Information and Communication Theory (ICT) Lab

Orthogonal Time Frequency Space: Implementation and Constraints

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Introduction and Motivation

Motivated by challenges encountered in wireless communication in high mobility scenarios, a modulation technique termed orthogonal time-frequency space (OTFS) in [1]. OTFS utilizes the delay-Doppler domain to represent information-carrying symbols. The effect of time-variant channels is static in the delay-Doppler. OTFS utilizes the time-invariance to outperform orthogonal frequency division multiplexing (OFDM) in several aspects. Traditionally, OTFS is considered an overlay technique for OFDM. This work presents an alternative implementation of OTFS based on the discrete Zak transform (DZT).

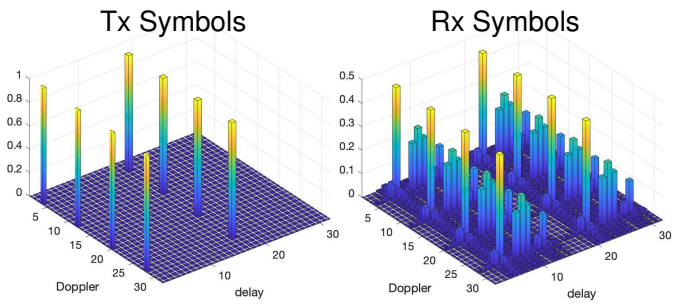

Figure 1: The effect of a time-variant channel on the symbols in the delay-Doppler domain is static, that is, all symbols experience the same channel.

OTFS via Overlay Technique [1]

- State-of-the-Art
- Map symbols between the delay-Doppler domain and the time-frequency domain using the symplectic finite Fourier transform (SFFT) and inverse symplectic finite Fourier transform (ISFFT)
- Nonorthogonal frequency division multiplexing (NOFDM):
  - Modulation: map transmit symbols in the time-frequency domain onto time and frequency translated transmit pulses $g(t)$
  - Demodulation: correlate received signal with time and frequency translated receive pulses $\gamma(t)$

\+ Reuse of existing OFDM hardware

\- Obscures input-output relation in the delay-Doppler domain

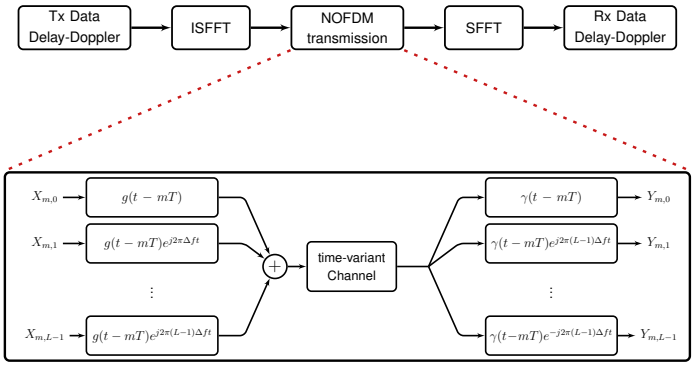

Figure 2: OTFS via the overlay technique

Zak Transform

- Zak transform: fundamental transform associated with the delay-Doppler domain [1]
- Composition of SFFT and OFDM modulation resembles Zak transform

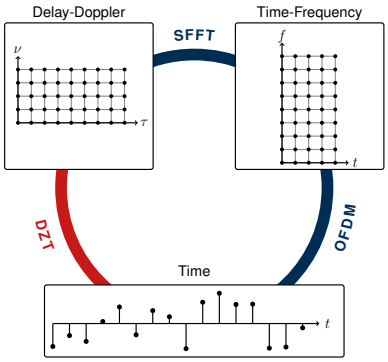

Figure 3: Relation between the different

OTFS via Discrete Zak Transform [2]

- Utilize inverse discrete Zak transform (IDZT) to map symbols in the delay-Doppler domain to a discrete-time sequence
- Use pulse amplitude modulation (PAM) and demodulation

\+ Reduced complexity

\+ Evaluation of input-output relation based on transform properties

\+ Pulse $p(t)$ allows controlling interference in the delay Domain

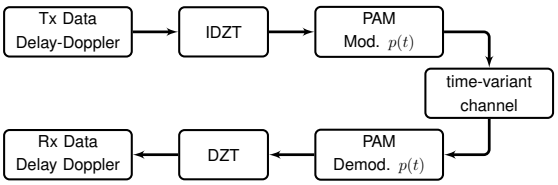

Figure 4: OTFS via the DZT

Conclusions

The DZT implementation of OTFS provides an appealing alternative to the traditional implementation of OTFS as an overlay technique. It utilizes the widely neglected fact that the overlay technique resembles the DZT, which is the transform naturally associated with the delay-Doppler domain. Both methods are equivalent only if rectangular pulses for OFDM in the overlay approach are considered.

References

[1] R. Hadani et. al., "Orthogonal Time Frequency Space Modulation" 2018.

[2] F. Lampel, A. Alvarado and F.M.J. Willems, "Orthogonal Time Frequency Space Modulation: A Discrete Zak Transform Approach " to be submitted.