Coplanar Waveguide-Fed Dual Exponentially Tapered Slot Antennas for Ultra-Wideband Applications

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A uniplanar coplanar waveguide-fed dual exponentially tapered slot antenna is proposed, using a lumped-element impedance-transforming coplanar waveguide-to-slotline transition as the antenna feeding structure. The proposed antenna features a compact size, wide impedance bandwidth, and consistent radiation patterns over the low-band of ultra-wideband (UWB) spectrum. In this work, the characteristics of proposed antenna both in frequency and time domains are carefully investigated. It is demonstrated that minimum distortion to the UWB input pulse can be expected.

I. Introduction

Ultra wideband (UWB) technology becomes the possible solution for short-range, low-power indoor data communication applications. It offers simultaneously high data rate communication and high accuracy positioning capabilities. One of the major challenges for UWB system is the antenna design, due to the wide operation bandwidth required. The antennas for UWB system require quite different design considerations and analyses from those for narrowband systems. Moreover, due to the pulse mode operation of UWB system, the UWB antennas need to be analyzed not only in frequency domain but also in time domain [1]. The analyses in time domain reveal the characteristics of the antenna when implemented in the UWB systems directly. Some previous works on UWB antenna designs may be found in the literature [2]-[3].

In 2002, the Federal Communication Commission (FCC) defines a radio system to be an UWB one if the fractional bandwidth of the signal is greater than 20% or 500 MHz on a –10dB level [4]. This leads to a new method of utilizing the UWB spectrum. It is based on using multiple bands with relatively narrower bandwidth to efficiently utilize the UWB spectrum, and transmits trains of UWB signals at different carrier frequencies. This may ease the design of RF front-end as well as the antenna [5].

In this work, a coplanar waveguide (CPW)-fed dual exponentially tapered slot antenna (DETSA) is proposed. Here the lumped-element CPW-to-slotline transition [6] is adopted as the antenna feeding structure to achieve a compact size. The antenna features uniplanar structure, wide impedance bandwidth, and consistent radiation patterns over the operation bandwidth. In this study, the antenna performance for applications in the low-band UWB system is also demonstrated.

II. Antenna Structure

Shown in Fig. 1 is the layout of proposed CPW-fed DETSA. Here the DETSA [7] is adopted to achieve a wide operation bandwidth. Although this antenna is often categorized into the traveling wave antenna with end-fire patterns, it is also demonstrated to act as a resonance-type antenna with uniform patterns in lower frequency range providing that the feeding structure is well designed. The tapered profiles of the antenna are described with the exponential functions [8]. The opening rates of the outer and inner boundaries of the tapered profile are equal to 0.15 and 0.25, respectively, for optimal antenna performance. The input slotline width is chosen as 0.3mm, and the corresponding characteristic impedance is around 85 ohm over the band.

For the antenna feeding structure, here the lumped-element impedance-transforming CPW-to-slotline transition [6] is adopted to connect the input CPW line to the DETSA. Specifically, the interdigital structure on the CPW center strip is used to realize a series capacitor, while the shorted slotline stub connected to one slot of CPW may be equivalent to a shunt inductor. The 50-ohm CPW line impedance

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may then be transformed to the higher antenna input impedance through this lumped-element L-section impedance matching circuit. In order to suppress the unwanted odd CPW mode excited at the CPW-slotline junction, bondwires at suitable positions are also included. The required circuit area for this transition is small because it is based on lumped-elements, such that total area of the proposed antenna can be reduced. The required values of the capacitor and inductor for the transition may be determined once the input impedance of the antenna is given. Their corresponding geometrical parameters may then be obtained through the closed-form design equations [6].

III. Results

A CPW-fed dual exponentially tapered slot antenna for Fig. 1 is fabricated on a Rogers 5880 duroid substrate (ε_r=2.2, tanδ = 0.0004, and thickness h = 1.575 mm), with the geometrical parameters specified on the same figure. The measurement is taken with the HP8722 network analyser, and the simulation is done by the Ansoft HFSS. Shown in Fig. 2 are the measured and simulated return losses of the proposed antenna. Good agreement between them is observed. The −10 dB impedance bandwidth is from 2.8 ~ 5.8 GHz, and the overall size of the antenna is 45 mm by 36.7 mm.

The measured radiation patterns at 4 GHz are shown in Fig. 3. The proposed antenna exhibits an almost omni-directional radiation pattern in the H-plane, with a peak antenna gain of 4.7 dBi. In order to examine the performance of proposed antenna when implemented in UWB systems, the wideband antenna transfer function for the antenna under test (AUT) is investigated. In this work, it is evaluated using

$$H_{AUT}(f,\theta,\phi)=\left(\left|S_{21AUT}(f,\theta,\phi)\right|-\left|S_{21STD}(f)\right|+Gain_{STD}(f)\right)_{in\ dBi}\left(\angle S_{21AUT}(f,\theta,\phi)-\angle S_{21STD}(f)\right) \quad (1)$$

where $S_{21_{AUT}}(f,\ \theta,\ \phi)$ is the measured frequency response of the proposed antenna at angle (θ, ϕ), and $S_{21_{STD}}(f)$ is that of a standard antenna with specific gain $Gain_{STD}(f)$. As shown in Fig. 4, the variations of antenna transfer functions for various directions in H-plane are small across the operation bandwidth. The phase response of the antenna transfer function at the boresight direction, i.e. θ = 90°, ϕ = 0°, is depicted in Fig. 5 as well, and linear phase response is demonstrated.

