Comparative Analysis of Broadband Pulses for an UWB Dielectric Resonator Antenna

Mian Shahzad Iqbal, Karu P. Esselle
Centre for Electromagnetic and Antenna Engineering,
Department of Engineering, Macquarie University, NSW 2109, Australia
Email: shahzad.mian@mq.edu.au, karu@ieee.org

***Abstract*—This paper investigates the time-domain characteristics of an ultrawideband (UWB) dielectric resonator antenna (DRA) for two UWB input pulses. The computed spectrum amplitude of a fifth-order Gaussian pulse has better compliance, as per FCC mask, compared to a first-order Rayleigh pulse. The correlation between the input pulses and the radiated pulses in many directions were found to be less when the antenna is excited by the first-order Rayleigh pulse. On the contrary, with the fifth-order Gaussian pulse excellent correlation factors are achieved in most directions. Therefore, this DRA with the fifth-order are suitable for an impulse radio (IR) UWB system.**

Keywords—dielectric antenna, pulse performance, time-domain, IR-UWB, UWB

I. Introduction

Dielectric resonators antennas (DRAs) are attractive due to their advantages of small size, high radiation efficiency, wide impedance bandwidth and ease of integration to the system. Their versatility in shape and the variety of possible feeding mechanism allow for better control of the results, and research to broaden its impedance bandwidth. Moreover, growing demand for multiple high-speed wireless applications on the same small terminal has necessitated the development of miniaturization of wideband antennas. Recently, an ultrawideband (UWB) DRA with a full ground plane has been designed to achieve the necessary frequency domain characterization such as input matching, while significantly reducing the radiated power into the lower hemisphere [1].

Impulse radio (IR)–UWB systems are based on the transmission of a train of extremely short pulses, typically in the range of subnanoseconds, which results in low radiated power spectral density (PSD) over an extremely broad bandwidth. Due to the broad frequency spectrum of UWB DRA, it can cause interference with other systems. Therefore, Federal Communications Commission (FCC) regulated the emission limit for the allocated 7.5 GHz bandwidth between 3.1 GHz and 10.6 GHz [2]. One of the challenges in the implementation of UWB system is the development of a suitable antenna that would enhance the advantages of a pulsed communication system.

In this paper, the UWB DRA presented in [1] is used to assess its time-domain characteristics. To do so, two different broadband pulses, a fifth-order Gaussian pulse and a first-order Rayleigh pulse, are employed. Furthermore, pulse -preserving capabilities of the UWB DRA are investigated in several directions.

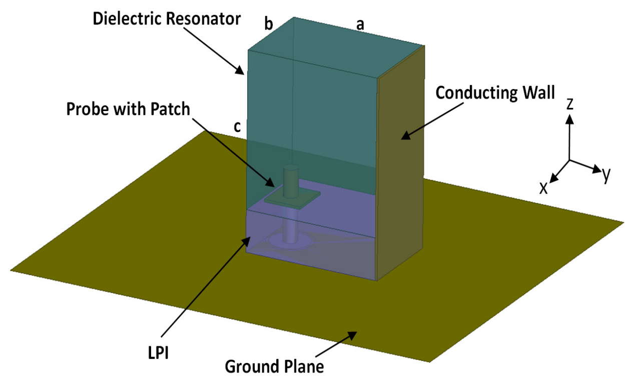


Fig. 1: UWB dielectric resonator antenna configuration

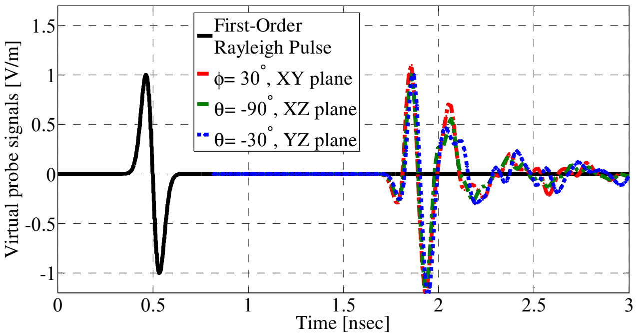
I. Antenna Design

The geometry of the rectangular DRA is shown in Fig. 1. The antenna consists of a dielectric resonator (DR) and a lower permittivity insert (LPI) with a dielectric constant of 9.2 and 2.2, respectively. The probe length above the dielectric segment (inside the DR) is d. The optimal dimensions of the DRA are as follows: a = 12 mm, b = 8 mm, c = 15.0 mm. Detailed configuration and characteristics can be found in [1].

