

STUDY OF A CIRCULAR DISC MONOPOLE ANTENNA FOR ULTRA WIDEBAND APPLICATIONS

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1. Introduction

Recently, there have been considerable research efforts being put into Ultra Wide Band (UWB) radio technology worldwide [1]. However, the non-digital part of a UWB system, i.e. transmitting/receiving antennas, remains as a particular challenging topic. The conventional UWB antennas in the 'non-resonant' type of geometry of either log periodic or spiral tend to be dispersive. They usually radiate different frequency components from different parts of the antenna, which distorts and stretches out the radiated waveform [2]. Besides, they are usually big in size and expensive to manufacture. There are great demands for small and low cost UWB antennas that are capable of covering the UWB spectrum with a reasonable performance. Previous studies have indicated that a wide band antenna can be realized by replacing the wire element of a conventional monopole with a planar element in the shape of square, disc and others [3-5]. It will be interesting to learn how this resonant type of antenna exhibits a wide band performance.

In this paper, a circular disc monopole is studied both numerically and experimentally with an emphasis on the understanding of its operation. Both simulation and measurement show that an optimal design of this type of antenna can provide a return loss in excess of -10dB over an extremely wide frequency range from 1.39GHz to greater than 10GHz.

2. Antenna design

The disc monopole antenna studied in this paper is illustrated in Figure 1. A circular copper disc with a radius of $R=25\text{mm}$ and a thickness of 0.4mm is selected as the radiator and mounted vertically above a 150mm square copper ground plane with a feed gap of h . The disc is excited by a 50Ω coaxial probe from the bottom through an SMA connector.

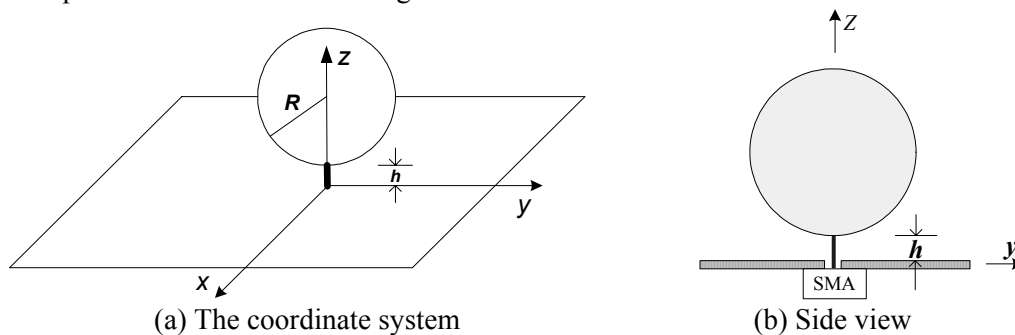


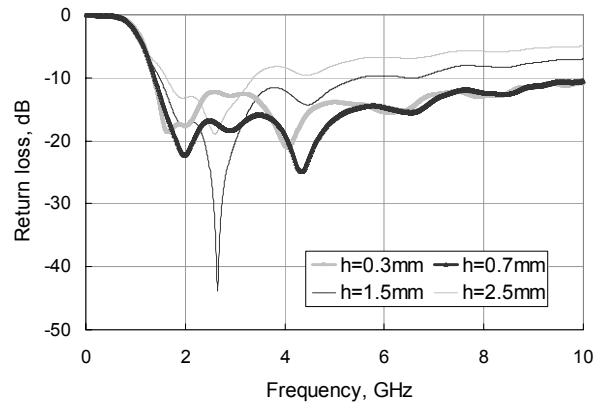
Figure 1. The geometry of the circular disc monopole

