

Practical Pulse Shaping for Delay-Doppler Communications

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How to implement delay-Doppler communications with practical pulse shaping. What are the unique properties of delay-Doppler communications.?

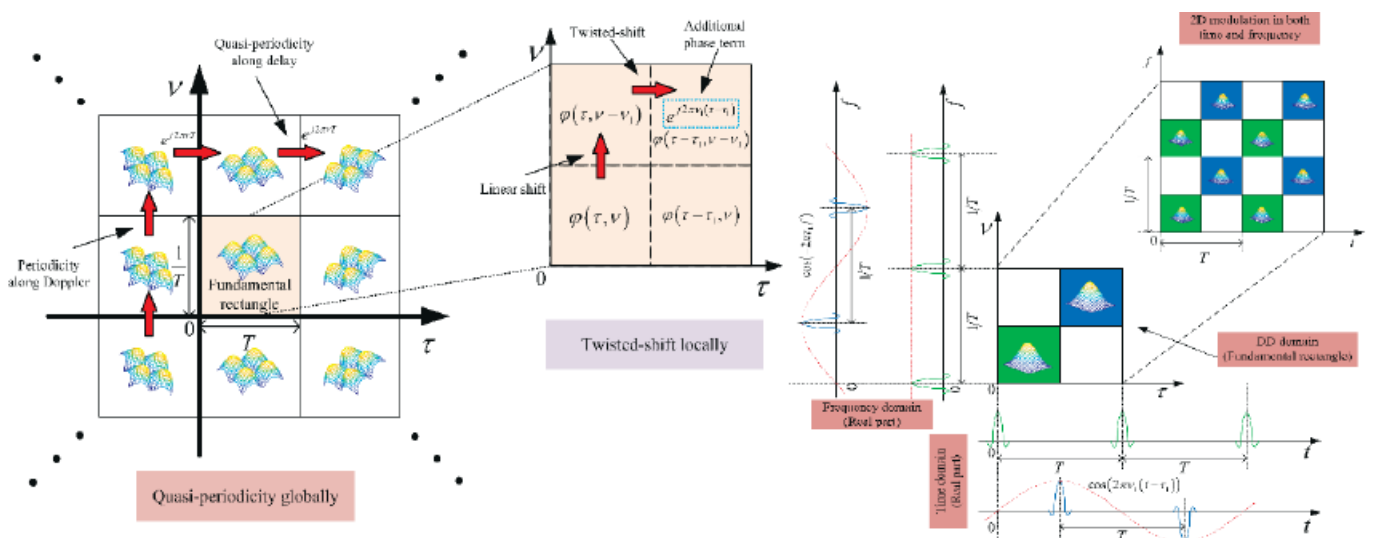


Fig. 1 DD domain basis functions exhibit quasi-periodicity globally, which is constructed by locally twisted-shifting the atom pulse.

Fig. 2 DD domain basis functions and equivalent representations in time and frequency domains.

The figures 1,2 and 3 show the key features of symbol carriers for DD communications. From Fig. 1, we notice that DD basis functions are quasi-periodic globally, while twisted-shifted locally. In Fig. 2, we observe that the global properties of DD basis functions characterize the time and frequency periodicity, while local properties are translated into time and frequency tones. Essentially, DD communications use time-frequency symmetrical pulses for signal transmission. Fig. 3 shows the response of DD basis function constructed using practical window functions, where we notice the DD orthogonality can be achieved by various windows with (truncated or approximated) periodicity.

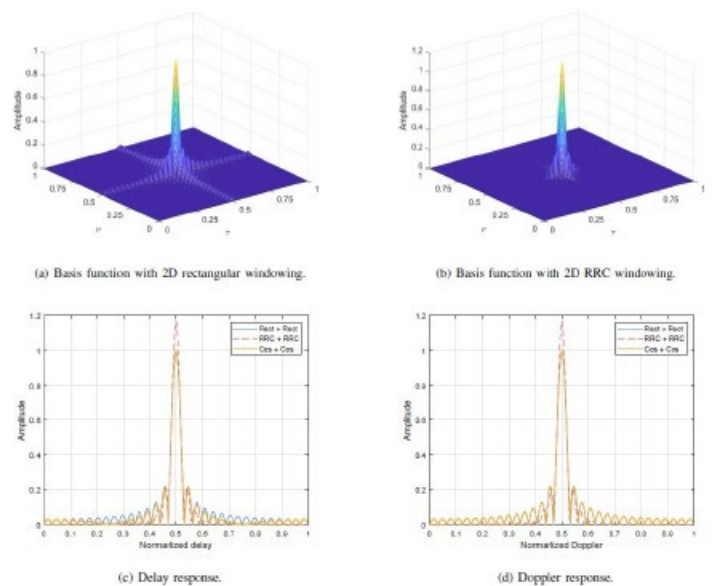


Fig. 3 DD basis functions with different shaping windows.

KEY FINDINGS

The recently proposed orthogonal time frequency space (OTFS) modulation, which is a typical Delay-Doppler (DD) communication scheme, has attracted significant attention thanks to its appealing performance over doubly-selective channels. In this paper, we present the fundamentals of general DD communications from the viewpoint of the Zak transform. We start our study by constructing DD domain basis functions aligning with the time-frequency (TF)- consistency condition, which are globally quasi-periodic and locally twisted-shifted. We unveil that these features are translated to unique signal structures in both time and frequency, which are beneficial for communication purposes. Then, we focus on the practical implementations of DD Nyquist communications, where we show that rectangular windows achieve perfect DD orthogonality, while truncated periodic signals can obtain sufficient DD orthogonality. Particularly, smoothed rectangular window with excess bandwidth can result in a slightly worse orthogonality but better pulse localization in the DD domain. Furthermore, we present a practical pulse shaping framework for general DD communications and derive the corresponding input-output relation under various shaping pulses. Our numerical results agree with our derivations and also demonstrate advantages of DD communications over conventional orthogonal frequency-division multiplexing (OFDM).

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