Printed circular disc monopole antenna for ultra-wideband applications

J. Liang, C.C. Chiau, X. Chen and C.G. Parini

A novel and simple design of a printed circular disc monopole antenna for ultra-wideband applications is presented. The parameters which affect the performance of the antenna are investigated. Good agreement is achieved between simulation and experiment.

Introduction: With the definition and acceptance of ultra-wideband (UWB) impulse radio technology in the USA [1], there is increasing demand for antennas capable of operating at an extremely wide frequency range. In recent years, several broadband monopole configurations, such as circular, square, elliptical, pentagonal and hexagonal, have been proposed for UWB applications [2–5]. These broadband monopoles feature wide operating bandwidths, satisfactory radiation properties, simple structures and ease of fabrication. However, they are not planar structures because their ground planes are perpendicular to the radiators. As a result, they are not suitable for integration with printed circuit boards. This drawback limits practical applications of these broadband monopoles.

In this Letter, a novel design of a printed circular disc monopole fed by a microstrip line is proposed based on our previous studies [6]. The parameters which affect the operation of the antenna are analysed both numerically and experimentally. It has been demonstrated that the optimal design of this type of antenna can yield an ultra-wide bandwidth with satisfactory radiation properties over the entire bandwidth.

Antenna design: The proposed monopole antenna is illustrated in Fig. 1. A circular disc monopole with a radius of $R = 10$ mm and a 50 Ω microstrip feed line are printed on the same side of the dielectric substrate (in this study, the FR4 substrate of thickness 1.5 mm and relative permittivity 4.7 was used). L and W denote the length and the width of the dielectric substrate, respectively. L is constant at 50 mm in this study. The width of the microstrip feed line is fixed at $W_1 =$ 2.6 mm to achieve 50 Ω impedance. On the other side of the substrate, the conducting ground plane with a length of $L_1 = 20$ mm only covers the section of the microstrip feed line. h is the height of the feed gap between the feed point and the ground plane.

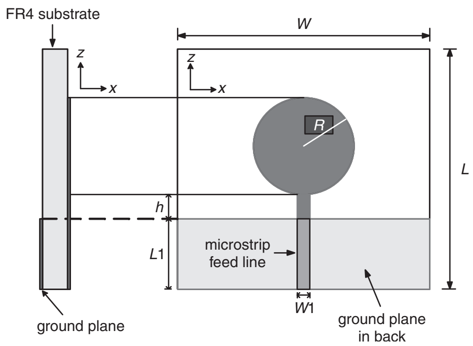

Fig. 1 *Geometry of proposed printed circular disc monopole*

Results and discussion: The simulations are performed using the CST Microwave Studio^{TM} package which utilises the finite integration technique for electromagnetic computation [7]. It has been shown in the simulation that the operating bandwidth of the proposed monopole antenna is critically dependent on the feed gap h and the width of the ground plane W, and these two parameters should be optimised for maximum bandwidth.

Fig. 2 illustrates the simulated return loss curves with different feed gaps ($h = 0$, 0.3, 0.7, and 1.5 mm) when W is fixed at 42 mm. It is observed in Fig. 2 that the −10 dB bandwidth changes significantly with varying feed gap h. This is due to the sensitivity of the impedance matching to the feed gap. The ground plane, serving as an impedance matching circuit, tunes the input impedance and the operating bandwidth while the feed gap is varied [6]. The optimised feed gap is found to be at $h = 0.3$ mm.

The simulated return loss curves with optimal feed gap h of 0.3 mm and different widths W of the ground planes, are plotted in Fig. 3. It can be seen that the performance of the antenna is heavily dependent on the width W because the current is mainly distributed and transmitted on the upper edge of the ground plane along the y-direction. Simulation shows that the ground plane with a width of $W = 42$ mm can achieve the maximum bandwidth.