3. Numerical and experimental studies

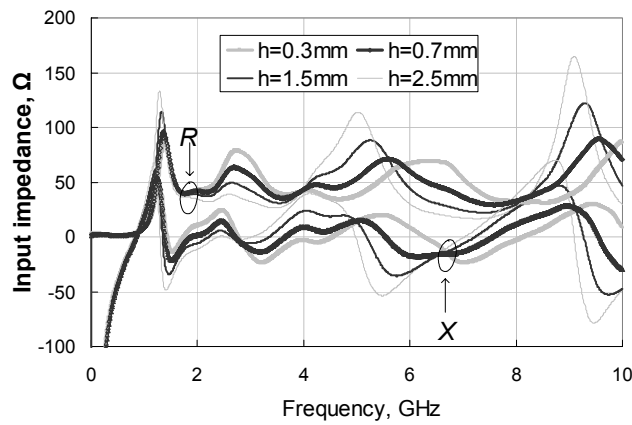
The simulations are performed by using a well-known package, CST Microwave StudioTM, which utilizes the Finite Integration Technique for electromagnetic computation [6]. The package is used to simulate the complete configuration of the antenna, including a 50Ω coaxial feeding port, and to investigate the characteristics of the antenna with different feed gaps.

It is observed that the performance of the disc monopole is critically dependent on the feed gap h . Figure 2 (a) illustrates the simulated return loss curves when $h=0.3, 0.7, 1.5,$ and 2.5mm , respectively; their corresponding input impedance curves are plotted in Figure 2 (b). It can be seen in Figure 2(a) that the antenna bandwidth (10dB) varies substantially with the feed gap and the optimal feed gap is around 0.7mm . The 10dB bandwidth spans from 1.39GHz to more than 10GHz when

$h=0.7\text{mm}$. Next, these results will be examined more closely in order to gain the insight into the operation of the antenna.



(a) Return loss



(b) Input impedance

Figure 2. Simulated return loss and input impedance for different feed gaps

As shown in Figure 2, the low return loss ($<-10\text{dB}$) always happens over the frequency range where the input resistance R is not far from to $50\ \Omega$ while the input reactance X is small for the four different feed gaps. When $h=0.7\text{mm}$, R fluctuates flatly at the level of $50\ \Omega$ while X remains small across an extremely wide frequency range, leading to an UWB characteristic. When $h=0.3\text{mm}$, the disc monopole also exhibits an UWB characteristic as the trend of the R and X curves is similar to that of $h=0.7\text{mm}$, except R rises slightly higher at the frequency around 3GHz , resulting in a higher return loss. However, when $h=1.5\text{mm}$, R rises to higher peaks ($>100\ \Omega$) and X fluctuates more widely (no longer small) towards higher frequencies ($>6\text{GHz}$), leading to a high return loss ($>-10\text{dB}$), i.e. a bad impedance matching. When $h=2.5\text{mm}$, the impedance mismatching starts at even lower frequency ($\sim 3\text{GHz}$), thus resulting in a narrow bandwidth. So the critical effect of the feed gap on the bandwidth can be well explained by examining the impedance matching of the antenna.

Furthermore, it is noticed that the resonances (peaks) of the input impedance in Figure 2 (b) correspond to various resonant modes of a circular disc, being detuned by the ground plane at different gaps. It is not surprising to observe that the minimum return loss (resonance) happens at the frequency where the resonant resistance (R peak) is close to $50\ \Omega$. For example, when $h=1.5\text{mm}$, the value of an R peak is $49.4\ \Omega$ at the frequency 2.67GHz , leading to a resonance with return loss as small as -43.9dB ; but the value of the first R peak is $114.3\ \Omega$ at the frequency 1.33GHz , resulting in a mismatch with a return loss of -7.8dB . However, when $h=0.3\text{mm}$, the first R peak lowers to a value of $83.1\ \Omega$ at the frequency 1.41GHz , resulting in a resonance with a return loss of -11.4dB . When $h=0.7\text{mm}$, the main resonance happens at 4.33GHz , where R peaks at a value of $47.2\ \Omega$.

