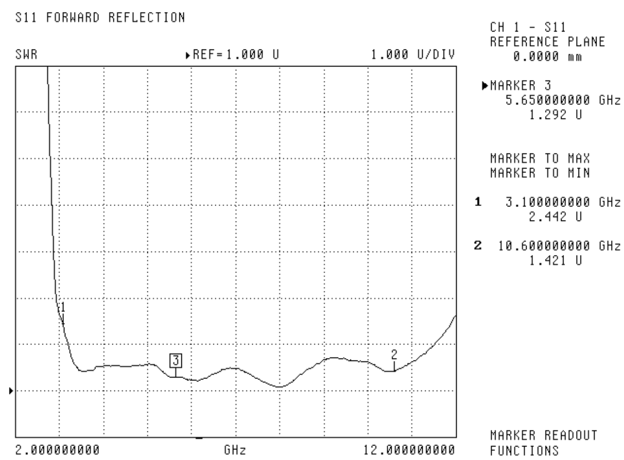

Figure 4. Measured VSWR curve.

Figure 5 plots the simulated and measured normalized radiation patterns in the xz- and yz-planes at 3.7, 6.7 and 9.7 GHz for the proposed antenna. The antenna has stable radiation patterns over the UWB in agreement with the numerical simulations, and the direction of maximum radiation is constantly around the z-axis (normal to the aperture plane). The xz-plane has omni-directional pattern, which is monopole-like and becomes more directional with the increase of frequency. The yz-plane has almost bi-directional patterns, especially

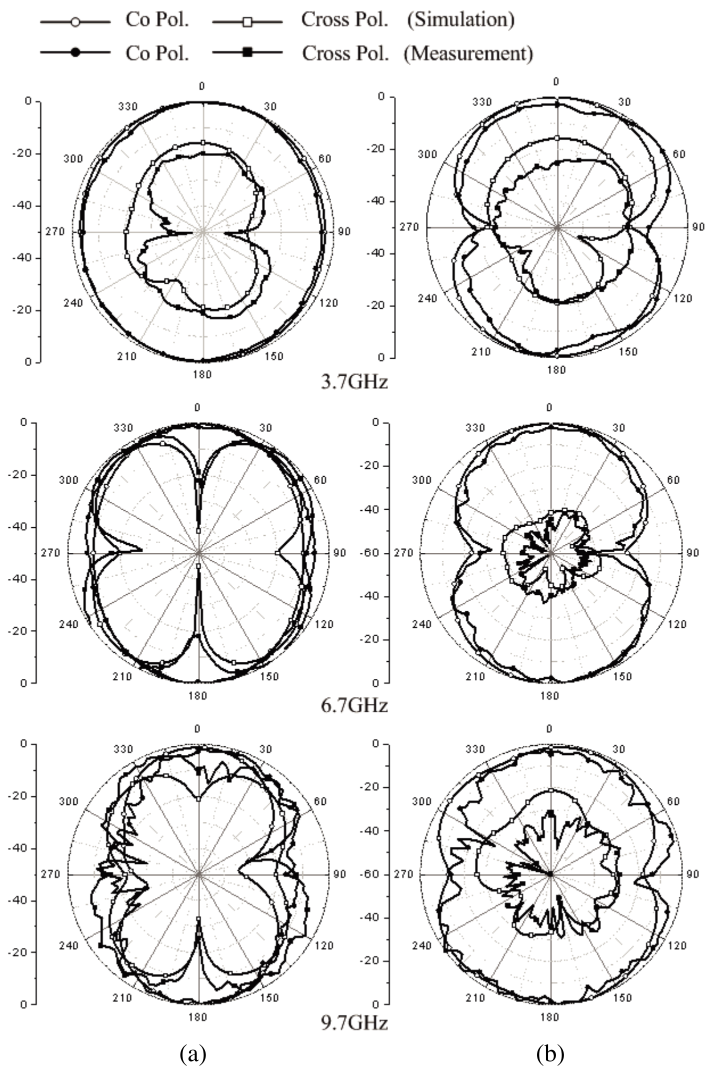

Figure 5. Simulated and measured radiation patterns at 3.7 GHz/6.7 GHz/9.7 GHz: (a) xz-plane, (b) yz-plane.

at lower frequencies. It is noted that the xz-plane patterns show relatively larger cross-polarization radiation than yz-plane. This behavior is largely due to the strong horizontal components of the surface current and electric field, which leads to a significant increase of the cross-polarization radiation.

4. CONCLUSION

A novel UWB aperture antenna with mushroom-shaped tuning stub is implemented. The antenna has compact aperture area of $22 \times 13\,\mathrm{mm}^2$, that is, the dimension is less than a quarter-wavelength for the lowest frequency (3.1 GHz). Its geometry has simple structure and less parameters, whose effects on impedance match are analyzed. The fabricated UWB antenna features omni-directional radiation pattern and stable radiation pattern. The antenna has only one layer of substrate with single-sided metallization, which makes the manufacturing of the antenna very easy and extremely low cost. In short, the proposed antenna is very useful for UWB system.

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