New PAPR Reduction Scheme for Alamouti Coded OFDM Systems

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Abstract

Additive mapping scheme represents alternative signals of selected mapping (SLM) by linear combination of signals in time domain for peak to average power ratio (PAPR) reduction in orthogonal frequency division multiplexing (OFDM) system. It can reduce the computational complexity considerably without sacrificing PAPR reduction performances especially for the OFDM system with quadrature amplitude modulation (QAM). In this paper, we extend the additive mapping scheme to Alamouti coded OFDM systems. The same method as in the single antenna can be applied to the Alamouti STBC-OFDM system. On the other hand, some modifications of additive mapping signals are needed for the Alamouti SFBC-OFDM system.

I. Introduction

Alternative symbol sequence $\mathbf{X}^{(u)}$ in selected mapping (SLM)[1] is generated by multiplying input symbol sequence $\mathbf{A}$ with phase sequence $\mathbf{P}^{(u)}$. After inverse fast Fourier transform (IFFT) of $\mathbf{X}^{(u)}$, one with the minimum peak to average power ratio (PAPR) among them is selected for transmission. More alternative signal sequences increase the possibility to improve the PAPR reduction performance, but the computational complexity increases as well. Additive mapping SLM scheme[2] can reduce the computational complexity of SLM without scarificing PAPR reduction performance. In this paper, we suggest to apply this scheme to Alamouti coded orthogonal frequency division multiplexing (OFDM) systems for PAPR reduction.

II. Additive Mapping SLM Scheme for Alamouti MIMO-OFDM

Additive mapping sequence of A_k for the phase sequence $P_k^{(u)} \in \{\pm 1\}$ can be expressed as

$$
\begin{aligned}
D_k^{(u)} &= D_{I,k}^{(u)} + jD_{Q,k}^{(u)} \\
&= \begin{cases} d(-1-j)\sqrt{M}/2, & A_k \in \mathbf{Q}^{(1)} \text{ and } P_k^{(u)} = -1 \\ d(+1-j)\sqrt{M}/2, & A_k \in \mathbf{Q}^{(2)} \text{ and } P_k^{(u)} = -1 \\ d(+1+j)\sqrt{M}/2, & A_k \in \mathbf{Q}^{(3)} \text{ and } P_k^{(u)} = -1 \\ d(-1+j)\sqrt{M}/2, & A_k \in \mathbf{Q}^{(4)} \text{ and } P_k^{(u)} = -1 \\ 0, & P_k^{(u)} = 1 \end{cases}
\end{aligned} \tag{1}
$$

where d is the smallest distance between symbols and $\mathbf{Q}^{(i)}$ is the set of symbols belonging to the ith quadrant of 2-dimensional signal space.

In Alamouti space-time block coded (STBC)-OFDM system, two independent input OFDM symbol sequences are generated for the first transmission in two antennas and Alamouti coding is applied to the next input OFDM symbol sequences for the second transmission. Therefore, additive mapping SLM scheme of each antenna is the same as that of the single antenna except that PAPR of the second transmission in two antennas is decided by that for the first transmission.

In this paper, therefore, we only consider the Alamouti space-frequency block coded (SFBC)-OFDM system, where an input symbol sequence $\mathbf{A}$ is encoded with $\mathbf{A}_{SFBC1}$ and $\mathbf{A}_{SFBC2}$ as

$$
\begin{aligned}
\mathbf{A}_{SFBC1} &= [A_0, -A_1^*, ..., A_{N-2}, -A_{N-1}^*]^T \\
\mathbf{A}_{SFBC2} &= [A_1, A_0^*, ..., A_{N-1}, A_{N-2}^*]^T.
\end{aligned} \tag{2}
$$

$\mathbf{A}_{SFBC1}$ can be divided into even and odd subcarrier indices as $\mathbf{A}_{SFBC1} = \mathbf{A}_{SFBC1,e} + \mathbf{A}_{SFBC1,o}$ and $\mathbf{A}_{SFBC2}$ is divided as

$$
\begin{aligned}
\mathbf{A}_{SFBC2,e} &= -\mathbf{C}_{-1}\mathbf{A}_{SFBC1,o}^* \\
\mathbf{A}_{SFBC2,o} &= \mathbf{C}_1\mathbf{A}_{SFBC1,e}^*
\end{aligned} \tag{3}
$$

where $\mathbf{C}_1$ and $\mathbf{C}_{-1}$ are $N \times N$ matrices to shift a vector cyclically by one position to the right and to the left, respectively.