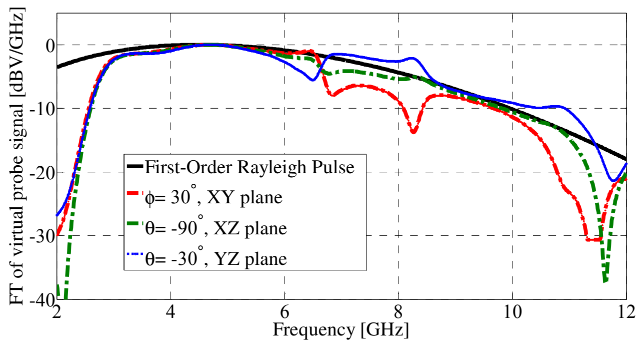
II. Results and Discussion

The time-domain characteristics of this antenna were evaluated using commercial full-wave simulation software in CST Microwave Studio. Two UWB pulses, mentioned previously, are used to excite the UWB DRA.

A first-order Rayleigh pulse [3] is employed to analyse the PSD in the entire UWB band. The spectrum amplitudes of the input pulse and the three radiated pulses in different directions are shown in Fig. 2. Due to brevity, only three different directions are considered. However, the computed correlation factor is analysed for the all-important directions. It can be seen from Fig. 2 (b) that input spectra of the first-order Rayleigh pulse does not follow the shape of the FCC regulatory mask. Moreover, it contains a significant amount of low-frequency

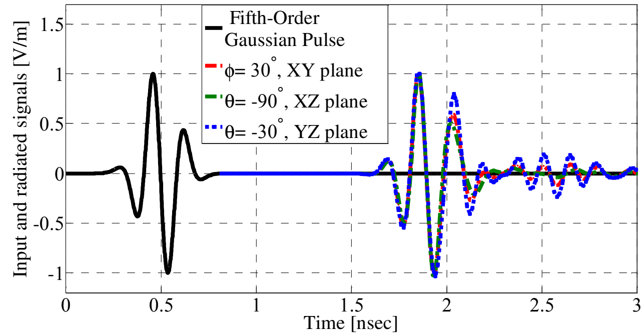


(a)

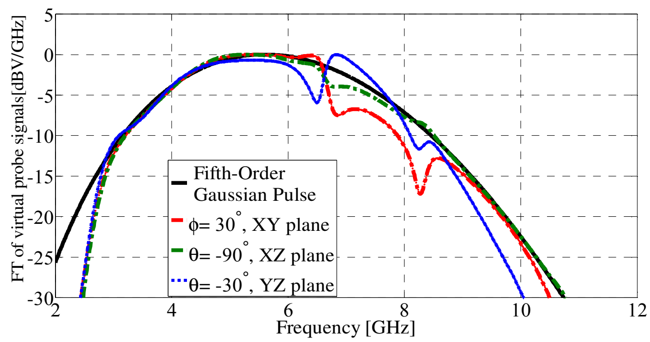


(b)

Fig. 2: Input and radiated signals for a first-order Rayleigh pulse: (a) Probe Signals and (b) Spectra



(a)



(b)

Fig. 3: Input and radiated signals for a fifth-order Gaussian pulse: (a) Probe Signals and (b) Spectra

energy below the lower input corner of the antenna bandwidth. Consequently, a substantial amount of pulse energy is reflected, which may contribute to the ringing of the radiated pulses.

Compared to the first-order Rayleigh pulse, another commonly known pulse, a fifth-order Gaussian pulse [4], is also considered as the input signal to the UWB DRA. Fig. 3 (a) and (b) shows the input signal in time domain and its radiated spectra in the frequency domain, respectively. It is worth mentioning that an input and radiated spectra of the fifth-order Gaussian pulse follow the FCC mask for both input spectrum and its radiated spectra, as shown in Fig. 3 (b).