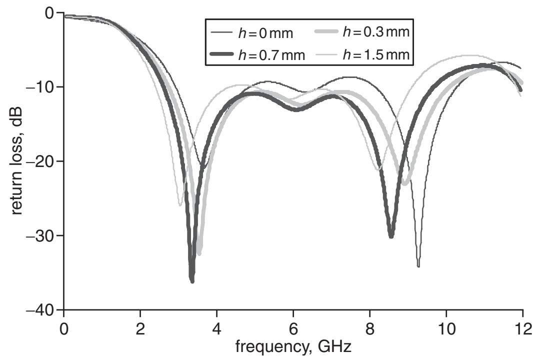

Fig. 2 *Simulated return loss for different feed gaps with W = 42 mm*

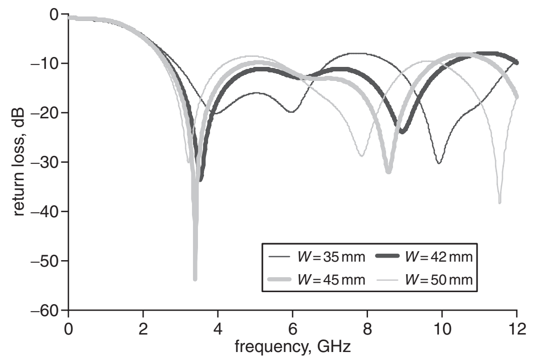

Fig. 3 *Simulated return loss for different width of ground plane with h = 0.3 mm*

The prototype of the printed circular disc monopole antenna with optimal design, i.e. $h = 0.3$ mm and $W = 42$ mm, as shown in Fig. 1, was tested in the laboratory at Queen Mary, University of London (QMUL). The return losses were measured using an HP 8720ES network analyser and the radiation pattern measurements were carried out inside an anechoic chamber.

Fig. 4 shows the simulated and measured return loss curves. The measured return loss agrees well with the simulation. The measured operating bandwidth of −10 dB is from 2.78 to 9.78 GHz, and in simulation from 2.69 to 10.16 GHz. The measurement confirms the UWB characteristic of the proposed printed circular disc monopole, as predicted in the simulation.

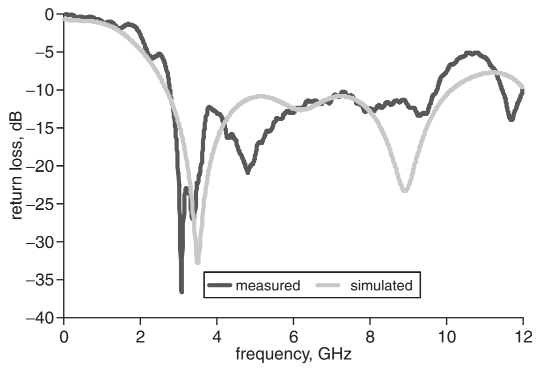

Fig. 4 *Simulated and measured return loss curves with W = 42 mm and h = 0.3 mm*

The measured and simulated radiation patterns at 3 and 9 GHz are plotted in Figs. 5 and 6, respectively. The patterns obtained in the measurement are close to those in the simulation. It can be seen that the proposed antenna is omnidirectional over the entire operating bandwidth.

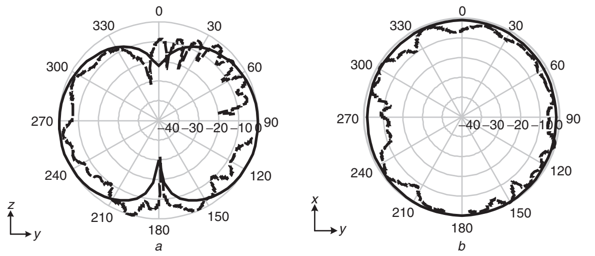

Fig. 5 *Simulated and measured radiation patterns with W = 42 mm and h = 0.3 mm at 3 GHz*

a E-plane *b H*-plane —— simulated ------- measured

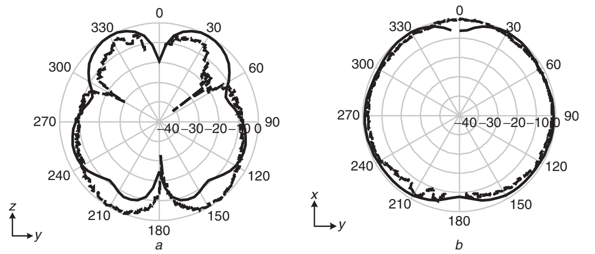

Fig. 6 *Simulated and measured radiation patterns with W = 42 mm and h = 0.3 mm at 9 GHz*

a E-plane *b H*-plane —— simulated ------- measured

Conclusion: A printed circular disc monopole antenna fed by microstrip line is proposed and investigated. It has been shown that the operating bandwidth of the antenna is heavily dependent on the feed gap due to the impedance matching. The width of the ground plane also plays an important role in determining the performance of the antenna because the current is mainly distributed along the *y*-direction on the ground plane. It has been demonstrated numerically and experimentally that the proposed printed circular disc monopole can yield an ultra-wide bandwidth, from 2.78 to 9.78 GHz, covering the frequency bands of most commercial wireless systems. It is also observed that the radiation patterns are similar to those of a traditional monopole. The results show this antenna is a good candidate for future UWB applications.

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