The additive mapping signal sequence $\mathbf{d}_{SFBC1}^{(l)}$ corresponding to $\mathbf{P}^{(l)}$ for $\mathbf{A}_{SFBC1}$ are also divided into even and odd terms and further seperated into in-phase and quadrature components as

$$
\begin{aligned}
\mathbf{d}_{SFBC1}^{(l)} &= \text{IFFT}(\mathbf{D}_{SFBC1}^{(l)}) \\
&= \text{IFFT}(\mathbf{D}_{e,I}^{(l)} + \mathbf{D}_{o,I}^{(l)} + j\mathbf{D}_{e,Q}^{(l)} + j\mathbf{D}_{o,Q}^{(l)})
\end{aligned} \tag{4}
$$

where $\mathbf{D}_{e,I}^{(l)}$, $\mathbf{D}_{o,I}^{(l)}$, $\mathbf{D}_{e,Q}^{(l)}$, and $\mathbf{D}_{o,Q}^{(l)}$ are in-phase components of even terms, in-phase components of odd terms, quadrature components of even terms, and quadrature components of odd terms for $\mathbf{D}_{SFBC1}^{(l)}$, respectively.

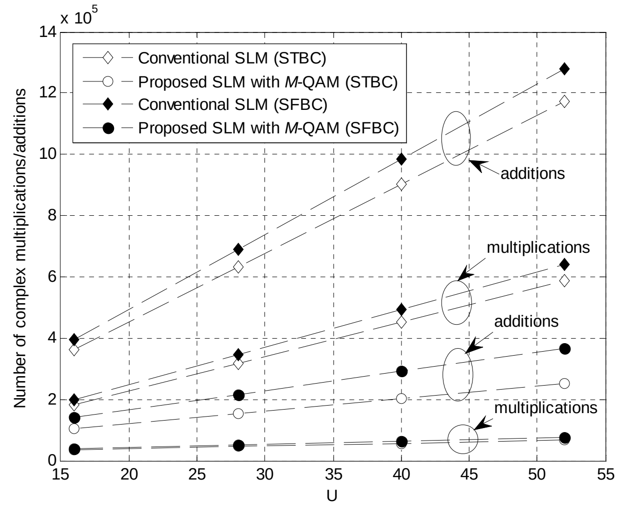

Fig. 1. Comparison of the computational complexity of the conventional SLM and the proposed SLM for serveal U's.

When the additive mapping sequence $\mathbf{D}_{SFBC1}^{(l)}$ for $\mathbf{A}_{SFBC1}$ is $\mathbf{D}_{SFBC1}^{(l)} = \mathbf{D}_I^{(l)} + j\mathbf{D}_Q^{(l)}$, the additive mapping sequence for $\mathbf{A}_{SFBC2}$ becomes

$$\mathbf{D}_{SFBC2}^{(l)} = (\mathbf{C}_1\mathbf{D}_{e,I}^{(l)} - \mathbf{C}_{-1}\mathbf{D}_{o,I}^{(l)}) - j(\mathbf{C}_1\mathbf{D}_{e,Q}^{(l)} - \mathbf{C}_{-1}\mathbf{D}_{o,Q}^{(l)}) \tag{5}$$

where $\mathbf{C}_1\mathbf{D}_{e,I}^{(l)}$, $-\mathbf{C}_{-1}\mathbf{D}_{o,I}^{(l)}$, $-\mathbf{C}_1\mathbf{D}_{e,Q}^{(l)}$, and $\mathbf{C}_{-1}\mathbf{D}_{o,Q}^{(l)}$ are in-phase components of odd terms, in-phase components of even terms, quadrature components of odd terms, and quadrature components of even terms for $\mathbf{D}_{SFBC2}^{(l)}$, respectively. Therefore, the additive mapping signal sequences $\mathbf{d}_{SFBC2}^{(l)}$ for $\mathbf{A}_{SFBC2}$ is

$$\begin{aligned}\mathbf{d}_{SFBC2}^{(l)} &= \text{IFFT}(\mathbf{D}_{SFBC2}^{(l)}) \\ &= (\mathbf{c}_1 \otimes \mathbf{d}_{e,I}^{(l)} - \mathbf{c}_{-1} \otimes \mathbf{d}_{o,I}^{(l)}) - j(\mathbf{c}_1 \otimes \mathbf{d}_{e,Q}^{(l)} - \mathbf{c}_{-1} \otimes \mathbf{d}_{o,Q}^{(l)}) \\ &= \Phi(\mathbf{d}_I^{(l)}) - j\Phi(\mathbf{d}_Q^{(l)})\end{aligned} \tag{6}$$