Figure 2 (a) shows that one resonance occurs around 1.96GHz for all the four feed gaps, which corresponds to a small hump just below $50\ \Omega$ on each of the input resistance curves in Figure 2

(b). Actually, the wavelength of 153.1mm at this resonance (1.96GHz) is very close to the disc perimeter of 157.1mm. This suggests that this resonance is mostly determined by the disc perimeter, not much detuned by the ground plane. It can be seen that the lower end of the antenna bandwidth is mainly influenced by this resonance, except for the smaller feed gap ($h=0.3\text{mm}$) where it is related to the resonance of the first R peak.

The simulated current distributions at different frequencies for the optimal feeding gap ($h=0.7\text{mm}$) are presented in Figures 3 (a)–(c). Figure 3 (a) shows the current pattern for the first resonance at 1.96GHz. Figure 3 (b) shows the current pattern near the main resonance at 4.25GHz, indicating approximately a second order harmonic. Figures 3 (c) shows a more complicated current pattern at 10GHz, corresponding to an even higher order harmonic.

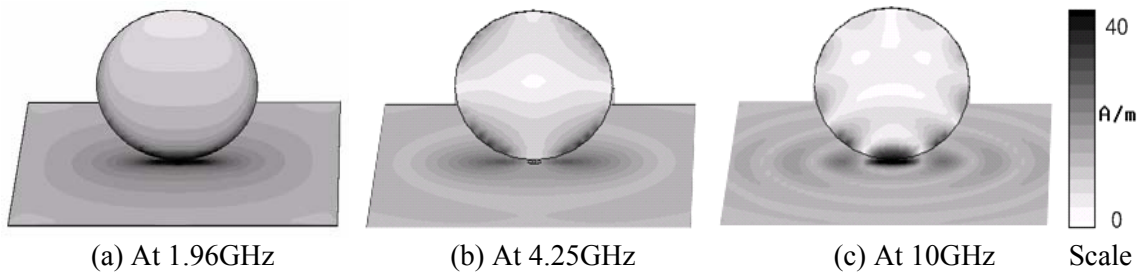


Figure 3. Current distributions ($h=0.7\text{mm}$)

As shown in Figure 1, the prototype of the circular disc monopole antenna with the optimal feed gap of $h=0.7\text{mm}$ and a 150mm square ground plane is built in the antenna laboratory at Queen Mary, University of London (QMUL). The return loss is measured by using a HP 8720ES network analyser and the measurements on radiation patterns are carried out inside an anechoic chamber.

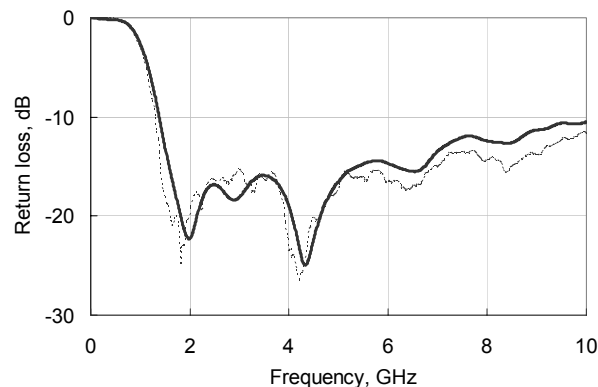


Figure 4. The simulated (solid line) and measured (dotted line) return loss ($h=0.7\text{mm}$)

As shown in Figure 4, the measured return loss curve agrees very well with the simulated one with differences less than 3dB, while the measured resonance frequencies are very close to the simulated ones with differences less than 5%. This confirms the UWB characteristic of the antenna, as predicted in the simulation.

The measured and simulated radiation patterns also agree very well at 2.05, 4.25 and 10GHz, as shown in Figure 5 (a)–(f), respectively. The vertical patterns have big back lobes at lower frequencies as the ground plane is finite (150mm square). With the increase of the frequency, the back lobes become smaller, splitting into many minor ones, while the front lobes start to form notches. This corresponds well to the current patterns in Figure 3. The horizontal patterns are omni-directional at lower frequencies and are only distorted slightly at higher frequencies (being pinched in less than 8dB in the x direction at 10GHz). The radiation patterns are generally omni-directional over the entire bandwidth.

