Outage Probability of an OTFS System in High Mobility Scenario

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Abstract

In this paper, we present the outage probability performance of orthogonal time frequency space (OTFS) system in high mobility scenario. The results confirm again that the OTFS provides a higher diversity order as the mobile speed increases even when the multipath intensity profile is identical.

Ⅰ. Introduction

Orthogonal time frequency space (OTFS) modulation which uses two-dimensional domain to multiplex the information symbols, referred to as delay-Doppler (DD) domain, has lately received a lot attention as a strong candidate for beyond 5G (B5G) communication systems due to its robust performance against high Doppler [1]. Also, to design OTFS-based systems, its different parameters need to be studied [2]. Therefore, this work shows outage probability performance of OTFS system and how this performance changes for the system under different mobility scenario [2].

Ⅱ. System Model

We consider an OTFS frame consists of $M\times N$ symbols in a single frame. These symbols are placed on a grid in the delay-Doppler (DD) domain, which through OTFS modulation are transformed to delay-time (DT) domain. Let $\boldsymbol{X}\in\mathbb{C}^{M\times N}$ be information symbol matrix in DD domain, and $\widetilde{\boldsymbol{X}}=\boldsymbol{X}\boldsymbol{F}_N^H$ be the DT signal, where $\boldsymbol{F}_N$ is the N point normalized discrete Fourier transform (DFT) matrix. The time domain signal is formed by adding cyclic prefix (CP) to each time symbol. The received signal $\boldsymbol{Y}=\widetilde{\boldsymbol{Y}}\boldsymbol{F}_N$ after passing through a time-varying high mobility channel in the delay-Doppler domain can be expressed as follows

$$\boldsymbol{y}=\mathrm{vec}(\boldsymbol{Y})=\boldsymbol{H}\boldsymbol{x}+\boldsymbol{w}\in\mathbb{C}^{NM\times 1} \quad (1)$$

where $\boldsymbol{x}=\mathrm{vec}(\boldsymbol{X})\in\mathbb{C}^{NM\times 1}$, $\boldsymbol{H}\in\mathbb{C}^{NM\times NM}$ is the delay-Doppler channel matrix, and $\boldsymbol{w}$ is the delay-Doppler additive white Gaussian noise (AWGN) vector.

The capacity of the system from (1) is given as

$$C=\frac{1}{NM}\log_2\left|\boldsymbol{I}_{NM}+\frac{E_s\boldsymbol{H}\boldsymbol{H}^H}{\sigma^2}\right| \quad (2)$$

The outage probability of the system is further given by

$$P_{out}=\Pr\left\{C=\frac{1}{NM}\log_2\left|\boldsymbol{I}_{NM}+\frac{E_s\boldsymbol{H}\boldsymbol{H}^H}{\sigma^2}\right|<R\right\} \quad (3)$$

where R is the target rate.

Ⅲ. Simulations and Results

For performance evaluation we have considered an OTFS system with the target rate $R=2$ bits/s/Hz, $M\times N=64\times 16, \Delta f=15\,\mathrm{KHz}$, and carrier-frequency of 4×10^9 Hz. The channel is generated by considering the delay-profile and power delay profile of extended vehicular A (EVA) model with $L=9$ taps and $L_{\max}=2$ and different user velocities v=100km/h, 500km/h and 1000km/h. The systems is considered under fractional Doppler, and each Doppler tap of the channel is taken from Jakes' model $v_i=v_{\max}\cos(\theta_i)$, where $\theta_i=$ Uniform$(0,2\pi)$. Fig. 1 shows a random realization of DD channels under mentioned user velocities, wherein we can see that the channel with user velocity 500km/h has more resolvable paths, which is also true on average for large channel realizations. Thus, the diversity order of the system increases with velocity. The results in Fig. 2 also confirms our observation as the outage performance of the system improves with increase in user velocities.

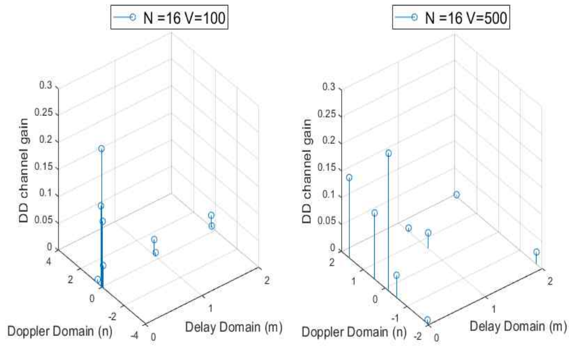

Fig. 1 DD channel under different user velocities

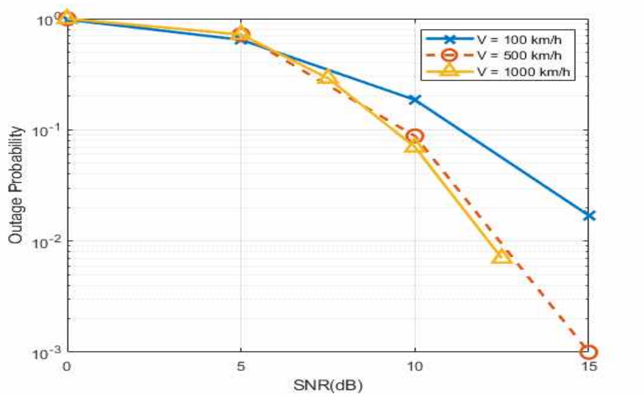

Fig. 2 Outage probability versus SNR for different user velocities

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