Tianshi LI, Ruisi HE, Bo AI, Mi YANG, Zhangdui ZHONG, Haoxiang ZHANG, 2021. OTFS modulation performance in a satellite-to-ground channel at sub-6-GHz and millimeter-wave bands with high mobility. *Front Inform Technol Electron Eng*, 22(4):517-526. https://doi.org/10.1631/FITEE.2000468

OTFS modulation performance in a satellite-to-ground channel at sub-6-GHz and millimeter-wave bands with high mobility

Key words: Delay-Doppler channel; High-mobility communications; Minimum mean squared error with successive detection (MMSE-SD); Orthogonal time frequency space (OTFS); Satellite-to-ground communications; Millimeter-wave communications

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Motivation

1. Orthogonal time frequency space (OTFS) modulation has been widely considered for high-mobility scenarios. Satellite-to-ground communications have recently received much attention as a typical high-mobility scenario and are facing great challenges due to the high Doppler shift.

2. OTFS technology has higher spectrum utilization rate and lower peak-to-average-power ratio (PAPR), which makes OTFS modulation more suitable for satellite-to-ground communication with high mobility than OFDM technology. However, the performance of OTFS modulation in satellite-to-ground high-mobility communications has not been well analyzed.

Method

1. The performance of OTFS modulation in satellite-to-ground communication is evaluated using the recently developed 5G non-terrestrial networks (NTNs) and channel model in 3GPP TR 38.811.

2. OTFS modulation performance is closely related to the signal detection technology. The performance of OTFS modulation will degrade because of the interference. Linear equalization methods do not perform very well because of the lack of interference cancellation. A method that can reduce the interference of the already detected data symbols on other data symbols is adopted to improve the performance of the OTFS system.

Major results

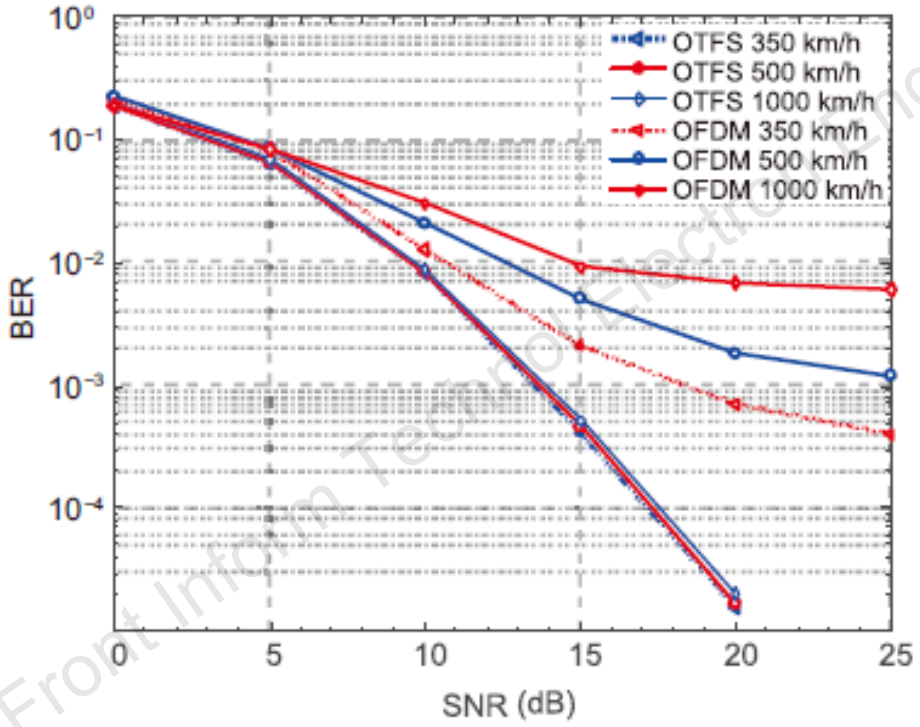

Fig. 3 BER performance of OTFS and OFDM for three different velocities, i.e., 350, 500, and 1000 km/h, in a GEO satellite-to-ground channel

BER: bit error rate; OTFS: orthogonal time frequency space; OFDM: orthogonal frequency division multiplexing; GEO: geostationary Earth orbit

Major results (Cont'd)