4. Conclusions

This paper has provided a further insight into the operation of a circular disc monopole. It has shown that the feed gap affects critically the impedance matching of the antenna, hence its operating

bandwidth. The first resonant frequency, which influences the lower end of the bandwidth, is mostly determined by the perimeter of the disc. Both simulation and measurement have shown that an optimal design of the antenna can yield an extremely wide bandwidth from 1.39GHz to greater than 10GHz, covering the frequency bands of most commercial wireless systems. They have also demonstrated that the radiation patterns are generally omni-directional, like a traditional monopole, over the entire bandwidth. These features make this type of antenna very attractive to UWB applications.

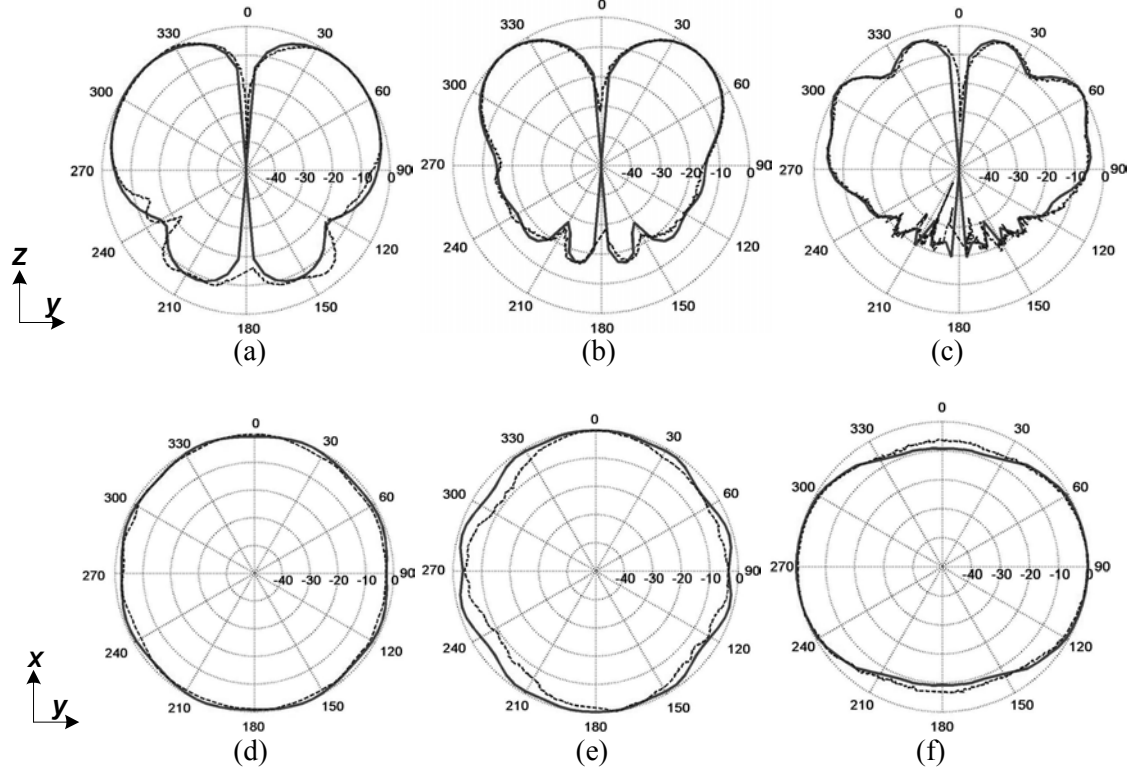


Figure 5. The simulated (solid line) and measured (dotted line) radiation patterns ($h=0.7\text{mm}$)
 (a) y - z plane at 2.05GHz (b) y - z plane at 4.25GHz (c) y - z plane at 10GHz
 (d) x - y plane at 2.05GHz (e) x - y plane at 4.25GHz (f) x - y plane at 10GHz

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