The previous discussion was limited to only a few directions. For a through comparison, a correlation factor, ρ, is computed to assess the pulse performance of the UWB DRA for different broadband pulses. Following the definition in [5], the correlation factor between a radiated-field waveform, and the input excitation signal was calculated to evaluate the UWB DRA's pulse performance. It is important to mention that only upper hemisphere (between -90^o and 90^o) was considered in this investigation, because this UWB DRA radiates most of the power in the upper hemisphere due to the presence of the full ground plane. Fig. 4 represents the pulse-performance of the UWB DRA in elevation planes for both first-order and fifth-order Gaussian pulses. The first-order Rayleigh pulse and the fifth-order Gaussian pulse have best ρ of 0.974 and 0.852, respectively, in the XZ plane. Analogously, the best values in YZ plane are 0.901 and 0.782 for first-order Rayleigh and fifth-order Gaussian pulse, respectively. The average ρ for fifth-

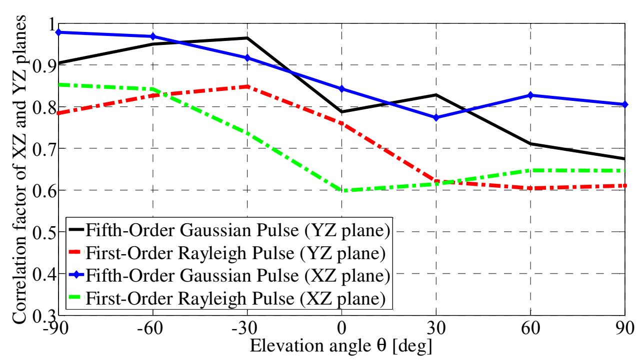


Fig. 4: Correlation factors of the UWB DRA in elevation planes with first-order Rayleigh and fifth-order Gaussian pulses

order Gaussian pulse in YZ and XZ planes is 0.831 and 0.872 whereas first-order Rayleigh pulse has an average ρ of 0.72 and 0.70. Based on these calculations, it is evident that fifth-order Gaussian pulse has better pulse performance compared to the first-order Rayleigh pulse.

III. CONCLUSION

In this paper, time-domain characteristics of an UWB rectangular DRA are investigated. The spectra of the first-order Rayleigh pulse and fifth-order Gaussian pulse are compared and analysed. It is found that fifth-order Gaussian pulse has better compliance to the FCC mask compared to the first-order Rayleigh pulse. For the fifth-order Gaussian pulse, the overall correlation factors between the radiated pulses and the input pulses are excellent in most directions whereas correlation factors for the first-order Rayleigh pulse are relatively weaker. This high correlation with the fifth-order Gaussian pulse should result in a good bit error rate (BER) performance and communication quality of IR-UWB systems.

REFERENCES

[1] G. Yuehe, K.P. Esselle, and T.S. Bird, "Compact Dielectric Resonator Antennas With Ultrawide 60-110% Bandwidth," Antennas and Propagation, IEEE Transactions on, vol. 59, pp. 3445-3448, 2011.

[2] First Report and Order in the Matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, ET Docket 98-153 Federal Communication Commission (FCC), Apr 2002.

[3] Z. N. Chen and X. H. Wu and H. F. Li and N. Yang and Chia. M. Y. W, "Considerations for source pulses and antennas in UWB radio systems," IEEE Antennas Propag. Mag. H, vol. 15, no.7 pp.1739-1748, 2004.

[4] M.T.K. Tam and R. D. Murch, " Pulse Preserving Capabilities of Printed Circular Disk Monopole Antennas With Different Grounds for the Specified Input Signal Forms," IEEE Trans. Antennas Propag., vol. 55, pp. 2866-2873, Oct 2007.

[5] D. Lamensdorf and L.Susman, "Broadband-pulse-antenna techniques," IEEE Antennas Propag. Mag., vol. 52, no.7, pp.1739-1748, 2004.