A Novel Ultra-Wideband Printed Monopole Antenna

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Abstract

In this paper, we introduce a novel printed monopole antenna for ultra-wideband (UWB) applications. The antenna is composed of two overlapped circular disc monopoles with a finite ground plane and fed by a $50\,\Omega$ microstrip line. The designed antenna operates over impedance bandwidth (2.9 to 11.6GHz) for return loss S_{11} < -10dB. The antenna also shows omni-directional radiation patterns and good gain flatness over the frequency range of interest. The antenna group delay variation is less than 1ns and the time-domain pulse distortion is small which indicates that the proposed antenna performance is suitable for UWB applications

1. Introduction

In the last few years, UWB technology has attracted a great interest for use in the industry and academia especially since Federal Communication Commission (FCC) allowed using the (3.1-10.6GHz) band for commercial applications [1]. The Antenna is one of the important components in UWB systems and it affects their overall performance. Recently, many kinds of UWB antennas have been introduced [2-5]. It is of a particular interest to design an antenna with simple structure, low profile, easy manufacturing, and low cost. Moreover the UWB antenna should have good impedance matching characteristics over the whole UWB frequency range. Also, it should have a flat gain, linear phase and constant group delay to minimize distortion of transmitted pulses waveforms. All these properties can be achieved in printed circular disc monopole antennas [2, 3].

In this paper, a novel printed monopole antenna with wide bandwidth capability for UWB applications is proposed. The antenna consists of two overlapped printed circular discs fed by a microstrip feed line with partial ground plane. In this design, the proposed antenna can operate from 2.9 to 11.6 GHz and shows good radiation pattern performance. This paper is organized as follows. Section 2 presents the configuration of proposed antenna. The simulated and measured results are presented and discussed in section 3. Finally, the conclusions of this work are given in Section 4.

2. Antenna Configuration

The proposed antenna structure consists of a two overlapped circular discs fed by a microstrip line. Figure 1 shows the proposed UWB printed monopole antenna topology, which has maximum dimensions of $50\text{mm} \times 41\text{mm} \times 1.575\text{mm}$ ($W \times L \times H$). The radiating element consists of a main circular disc of radius r and another overlapped circular disc. The overlapped circular disc of radius r is located at a distance $(\Delta x, \Delta y) = (3.5, 3)$ mm from the origin which is the center of the main circular disc. The antenna is fabricated on Rogers RT-5880 substrate of thickness of H =1.575mm and relative permittivity of ε_r =2.2. The feeding structure is a $50\,\Omega$ microstrip feed line with width W_{feed} =3.4mm and they are printed together on the same side of the dielectric substrate. The perfect conducting partial ground plane which exists on the other side of the substrate covers only a section of the microstrip feed line. The ground plane is designed to be finite for matching purpose and to obtain an UWB bandwidth. The ground plane has an area of $W \times L_G$ = (41mm $\times$ 18mm). The feed gap which is the separation distance between the feed point and the ground plane is d =1mm.

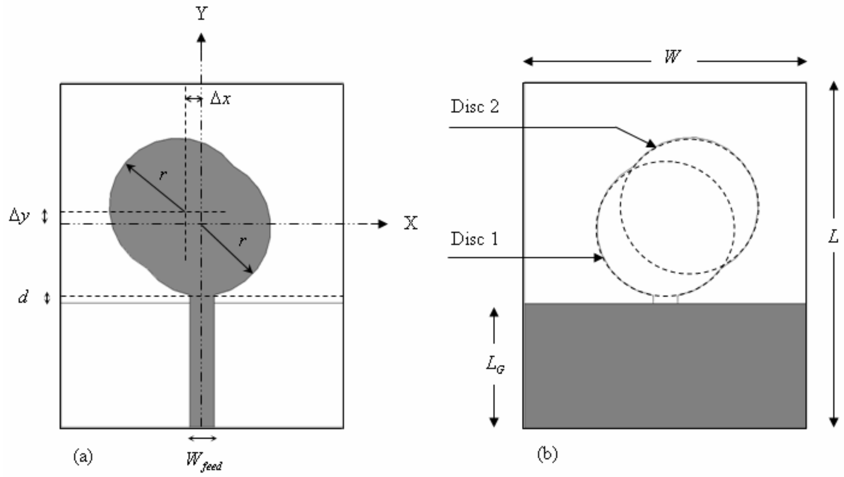

Figure 1 Structure of the proposed antenna design (a) front view (b) back view.

