A Blind SLM PAPR Reduction Scheme Using Cyclic Shift in STBC MIMO-OFDM System

Hyun-Seung Joo, Jong-Seon No
Dept. of Electrical Eng. and Computer Science, INMC
Seoul National University, Seoul 151-744, Korea
email: joohs@ccl.snu.ac.kr, jsno@snu.ac.kr

Dong-Joon Shin
Dept. of Electronics and Computer Eng.
Hanyang University, Seoul 133-791, Korea
email: djshin@hanyang.ac.kr

***Abstract*—In this paper, we propose a blind SLM scheme using cyclic shift (BSLM-CS) in STBC MIMO-OFDM. After an OFDM signal sequence in each transmit antenna is cyclically shifted, alternative signal sequences in the proposed scheme are generated by linearly combining OFDM signal sequences using addition and subtraction without the need of the additional IFFT. Therefore, the proposed BSLM-CS scheme has low computational complexity for transmitting the alternative signal sequence with the lowest PAPR. In oder to recover the data at the receiver without side information, the ML decoder for the BSLM-CS scheme can be derived similar to the conventional BSLM scheme. The BER performance of the proposed scheme is not degraded compared to the conventional SLM scheme with the perfect side information.**

I. Introduction

Multiple-input multiple-output (MIMO) systems employing multiple transmit and receive antennas can increase either the transmission rate or transmission diversity in the wireless communications. In addition, orthogonal frequency division multiplexing (OFDM) is an efficient transmission method of high speed data rate in the multipath fading channel. In order to combine the advantages of both the MIMO and OFDM, space-time block coded (STBC) MIMO-OFDM systems are now extensively considered. However, an OFDM signal of the transmitter occasionally has the high peak-to-average power ratio (PAPR) from the summation of many subcarriers. An OFDM system with high PAPR requires a costly linear power amplifier with large dynamic range for the transmitter.

Many PAPR reduction schemes have been proposed for OFDM systems. Selected mapping (SLM), one of symbol scrambling methods, can reduce the PAPR of OFDM signals with no signal distortion [1]. The key idea of the SLM scheme is that the OFDM signal with the lowest PAPR is selected for transmission from the several alternative OFDM signals which are obtained by applying inverse fast Fourier transform (IFFT) to each alternative symbol sequence. The alternative symbol sequences are generated from an input symbol sequence multiplied by the phase sequences. The extension of SLM scheme to the MIMO-OFDM system were proposed in [2] and [3].

Yung *et al*. proposed the time domain SLM scheme using cyclic shift with low complexity [3]. However, the transmission of side information in the time domain SLM scheme is not easy for MIMO-OFDM system. Also, wrong side information results in the critical degradation of bit error rate (BER) performance.

In this paper, we propose a blind SLM scheme using cyclic shift (BSLM-CS). After an OFDM signal sequence in each transmit antenna is cyclically shifted, alternative signal sequences in the proposed scheme are generated by linearly combining OFDM signal sequences using addition and subtraction. In order to recover the data at the receiver, a maximum likelihood (ML) decoder of the BSLM-CS scheme can be derived similar to the conventional BSLM [4]. Our proposed scheme has almost no degradation of BER performance compared to the MIMO-SLM scheme with perfect side information (PSI).

II. BSLM-CS Scheme in STBC MIMO-OFDM System

We consider a MIMO-OFDM system with N_t transmit antennas and N_r receive antennas. In the lth transmit antenna, an input symbol sequence $\mathbf{X}_l = [X_{l,0}\ X_{l,1}\ \cdots\ X_{l,N-1}]$ is given as a vector of complex-valued symbols with the time duration T_s. After splitting the serial data into parallel data streams, all substreams are summed by applying IFFT. The discrete time OFDM signal of lth transmit antenna after IFFT is given as

$$x_{l,k} = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_{l,n} e^{j2\pi \frac{n}{N} k}, \qquad 0 \le k \le N-1 \quad (1)$$

where $X_{l,n}$ is the input data symbol loaded on the nth subcarrier in the lth transmit antenna and N is the number of the subcarriers.

The maximum PAPR among N_t transmit signals should be as small as possible. Since the worst PAPR among the transmit signals is critical, the PAPR in MIMO-OFDM systems is defined as

$$\mathrm{PAPR} = \frac{\max\limits_{1 \le l \le L, 0 \le k \le N-1} |x_{l,k}|^2}{E[|x_{l,k}|^2]} \quad (2)$$

where $E[\cdot]$ is the average power of the OFDM signal.

To simplify the proposed scheme for MIMO-OFDM, we consider the STBC MIMO-OFDM system with $N_t = N_r = 2$. $2N$ input data symbols split into two streams $\mathbf{X}_1$ and $\mathbf{X}_2$, where each $\mathbf{X}_l$, $l = 1, 2$, corresponds to the symbol sequence

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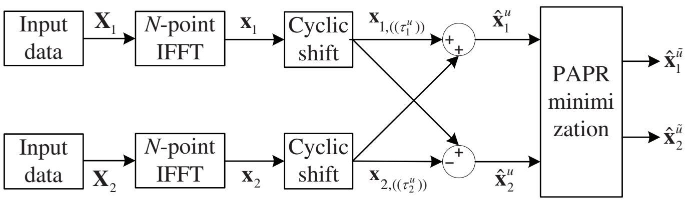

Fig. 1. The transmitter of the proposed scheme.

