Abstract

Emerging 5G and beyond wireless networks predominantly rely on OFDMA based multi-cell systems. However, these systems are not robust in environments with high delay and Doppler spread, leading to degraded spectral efficiency (SE) and reliability. To address this, Multi-Carrier Orthogonal Time Frequency Space (MC-OTFS) modulation has been proposed. MC-OTFS maps information symbols in the delay-Doppler (DD) domain, where the wireless channel exhibits greater sparsity compared to the traditional time-frequency (TF) domain, offering improved robustness in high DD spread scenarios. While the performance of single-cell MC-OTFS under DD spread conditions has been studied, the analysis of multi-cell MC-OTFS systems in such environments remains limited. In our research, we investigated the spectral efficiency performance of multi-cell MC-OTFS in high DD spread channels and benchmarked it against traditional OFDM systems. Our findings showed that inter-cell interference (ICI) significantly limits the SE of multi-cell MC-OTFS.

To mitigate this limitation, we proposed a guard band (GB) scheme with reuse of DD resources across cells. This technique effectively reduces ICI in DD spread channels and enhances overall system spectral efficiency. Our evaluations demonstrated that the proposed GB scheme improves performance in multi-cell MC-OTFS systems under high delay and Doppler conditions. In the second part of our research, we addressed the challenge of low-complexity equalization in Zak-OTFS modulated systems. Although Zak-OTFS, a recently proposed variant, offers better robustness against DD spread compared to MC-OTFS, it requires joint DD-domain equalization, which is computationally intensive—particularly in downlink scenarios, where user terminals (UTs) have limited processing capabilities. To overcome this challenge, we propose two low-complexity equalization techniques for Zak-OTFS, transmitter side precoding/pre-filtering and receiver side post-filtering. In transmitter side precoding, we introduce an optimized precoder at the Zak-OTFS transmitter. By selecting an appropriate filtering scheme, we enabled single-tap equalization at the receiver, eliminating the need for complex joint equalization and reducing computational overhead. In receiver side post-filtering technique, we design an optimal post filter at the receiver that leverages the sparsity of the DD-domain channel. Since the DD-domain channel is more stationary than the TF-domain counterpart, it enables less frequent channel estimation, reducing pilot overhead and enhancing energy efficiency. This allows the system to maintain reliable performance over longer time intervals without re-estimating the channel frequently. Together, these contributions advance the understanding and practical viability of OTFS-based systems in realistic, high-mobility wireless environments. The proposed methods not only improve spectral and energy efficiency but also reduce system complexity, making them well-suited for future multi-cell deployments in 5G and beyond.