3. Results

Simulations have been carried out with the Ansoft High Frequency Structure Simulator (HFSS) software [6] and CST Microwave Studio [7] to determine the antenna return loss bandwidth, input impedance, radiation patterns, gain, group delay, and transmitted pulses waveform distortion.

3.1 Impedance Bandwidth

Figure 2 shows the variation of the measured and simulated return loss of the proposed antenna with frequency. It shows that measured impedance bandwidth is 8.7GHz starting from 2.9 to 11.6GHz for 10dB return loss. Simulation results show that the impedance bandwidth is about 9.15GHz starting from 2GHz to 11.15GHz. The simulation result by Ansoft HFSS is closer to the measurement and it confirms the UWB characteristic for the antenna. The input impedance as a function of the frequency for the proposed monopole antenna is plotted in Fig. 3. It is clearly shown that the return loss < -10dB occurs over the frequency range when the input impedance is matched to 50 Ω . This means that the input resistance R is close to 50 Ω while the input reactance X is zero for the proposed antenna.

3.2 Radiation Patterns

The simulated radiation patterns of the proposed printed monopole antenna at 3 GHz, 6.7GHz, 10GHz and 11.2GHz along both X-Z plane (H-plane) and Y-Z plane (E-plane) are illustrated in Fig. 4 and 5, respectively. The results show that the radiation pattern is quite stable as the frequency changes with a nearly omni-directional radiation patterns in the H-plane and the monopole-like radiation patterns in the E-plane.

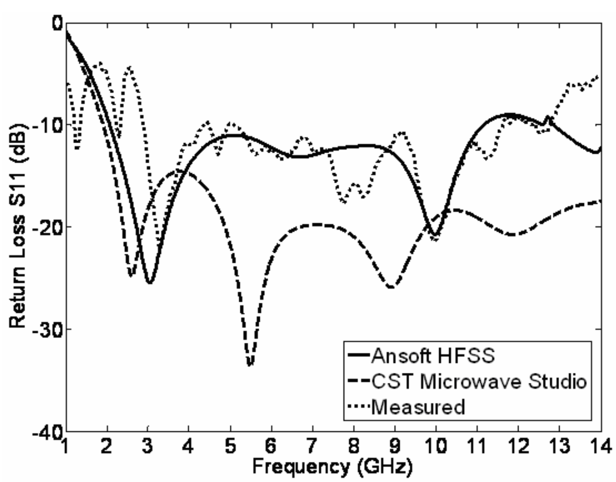

Figure 2 Measured and simulated antenna return loss.

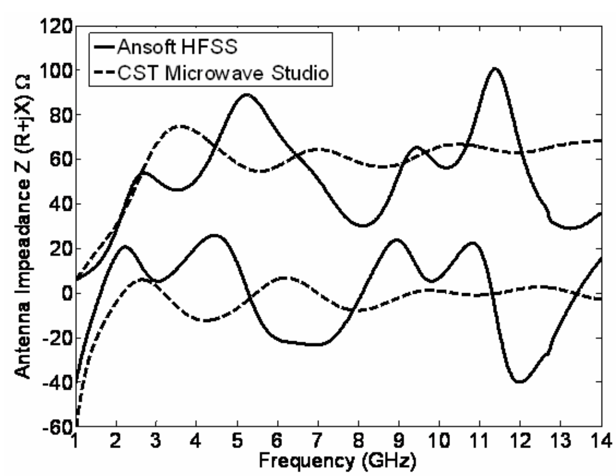

Figure 3 Simulated antenna input impedance curves.

3.3 Simulated Gain

The gain of the proposed antenna in the boresight direction is also studied using Ansoft HFSS and presented in Fig. 6. The antenna gain varies from 3.6 dB to 5.9 dB over the operating UWB frequency range. It can be concluded that the gain variation is less than 2.5 dB over the entire operating frequency range from 3 to 11 GHz.

