Study on Coded OTFS with Iterative Demodulation and Decoding

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Abstract

This paper investigates the performance of the iterative demodulation and decoding (IDD) method proposed for orthogonal time frequency space (OTFS) modulation. In particular, the coded performance with different LLR computation methods and number of IDD iterations is provided for the LDPC coded OTFS system with the IDD based on maximal ratio combining.

Ⅰ. Introduction

Orthogonal time frequency space (OTFS) modulation has been proposed to cope with high mobility by mutliplexing modulation symbols in a two-dimensional domain called delay-Doppler (DD)[1]. For the coded OTFS system, an iterative demodulation and decoding (IDD) applying maximal ratio combining (MRC) was proposed in [2] which was shown to outperform that applying message passing algorithm. We investigate the performance of the MRC-based IDD [2] in more depth under different parameters and conditions including log-likelihood ratio (LLR) computation methods.

Ⅱ. System Model

Fig. 1 illustrates the coded OTFS modulation system considered in this paper. The information bits are LDPC encoded and then modulated by QAM. Let $\boldsymbol{X}\in\mathbb{C}^{M\times N}$ be an $M\times N$ matrix of QAM symbols on a two-dimensional DD grid. We perform OTFS modulation to map the symbols in the delay-time (DT) domain as $\tilde{\boldsymbol{X}}=\boldsymbol{X}\boldsymbol{F}_N^H$, where $\boldsymbol{F}_N$ is the $M\times N$ point normalized discrete Fourier transform (DFT) matrix. The DT signal is transmitted after adding the cyclic prefix (CP) for each time symbol. The received signal through a time-varying multipath channel is expressed by $\tilde{\boldsymbol{Y}}$ in the DT domain and by $\boldsymbol{Y}=\tilde{\boldsymbol{Y}}\boldsymbol{F}_N$ in the DD domain. The receiver performs demoulation and decoding to estimate the information bits.

The received signal in the DD domain can be expressed as

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

with $\boldsymbol{x}=\mathrm{vec}(\boldsymbol{X})$, where $\boldsymbol{H}\in\mathbb{C}^{NM\times NM}$ and $\boldsymbol{w}$ are the channel matrix and additive white Gaussian noise (AWGN) vector in the DD domain, respectively. The signal at the mth delay grid of (1) is given by

$$\boldsymbol{y}_m=\sum_{l\in L}\boldsymbol{K}_{m,l}\boldsymbol{x}_{[m-l]_M}+\boldsymbol{w}_m\in\mathbb{C}^{N\times 1} \quad (2)$$

where $\boldsymbol{K}_{m,l}=circ\left[\nu_{m,l}(0),\ldots,\nu_{m,l}(N-1)\right]$ is the Doppler spread matrix at the lth delay tap determined by the circulant matrix of the delay-Doppler channel vectors $\boldsymbol{\nu}_{m,l}$ and L is the set of multipaths.

The iterative decoding and demodulation (IDD) proposed for the coded OTFS modulation system in [2] employs maximum ratio combining (MRC) in an iterative manner as shown in Fig. 1. The MRC estimates $\boldsymbol{x}_m$ from the multipath delayed signal $\boldsymbol{y}_{m+l}$ by removing the intersymbol interference (ISI) as

$$\boldsymbol{b}_m^l=\boldsymbol{y}_{m+l}-\sum_{l'\in L,l'\neq l}\boldsymbol{K}_{m+l,l'}\hat{\boldsymbol{x}}_{m+l-l'}, \quad (3)$$

where $\hat{\boldsymbol{x}}_m$ is a hard decision estimate with the output of the LDPC decoder. Through MRC of $\boldsymbol{b}_m^l\in\mathbb{C}^{N\times 1}, l=1,2,\cdots,L$ and normalization, we obtain MRC soft estimate $\boldsymbol{c}_m=\boldsymbol{x}_m+\boldsymbol{e}_m$, where $\boldsymbol{e}_m$ is the post-MRC noise plus interference modeled by zero mean Gaussian with variance σ_m^2 [2]. The LLR for the bits constituting QAM symbols in $\boldsymbol{x}_m$ is computed for LDPC decoding. The IDD iterations are performed up to maximum I_{IDD} iterations under a stopping criterion.

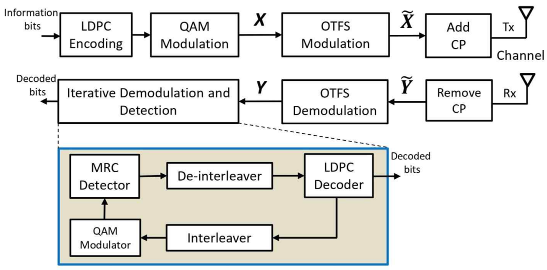

Fig. 1 Coded OTFS modulation system with the IDD receiver.

Ⅲ. . Simulation Results

The system parameters are set to $M\times N=64\times 14$, $\Delta f=15\,\mathrm{KHz}$ and the channel is generated by adopting the extended vehicular A (EVA) model with Doppler shift having unifrom distribution up to maximum Doppler shift v_{max} for each path. Fig. 2 illustrates the coded BER with 64QAM at vehicular speed 500km/h as the number of iterations and different LLR computation methods. It is shown that approximate LLR deviates from the exact LLR in the high SNR region.

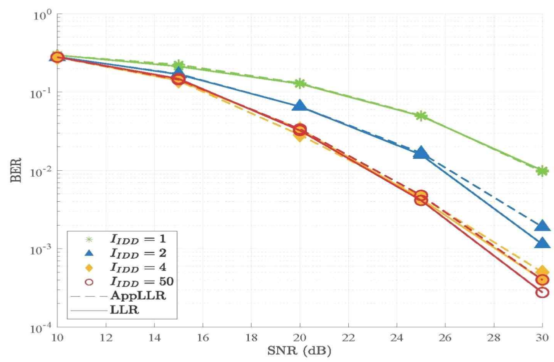

Fig. 2 Coded BER vs SNR with different iterations.

Acknowledgment

This work was supported by the Ministry of Science and ICT, South Korea through the Institute for Information & Communications Technology Planning & Evaluation (IITP) under the Information Technology Research Center Support Program under Grant IITP-2021-0-02046.

References

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