where $\mathbf{c}_k = [1, e^{j2\pi k/N}, e^{j2\pi(2k)/N}, ..., e^{j2\pi(N-1)k/N}]^T$, $\mathbf{d}_{e,I}^{(l)} = \text{IFFT}(\mathbf{D}_{e,I}^{(l)})$, $\mathbf{d}_{e,Q}^{(l)} = \text{IFFT}(\mathbf{D}_{e,Q}^{(l)})$, $\mathbf{d}_{o,I}^{(l)} = \text{IFFT}(\mathbf{D}_{o,I}^{(l)})$, and $\mathbf{d}_{o,Q}^{(l)} = \text{IFFT}(\mathbf{D}_{o,Q}^{(l)})$. It is known that $\Phi(\mathbf{d}_I^{(l)})$ and $\Phi(\mathbf{d}_Q^{(l)})$ can be obtained only by sign inversions, complex conjugations, reordering of $\mathbf{d}_{e,I}^{(l)}$ and $\mathbf{d}_{o,I}^{(l)}$, and $\mathbf{d}_{e,Q}^{(l)}$ and $\mathbf{d}_{o,Q}^{(l)}$, respectively, followed by additional $N/2$ multiplications and N additions. Once alternative signal sequences for $\mathbf{A}_{SFBC1}$ are generated by the same way as the single-antenna case, alternative signal sequences for $\mathbf{A}_{SFBC2}$ are determined by (6).

III. Simulation Results

Fig. 1 compares the computational complexity of the conventional SLM and the proposed SLM for several U's. The both number of additions and multiplications are considerably reduced for the proposed SLM. Fig. 2 shows PAPR reduction performance using complementary cumulative distribution function (CCDF).

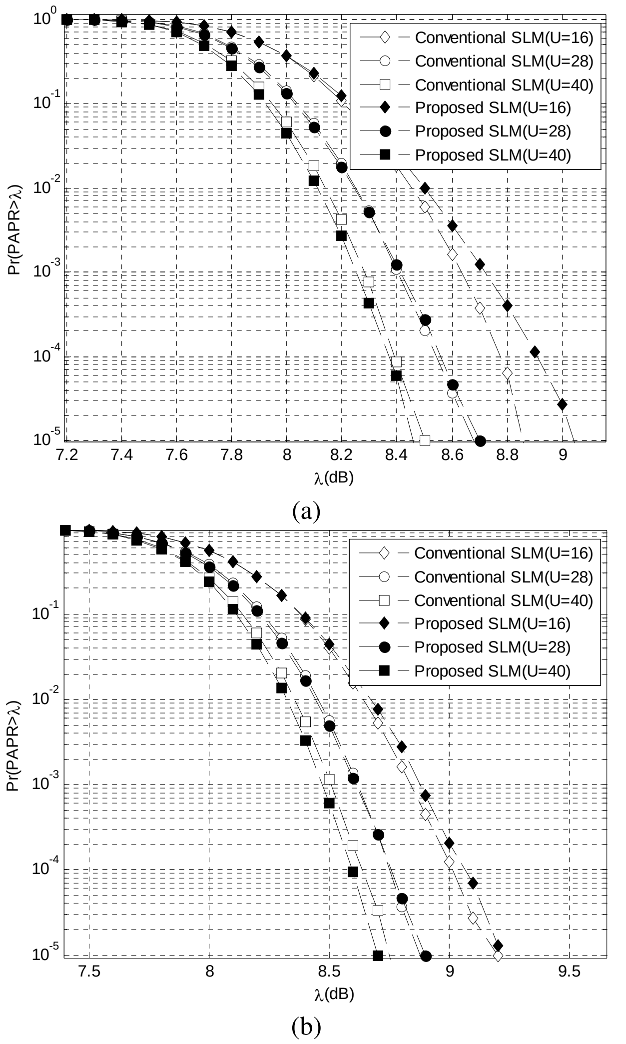

Fig. 2. PAPR reduction performances of the conventional SLM and the proposed SLM ($N = 512$, 16-QAM). (a) STBC. (b) SFBC.

IV. Conclusions

In this paper, additive mapping SLM scheme is applied to Alamouti coded OFDM systems. We derive and simulate the proposed scheme for SFBC-OFDM system. It can be adopted to any kind of MIMO-OFDM systems if input symbol sequence of one transmit antenna can be represented by linearly transforming input symbol sequence of another transmit antenna.

V. Acknowledgement

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References

[1] R. W. Bäuml, R. F. H. Fischer, and J. B. Huber, "Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping," *Electron. Lett.*, vol. 32, no. 22, pp. 2056–2057, Oct. 1996.

[2] H. -B. Jeon, S. -J. Heo, H.-S. Joo, J. -S. No, and D. -J. Shin, "PAPR reduction scheme of OFDM signals using additive mapping," in *Proc. KICS JCCI*, Apr. 2010, pp. 410–412.