3.4 Group Delay Characteristics

In UWB system, linear phase response of the radiated field as well as stable group delay response is desirable for not distorting the shape of the transmitted electrical pulse. The simulated antenna group delay over frequency from 1 to 14GHz is presented in Fig. 7. From the HFSS simulation, the variation of the group delay is less than 500 ps (0.5 ns) while the calculated maximum group delay is about 3 ns. Therefore, the antenna group delay is approximately constant within the frequency band of interest.

3.5 Time Domain Characteristics

UWB systems typically transmit very short duration pulses, unlike the traditional communication schemes, which use continuous sinusoidal waves [8]. To examine time-domain performance of the antenna, Gaussian pulses are selected to be the source waveforms and applied to the proposed antenna. The time domain characteristics of the proposed antenna are

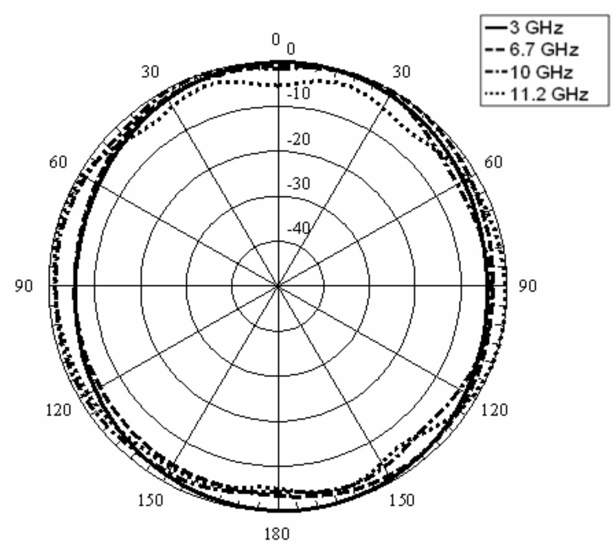

Figure 4 Simulated radiation patterns for the proposed antenna on XZ-plane (H-plane).

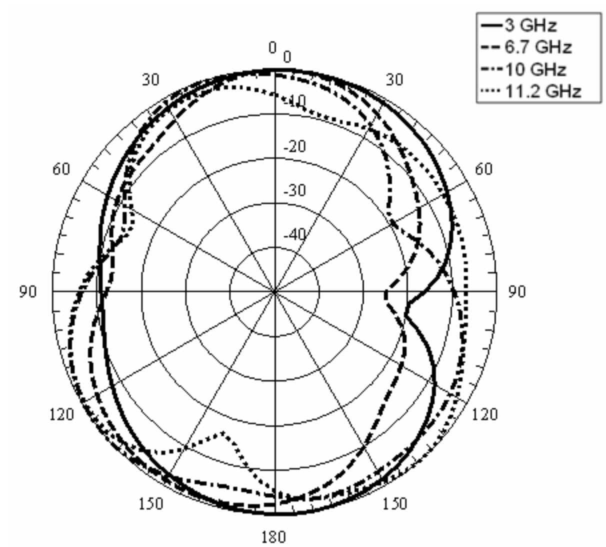

Figure 5 Simulated radiation patterns for the proposed antenna on YZ-plane (E-plane).

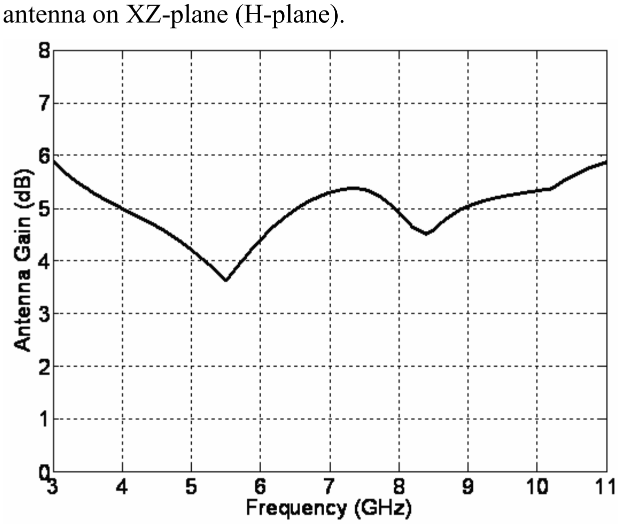

Figure 6 Simulated antenna gains.

