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A MINIATURE UWB SEMI-CIRCLE MONOPOLE PRINTED ANTENNA

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Abstract—A semi-circle monopole printed antenna is proposed. Its radiation unit and the ground plane are in the same shape, and both of them are coplanar-printed. The antenna is fed by a microstrip line, which is connected to the radiation unit through a via-hole. The measured impedance bandwidth is about 3.1 GHz–15.1 GHz with VSWR < 2, and the ratio bandwidth can reach $4.9 : 1$. The omnidirectional characteristic is also excellent in H-plane. Moreover, because of the introduction of the semi-circle radiation unit and the ground plane, the length of the radiation unit can be miniaturized in polarization direction, which is only 14% of wavelength of the lowest operating frequency. The antenna size is just $29\,\mathrm{mm} \times 29.5\,\mathrm{mm} \times 1.0\,\mathrm{mm}$, which can make it well integrate into UWB communication systems.

1. INTRODUCTION

The ultra wideband (UWB) technology has been widely applied to various communication systems, and many countries have put forward their own UWB technology standard. For example, the sanction of civil UWB in 3.1–10.6 GHz, formulated by U.S. Federal Communications Commission (FCC), has been widely applied, and nowadays most UWB antennas are designed for this bandwidth. Many researchers also proposed a number of antenna structures, including wafer monopole

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antenna [1], various polygonal monopole antennas [2–4] and wide-slot antennas [5, 6]. Some antenna techniques, such as impedance-transformation technique and coupling technique, have been used to broaden antenna bandwidth. In addition, the feeding methods of UWB antenna are chiefly based on the printed transmission-line feeding technique, including the coplanar waveguide (CPW) feeding [7], microstrip line feeding [8] and strip-line feeding [9]. However, the CPW feeding technique usually requires wide feeding lines and narrow-spacing between the strips, which would make the antenna hard to realize its precise manufacture and impedance matching. Moreover, currently microstrip line feeding technique would make monopole antenna's ground plane and radiation unit separately print on two sides of the dielectric substrate, which would also impact the antenna radiation characteristics. What's more, the strip-line feeding technique is more complex in the practical design and hard to debug.

A semi-circle monopole printed antenna fed by microstrip line is proposed in this paper. The radiation unit and the ground plane are in the same semi-circle shape, and both of them are printed on the same side of the dielectric substrate. The microstrip line is connected to the radiation unit through a via-hole. Therefore, adjusting the via-hole's parameters can make antenna bandwidth improvement possible. Furthermore, the feeding line would not affect the feeding slot between the radiation unit and the ground plane, which renders the impedance matching more easily in wideband. Design of the proposed antenna, as well as the simulated and experimental results, would be presented in the following sections.

2. ANTENNA DESIGN

The sketch of the proposed antenna with associated geometrical parameters is presented in Fig. 1. This monopole is printed on a 29.5 mm × 29 mm FR-4 substrate with 0.1 mm thickness and relative permittivity $\varepsilon_r = 4.4$. Both the radiation unit and the ground plane are semi-circle shape with radius of 14 mm and printed on the front-side of the substrate. Centers of the two semi-circles are collinear, and the minimum distance between them is 0.5 mm. The microstrip line is printed on the substrate's back-side which is connected to the radiation unit through a 0.5 mm diameter via-hole. This design is adopted to ensure the currents, flowing around the shorter distance between the two semi-circles, can be equi-amplitude and reverse-phase. The antenna model has been simulated by CST MICROWAVE STUDIO®, and effects of structural parameters on antenna performance are shown in the next section.

