PTS Scheme Using Additive Mapping Sequence for Peak Power Reduction in OFDM Systems

Hyun-Bae Jeon, Kee-Hoon Kim, Jong-Seon No
Department of EECS, INMC,
Seoul National University,
Seoul, 151-744, Korea,
{lucidream, kkh}@ccl.snu.ac.kr, jsno@snu.ac.kr

Dong-Joon Shin
Department of EE,
Hanyang University,
Seoul, 133-791, Korea,
djshin@hanyang.ac.kr

***Abstract*—In this paper, a new low-complexity partial transmit sequence (PTS) scheme is proposed, which generates alternative signal sequences by adding mapping signal sequences of each subblock to each signal subsequence. The proposed scheme considerably reduces the computational complexity without sacrificing BER and PAPR reduction performance, especially for the OFDM system with quadrature amplitude modulation (QAM).**

I. Introduction

One of the most critical drawbacks of orthogonal frequency division multiplexing (OFDM) is high peak to average power ratio (PAPR), which results in significant inter-modulation and undesirable out-of-band radiation when an OFDM signal passes through nonlinear devices such as high power amplifier (HPA) [1]. Since HPA with high linearity is too expensive, it is desirable to reduce PAPR of an OFDM signal in digital domain before it is converted to analog signal.

There are many schemes proposed to reduce PAPR of OFDM signal and partial transmit sequence (PTS) [2] is one of the most well-known PAPR reduction schemes. In PTS scheme, inverse Fourier transform (IFFT) is applied to the disjoint symbol subsequences of an OFDM symbol sequence and phase sequences are multiplied to the signal subsequences separately to generate the alternative signal sequences. As many IFFT as the number of subsequence is the main complexity of PTS scheme and many low-complexity PTS schemes have been suggested.

In this paper, a new low-complexity PTS scheme is proposed, which generates alternative signal sequences by adding mapping sequences to an OFDM signal sequence. The proposed scheme shows better PAPR reduction performance with less complexity compared with the conventional PTS scheme.

II. Conventional PTS Schemes

An input symbol sequence $\mathbf{A}$ is partitioned into V disjoint symbol subsequences $\mathbf{A}_v = [A_{v,0}, A_{v,1}, ..., A_{v,N-1}], v = 1,\ 2, ..., V$, where $A_{v,k} = 0, 0 \le k < N-1$ except for a single v. The signal subsequence $\mathbf{a}_v = [a_{v,0}, a_{v,1}, ..., a_{v,N-1}]$ is generated by IFFTing $\mathbf{A}_v$ and multiplied by a constant phase r_v^w usually chosen from $\mathcal{Z} = \{\pm 1\}$ or $\{\pm 1, \pm j\}$. The resulting PTS signal sequence $\mathbf{a}^{(u)} = [a_0^{(u)}, a_1^{(u)}, ..., a_{N-1}^{(u)}]$ is

$$\mathbf{a}^{(u)} = \sum_{v=1}^{V} r_v^w \mathbf{a}_v, \quad 0 \le u < |\mathcal{Z}|^{V-1}. \tag{1}$$

Among $U = |\mathcal{Z}|^{V-1}$ PTS signal sequences, the one with minimum PAPR is selected for transmission, where PAPR of $\mathbf{a}^{(u)}$ is defined as

$$\mathrm{PAPR}(\mathbf{a}^{(u)}) \doteq \frac{\max_{0 \le n < N} |a_n|^2}{\mathrm{E}\left[|a_n|^2\right]} \tag{2}$$

where $\mathrm{E}[\cdot]$ denotes the expectation operator.

III. A New PTS Scheme Using Additive Mapping Signal Sequence

In this section, we propose a new method to generate PTS signal sequences by additive representation. Additive mapping sequence for $A_{v,k}$ is defined as [3]

$$D_{v,k} = \begin{cases} d(-1-j)\sqrt{M}/2, & A_{v,k} \in \mathbf{Q}^{(1)} \\ d(+1-j)\sqrt{M}/2, & A_{v,k} \in \mathbf{Q}^{(2)} \\ d(+1+j)\sqrt{M}/2, & A_{v,k} \in \mathbf{Q}^{(3)} \\ d(-1+j)\sqrt{M}/2, & A_{v,k} \in \mathbf{Q}^{(4)} \\ 0, & A_{v,k} = 0 \end{cases} \tag{3}$$

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. $D_{v,k}$ can be expressed by the in-phase and quadrature components as $D_{v,k} = D_{v,k,I} + jD_{v,k,Q}$ and additive mapping signal sequences $\mathbf{d}_{v,I} = [d_{v,0,I}, d_{v,1,I}, ..., d_{v,N-1,I}]$ and $\mathbf{d}_{v,Q} = [d_{v,0,Q}, d_{v,1,Q}, ..., d_{v,N-1,Q}]$ are generated by IFFTing $\mathbf{D}_{v,I} = [D_{v,0,I}, D_{v,1,I}, ..., D_{v,N-1,I}]$ and $\mathbf{D}_{v,Q} = [D_{v,0,Q}, D_{v,1,Q}, ..., D_{v,N-1,Q}]$.