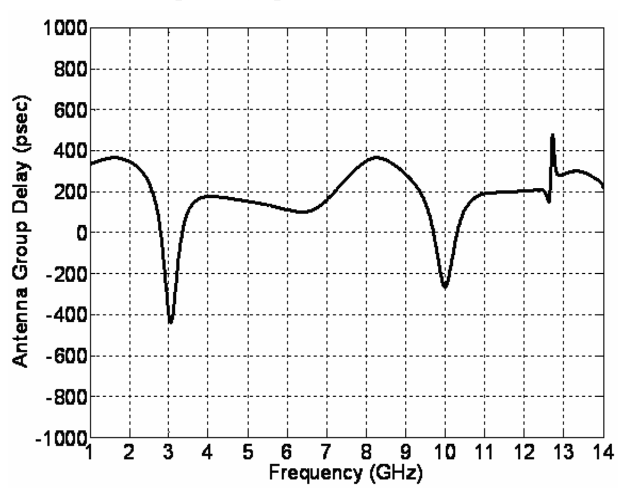

Figure 7 Simulated antenna group delay.

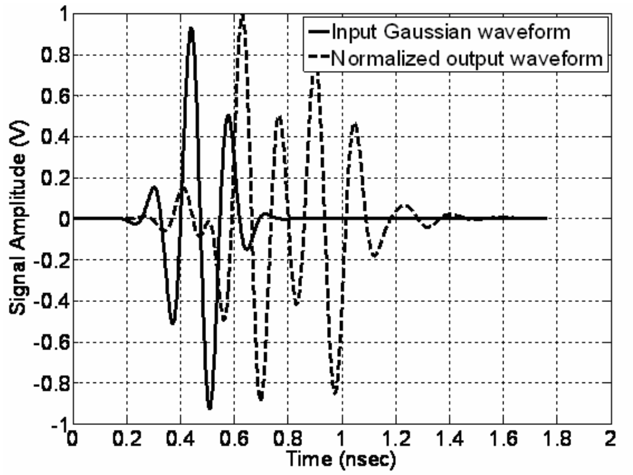

Figure 8 Simulated time domain analysis: input and output pulse waveforms.

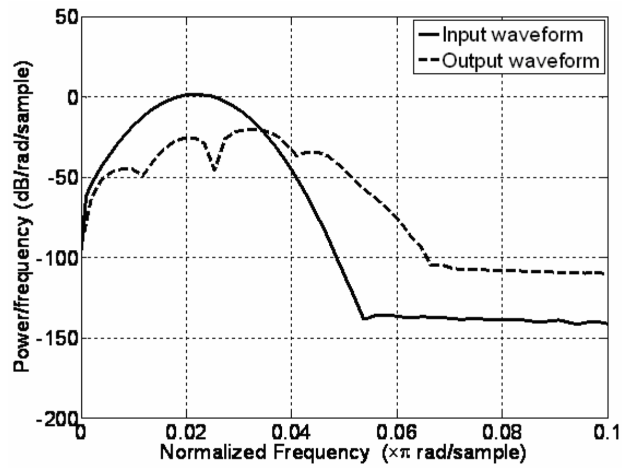

Figure 9 The simulated PSD of input and output pulse waveforms for the proposed antenna.

studied using CST Microwave Studio and presented in Fig. 8. The corresponding Power Spectral Density (PSD) of the input Gaussian waveform and the output waveform are plotted in Fig. 9. It can be concluded that there is a small acceptable pulse distortion and these characteristics indicate that the proposed antenna is suitable for UWB impulse radio communication.

4. Conclusion

In this paper, we presented a novel monopole antenna for UWB applications. The antenna return loss bandwidth is from 2.9 to 11.6GHz covering the whole UWB frequency band. The proposed antenna satisfied the bandwidth required for UWB applications. The simulated radiation patterns show good monopole-like patterns and the gain variation is less than 2.5 dB over the frequency band. Good linear phase response, constant group delay characteristics and small pulse distortion in time-domain were observed.

5. References

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