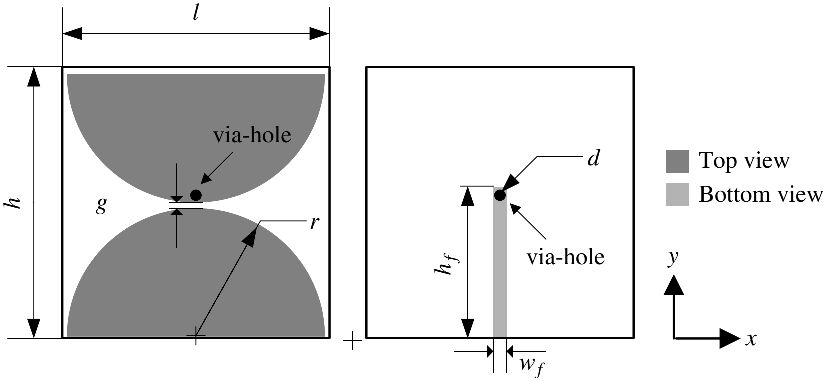


Figure 1. The sketch of the proposed antenna with associated geometrical parameters. $h = 29.5\,\text{mm}$, $l = 29\,\text{mm}$, $g = 0.5\,\text{mm}$, $r = 14\,\text{mm}$, $d = 0.5\,\text{mm}$, $h_f = 16.5\,\text{mm}$, $w_f = 1.5\,\text{mm}$.

3. EFFECTS OF THE STRUCTURAL PARAMETERS ON ANTENNA PERFORMANCE

The distance between the two semi-circles is denoted by g in Fig. 1, which mainly affects antenna bandwidth by influencing the impedance characteristic. Fig. 2 presents the simulated results of $|S_{11}|$ when g takes 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm, respectively. When g decreases, magnitudes of $|S_{11}|$ in high frequency band also decrease, and the higher the frequency is, the more obviously decreasing trend of $|S_{11}|$ is. Moreover, from Fig. 2, when $g = 1.5\,\text{mm}$, the proposed antenna has lost its broadband characteristic. Therefore, the distance between the radiation unit and the ground should be controlled within 1.5 mm. $|S_{11}|$ will reduce with the decrease of g during 3.1–6.0 GHz, and the antenna impedance remains stable with $|S_{11}|$ less than $-10\,\text{dB}$ when g takes 0.5 mm.

In addition, the width of the feeding line, w_f, can control the feeding line's characteristic impedance. In order to reach a satisfying matching, it is required to adjust w_f to make characteristic impedance equal to the input impedance. It can be proved that when the values of ε_r and substrate's thickness are confirmed, the feeding line's characteristic impedance will decline if w_f increases. In this paper, when w_f takes 1.5 mm, the characteristic impedance of the microstrip line is about $60\,\Omega$.

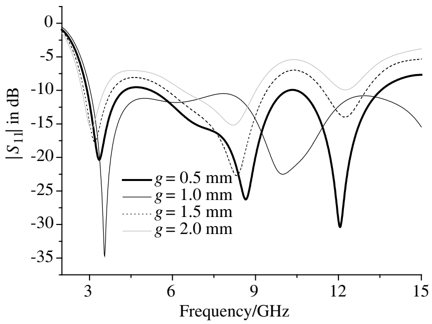


Figure 2. The simulated results of $|S_{11}|$ with varying g.

Figure 3. Prototype of the proposed antenna.

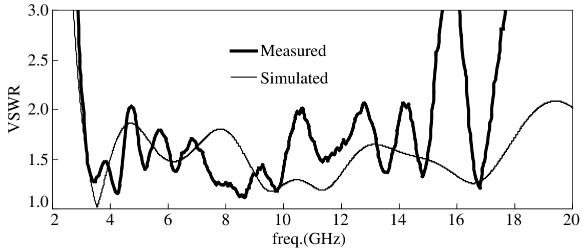
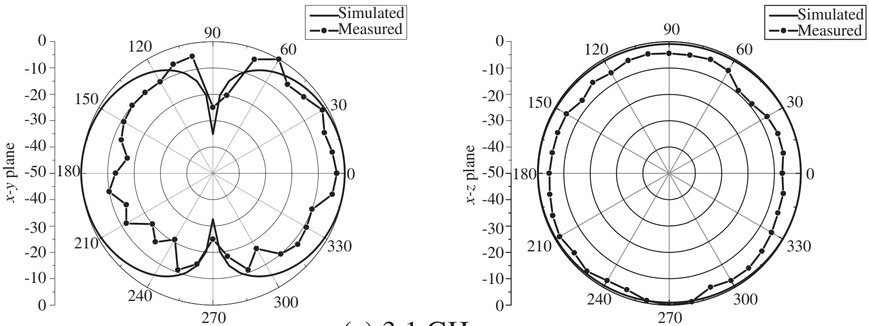