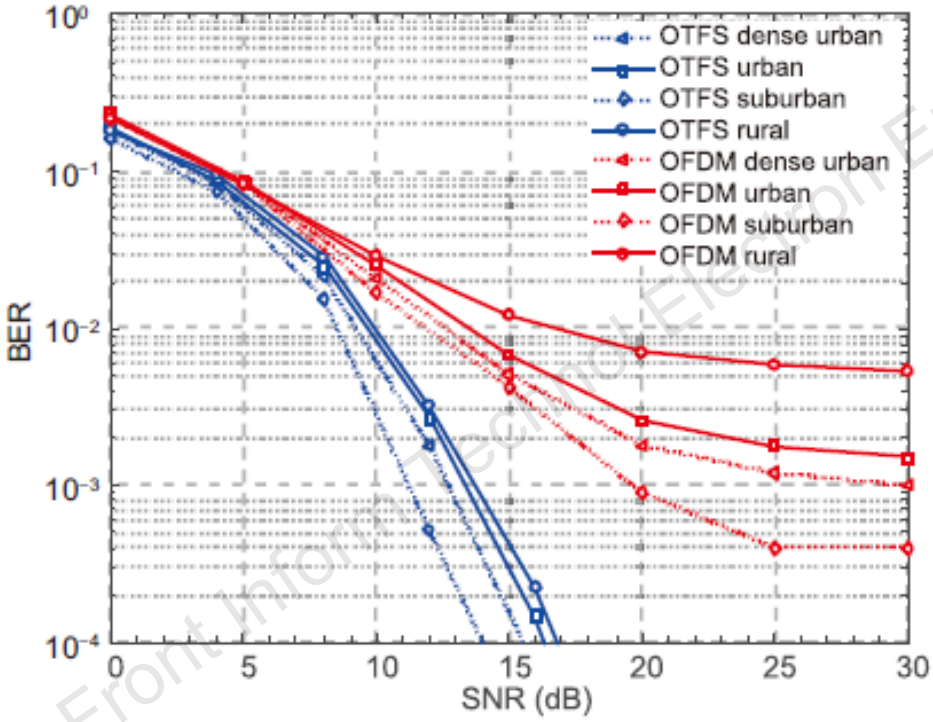

Fig. 4 BER performance of OTFS and OFDM in a GEO satellite-to-ground channel in dense urban, urban, suburban, and rural scenarios, under LoS conditions

BER: bit error rate; OTFS: orthogonal time frequency space; OFDM: orthogonal frequency division multiplexing; GEO: geostationary Earth orbit; LoS: line-of-sight

Major results (Cont'd)

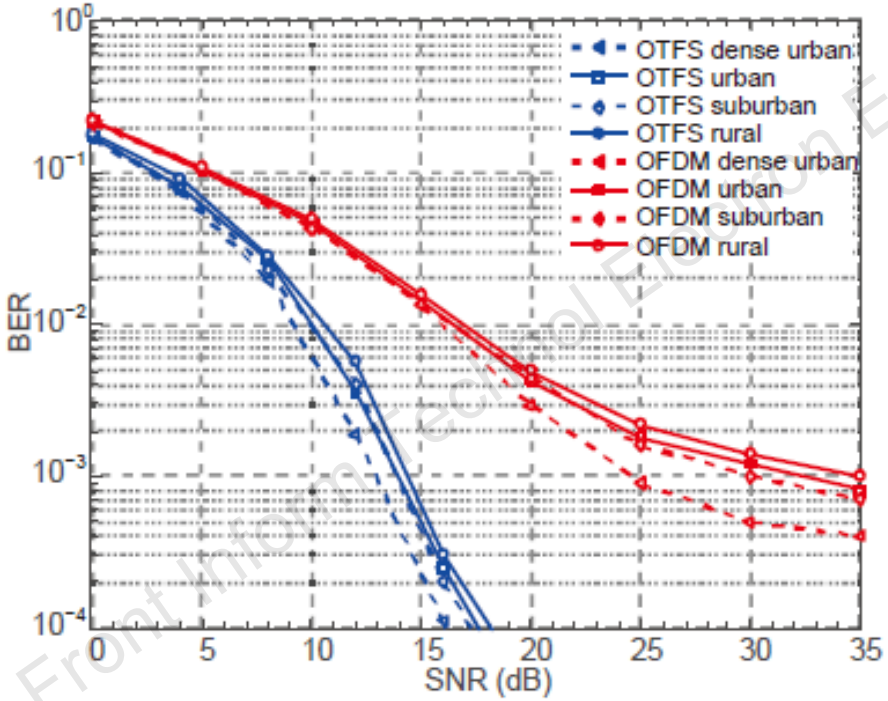

Fig. 7 BER performance of OTFS and OFDM in an LEO satellite-to-ground channel in dense urban, urban, suburban, and rural scenarios, under LoS conditions

BER: bit error rate; OTFS: orthogonal time frequency space; OFDM: orthogonal frequency division multiplexing; LEO: low Earth orbit; LoS: line-of-sight

Major results (Cont'd)