The performance of UWB system can be degraded easily by pulse waveform distortion. To examine the level of distortion introduced by the antenna, the proposed antenna is test with an assumed input pulse

$$\mathrm{Input}(t)=Ae^{-t^2/2\sigma^2}\cos(2\pi ft) \quad (2)$$

where σ = 1 ns and A is a normalized constant. Fig. 6(a) depicts the waveform of the input pulse and the corresponding spectrum normalized to the FCC indoor emission mask is shown in Fig. 6(b). The spectrum of the input pulse, Input(f), is then multiplied with the measured antenna transfer function, and an inverse Fourier transform is performed to achieve the required time domain response. This can be expressed by

$$\mathrm{Output}(t,\theta,\phi)=\Im^{-1}\left\{\mathrm{Input}(f)\cdot H_{AUT}(f,\theta,\phi)\right\} \quad (3)$$

Shown in Fig. 7 are the output waveforms at the receiving antenna terminal in the H-plane at ϕ = 0°, 90°, 180°, 270°. A minimum distortion is observed as expected, which guarantees the effectiveness of implementing the proposed antenna in low-band UWB systems.

IV. Conclusion

In this work, a uniplanar CPW-fed DETSA with a compact size is proposed for implementation in the multi-band UWB system. The proposed antenna exhibits a wide impedance bandwidth, almost uniform H-plane patterns and little distortion to the input pulse signal. It may find applications in the low band of UWB systems.

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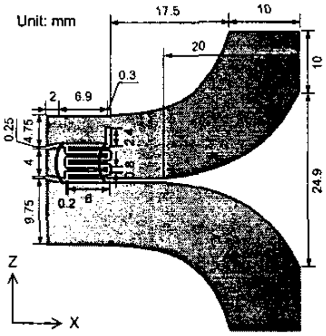


Fig. 1. Layout of CPW-fed dual exponentially tapered slot antenna.

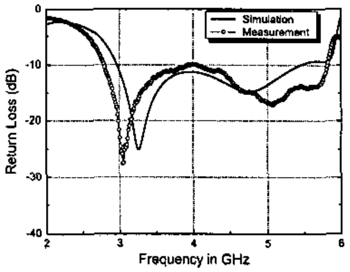
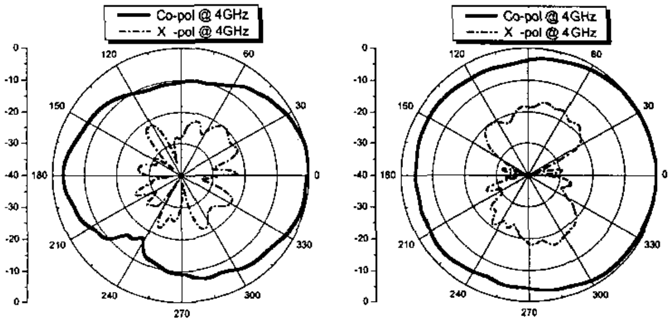


Fig. 2. Measured and simulated return losses for the proposed antenna.



(a) (b)

Fig. 3. Measured (a) *E*-plane and (b) *H*-plane radiation patterns at 4 GHz.

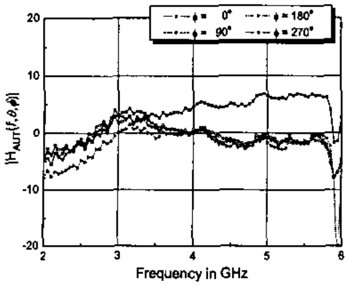


Fig. 4. Magnitude of the measured antenna transfer functions in the H-plane at $\phi = 0°, 90°, 180°, 270°$.

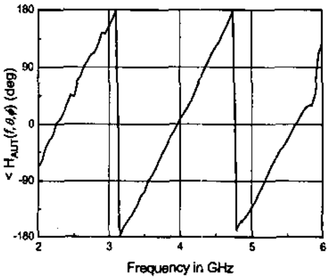
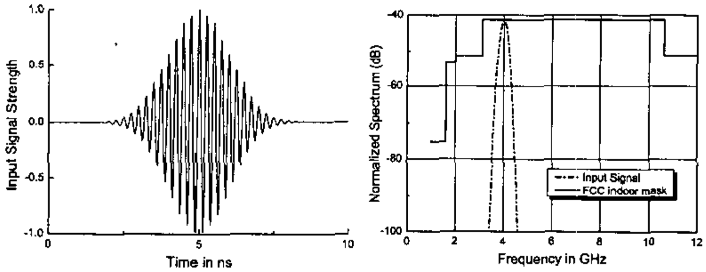


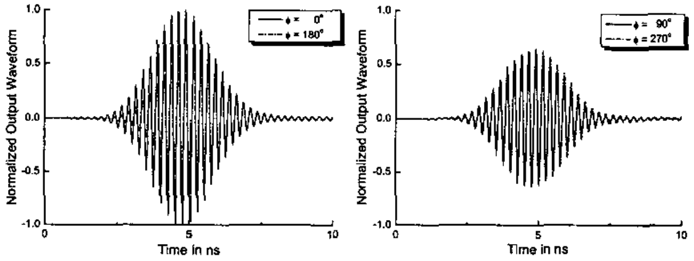
Fig. 5. Phase response of the measured antenna transfer function at the boresight direction ($\theta = 90°$, $\phi = 0°$).



(a)

(b)

Fig. 6. (a) The waveform of the input pulse. (b) The spectrum of the input pulse normalized to the FCC mask.



(a)

(b)

Fig. 7. Output waveforms at the receiving antenna terminal in H-plane at (a) $\phi = 0°, 180°$ (b) $\phi = 90°, 270°$.