of the N subcarriers of an OFDM block in the lth transmit antenna. A BSLM-CS scheme for PAPR reduction is depicted in Fig. 1. Suppose that the cyclically shifted signal sequences by τ_l^u positions for two transmit antennas are given as

$$\mathbf{x}_{l,((\tau_l^u))} = [x_{l,(0-\tau_l^u)\mathrm{mod}N} \; x_{l,(1-\tau_l^u)\mathrm{mod}N} \; \cdots \; x_{l,(N-\tau_l^u)\mathrm{mod}N}] \tag{3}$$

where $u \in \{1, 2, \cdots, U\}$ and $l \in \{1, 2\}$. To generate alternative signal sequences, $\mathbf{x}_{1,((\tau_1^u))}$ and $\mathbf{x}_{2,((\tau_1^u))}$ are linearly combined as addition and subtraction. Therefore, the alternative signal sequences in the two transmit antennas can be expressed as

$$\hat{\mathbf{x}}_1^u = \mathbf{x}_{1,((\tau_1^u))} + \mathbf{x}_{2,((\tau_2^u))} \tag{4}$$

$$\hat{\mathbf{x}}_2^u = \mathbf{x}_{1,((\tau_1^u))} - \mathbf{x}_{2,((\tau_2^u))}. \tag{5}$$

Equations (4) and (5) do not need any multiplication. Therefore, the computational complexity for PAPR reduction is very low. After the two alternative signal sequences $\hat{\mathbf{x}}_1^{\tilde{u}}$ and $\hat{\mathbf{x}}_2^{\tilde{u}}$ with the lowest PAPR are selected, they are processed by an Alamouti encoder to form a STBC consisting of two signal pairs given by

$$\mathcal{G}_2 = \begin{bmatrix} x_{1,k} & x_{2,k} \\ -x_{2,k}^* & x_{1,k}^* \end{bmatrix}. \tag{6}$$

Due to cyclic shift operation in the time domain, each symbol of the signal sequence is rotated by $e^{-j2\pi\tau_l^u \frac{k}{N}}$ in the frequency domain. Therefore, the ML decoder of the BSLM-CS scheme can be derived similar to that of the conventional BSLM [4]. The received symbol $R_{l,n}$ after FFT at the receiver can be written as

$$R_{l,n} = H_{l,n} X_{l,n} e^{-j2\pi\tau_l^{\tilde{u}} \frac{k}{N}} + \bar{N}_{l,n} \tag{7}$$

where $H_{l,n}$ is the frequency response of the fading channel at the nth subcarrier in the lth receive antenna, and $\bar{N}_{l,n}$ is a complex additive white Gaussian noise (AWGN) sample. Without the side information of $\tilde{u}$, the ML decoder computes the decision metric for decoding the received signal sequence rotated by the $\tau_l^{\tilde{u}}$. The simplified decision metric for the proposed scheme can be written as

$$D_l = \min_{\tau_l \in \mathbf{A}_l} \sum_{n=0}^{N-1} \min_{\bar{X}_n \in Q} |R_{l,n} e^{j2\pi\tau_l^{\tilde{u}}} - H_{l,n}\bar{X}_n|^2 \tag{8}$$

where $l \in \{1, 2\}$, $\mathcal{Q}$ is a signal constellation of the size q, and $\mathbf{A}_l$ is a set of τ_l^u's values for the lth transmit antenna. The total computational complexity of (8) for each receive antenna is $qN|\mathbf{A}_l|\,|\cdot|^2$ operations. Fig. 2 compares the BER performance

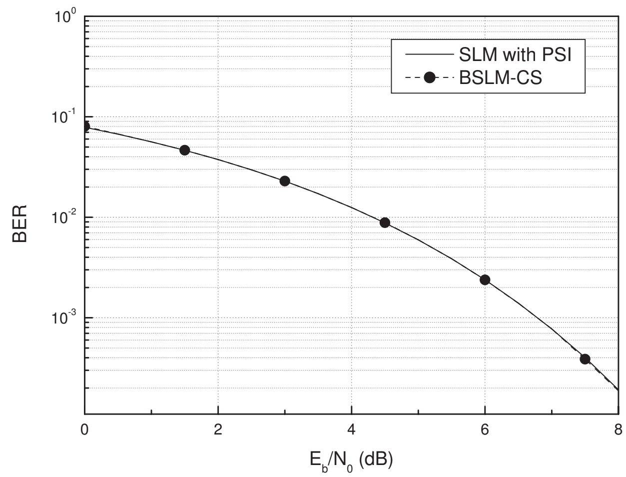

Fig. 2. BER performance of the BSLM-CS and SLM with PSI with N=256, U=16, and QPSK.

of the proposed scheme to the conventional SLM scheme with PSI. We simulate the STBC MIMO-OFDM system with $N = 256$, $U = 16$, and QPSK. Fig. 2 shows that the proposed decoder (8) almost perfectly recovers the received data.

III. Conclusion

In this paper, we proposed the BSLM-CS scheme for PAPR reduction of STBC MIMO-OFDM signals. Since the transmit antenna sequences are only cyclically shifted and linearly combined as addition and subtraction without multiplication of the phase sequence, the proposed BSLM-CS scheme has low computational complexity for transmitting the alternative signal sequences with the lowest PAPR. In order to recover the data at the receiver without side information, the ML decoder for the BSLM-CS scheme can be derived similar to the conventional BSLM scheme. The BER performance of the proposed scheme is not degraded compared to the conventional SLM scheme with the PSI.

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