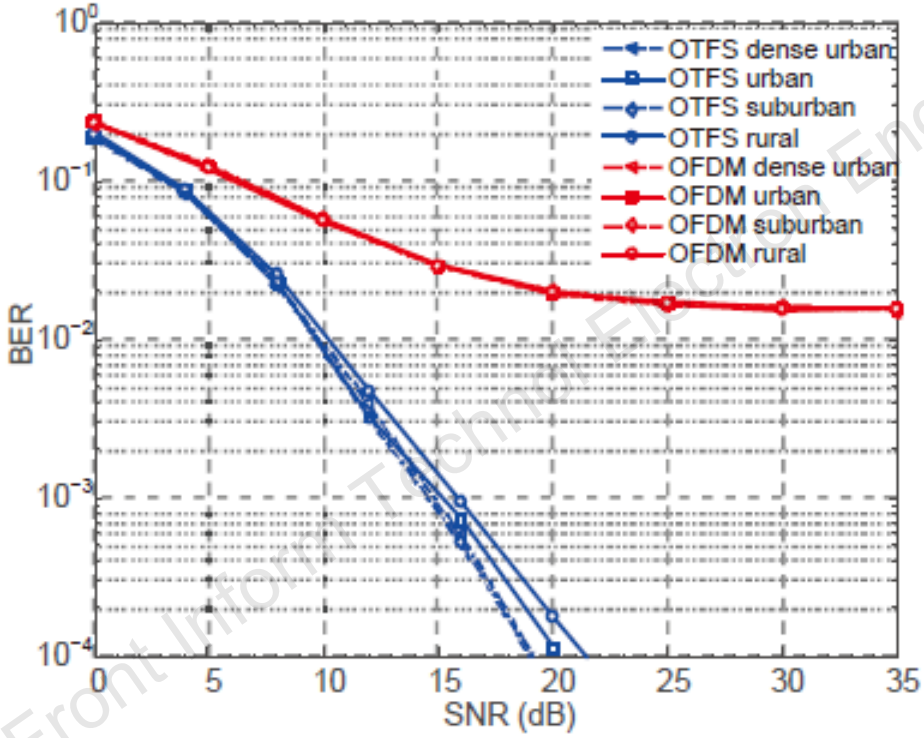

Fig. 8 BER performance of OTFS and OFDM in an LEO satellite-to-ground channel in dense urban, urban, suburban, and rural scenarios, under NLoS conditions

BER: bit error rate; OTFS: orthogonal time frequency space; OFDM: orthogonal frequency division multiplexing; LEO: low Earth orbit; NLoS: non-line-of-sight

Major results (Cont'd)

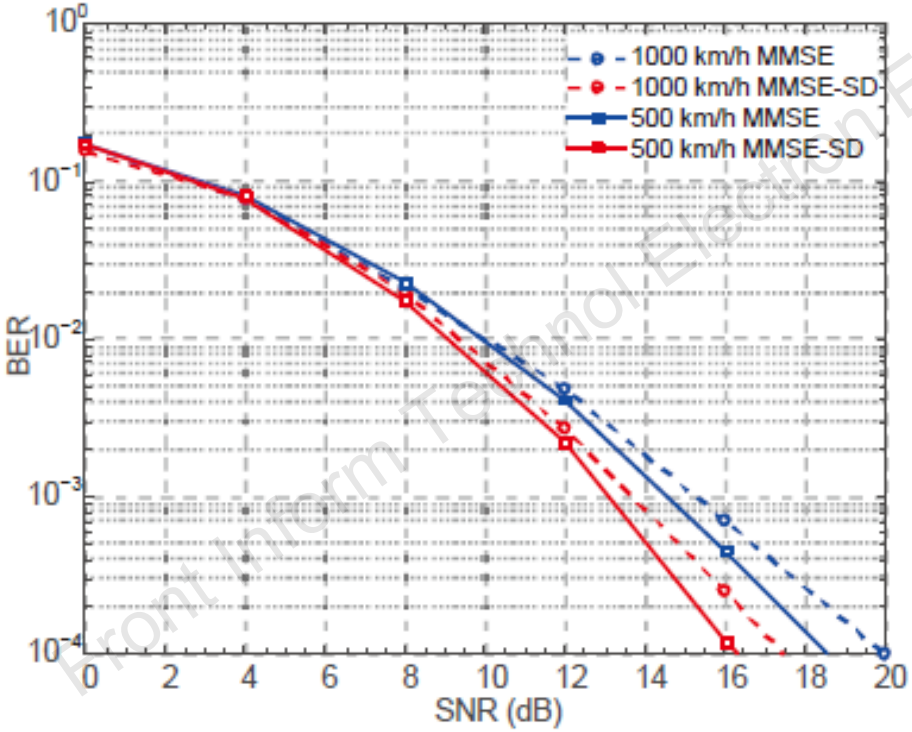

Fig. 9 BER performance of MMSE-SD and MMSE at the carrier frequency of 2.2 GHz in a dense urban scenario

BER: bit error rate; MMSE: minimum mean squared error; MMSE-SD: MMSE with successive detection

Conclusions

1. The feasibility of applying OTFS modulation in satellite-to-ground communications is analyzed in this paper. OTFS modulation performs better than OFDM in satellite-to-ground high-mobility communications. Different terminal velocities do not have a significant impact on OTFS BER performance.

2. Different scenarios such as dense urban, urban, suburban, and rural do not have a significant impact on the BER performance of OTFS modulation in NLoS conditions, and the MMSE-SD signal detection method can achieve about 2 dB gain compared with the MMSE method.