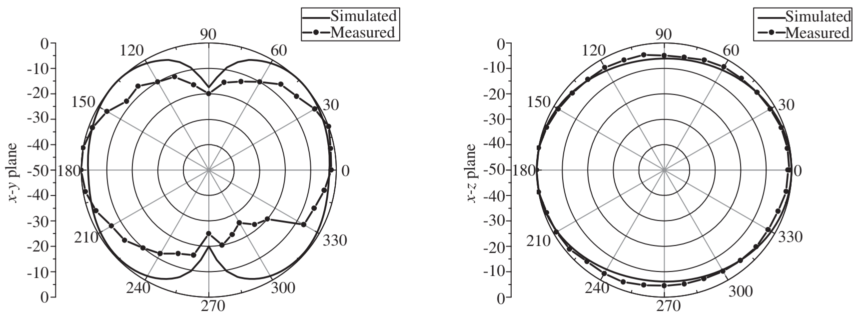
Figure 4. The simulated and measured results of antenna VSWR.

4. RESULTS OF SIMULATION AND EXPERIMENT

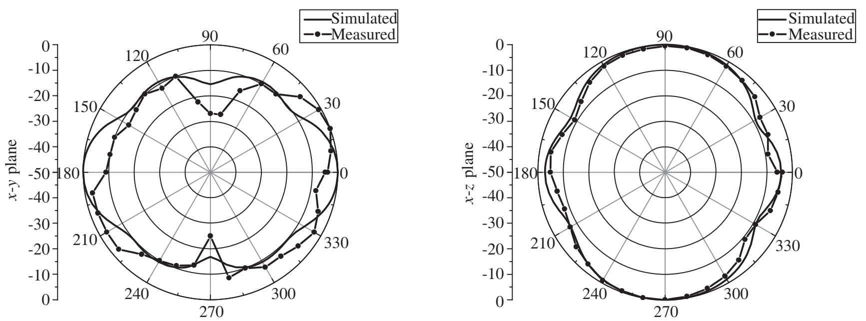
According to the discussion above, the final optimum antenna has been obtained by simulation, and its prototype has been manufactured (Fig. 3). Antenna's voltage standing wave ratio (VSWR) is measured by Agilent E8363B vector network analyzer, and the experimental results, as well as the simulated, are presented in Fig. 4. The measured impedance bandwidth is from 3.1 GHz to 15.1 GHz with VSWR < 2.0, which well matches the simulated, and the band can also satisfy the requirements of short-range UWB wireless communications. The antenna radiation patterns are measured using the revolving-antenna method in the anechoic chamber. Both the patterns' measured and simulated results at 3.1 GHz, 6.85 GHz and 10.6 GHz, respectively, are presented in Fig. 5. The results indicate that the proposed antenna can achieve satisfying omnidirectional radiation in H-plane.



(a) 3.1 GHz



(b) 6.85 GHz



(c) 10.6 GHz

Figure 5. The simulated and measured results of antenna patterns.

5. CONCLUSION

A UWB semi-circle monopole printed antenna is proposed, and the effects of different parameters on antenna performance have been discussed and analyzed in detail. The design of the via-hole and the semi-circle ground plane can effectively solve the problem that the introduction of wide feeding-line would destruct antenna impedance bandwidth. The proposed antenna can achieve impedance bandwidth from 3.1 GHz to 15.1 GHz with VSWR < 2.0, which can cover the S/C/X/Ku bands, and the radiation pattern in H-plane has fine omnidirectional characteristic. This antenna is printed on the FR-4 substrate, and the total dimension is just $29.5\,\text{mm} \times 29\,\text{mm} \times 1.0\,\text{mm}$. Its compact size can make it easily integrate with the communication systems. Finally, all the proposed antenna's main performance can meet the requirements of UWB application, which can be used in UWB short-range communications.

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