The PTS signal subsequences $\mathbf{m}_v^{(l)}, 0 \le l < 4$ can be generated by the linear combinations of these additive mapping signal sequences and $\mathbf{a}_v$, that is, $\mathbf{m}_v^{(0)} = \mathbf{a}_v$, $\mathbf{m}_v^{(1)} = \mathbf{a}_v + \mathbf{d}_{v,I}$, $\mathbf{m}_v^{(2)} = \mathbf{a}_v + j\mathbf{d}_{v,Q}$, and $\mathbf{m}_v^{(3)} = \mathbf{a}_v + \mathbf{d}_{v,I} + j\mathbf{d}_{v,Q}$. The resulting PTS signal sequence is given as

$$\mathbf{a}^{(u)} = \sum_{v=1}^{V} \mathbf{m}_v^{(l)}, \quad 0 \le u < 4^V. \tag{4}$$

Therefore, it is possible to generate 4^V PTS signal sequences for V subsequence partitioning.

The computational complexity of PTS scheme depends on the method of subsequence partitioning. In random subsequence partitioning, IFFT should be applied to each $\mathbf{A}_v$ and $\mathbf{D}_v$ and the total number of IFFT for V subsequence partitioning is $2V$. On the other hand, the total number of IFFT is reduced to 2 in the case of interleaved subsequence partitioning. In all cases, the total number of IFFT for the proposed PTS scheme is twice of that of the conventional PTS. However, the proposed PTS scheme can generate more PTS signal sequences than that of the conventional PTS scheme. Moreover, simulation results show that the proposed PTS scheme using interleaved subsequence partitioning suffers less PAPR performance degradation compared with the conventional PTS scheme. The additional complexity to combine the signal subsequences and calculate the peak value is negligible compared with that of IFFT.

IV. Simulation Results

In this section, the PAPR reduction performances of the conventional PTS scheme and the proposed PTS scheme are presented. The total number of PTS signal sequence U for the conventional PTS scheme is 8 and 64 for $V = 2$ and $V = 4$, respectively because $\mathcal{Z} \in \{\pm 1, \pm j\}$ while U for the proposed PTS scheme is 16 and 256 for $V = 2$ and $V = 4$, respectively. Fig. 1 shows CCDFs of the PTS schemes modulated with 16-QAM and 64-QAM for $N = 512$. The conventional PTS schemes using interleaved subsequence partitioning show the worst PAPR reduction performance regardless of the number of subsequences. On the other hand, the PAPR reduction performances for the proposed PTS scheme using interleaved subsequence partitioning are a little bit worse than those using random subsequence partitioning especially for 64-QAM. It is because the proposed PTS scheme changes the amplitude as well as the phase of input symbols to generate PTS signal sequence. Therefore, the proposed PTS scheme using interleaved subsequence partitioning can be a good PAPR reduction algorithm with low-complexity implementation.

V. Conclusion

In this paper, we propose a new PTS scheme using additive mapping sequence for PAPR reduction in OFDM systems. The proposed PTS scheme generates many PTS signal sequences by changing the amplitude as well as the phase of input symbols. Especially, the proposed PTS scheme using interleaved subsequence partitioning shows very good PAPR reduction performance with low-complexity implementation.

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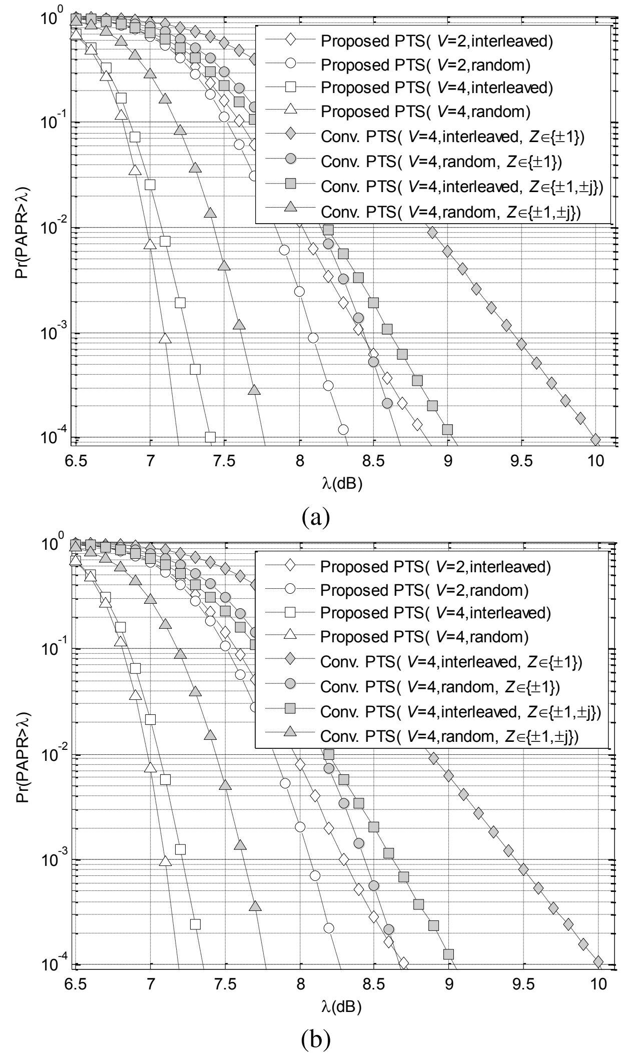

Fig. 1. Comparison of PAPR reduction performance of the conventional PTS and the proposed PTS for $N = 512$. (a) 16-QAM. (b) 64-QAM.

References

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