A Modified PTS Scheme with Monte Carlo Method for PAPR Reduction in OFDM Systems

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Abstract*-The peak-to-average power ratio (PAPR) reduction technique with low quantity of computation is proposed by combining the Monte Carlo Method and the partial transmit sequence (PTS). Its performance improvement in the orthogonal frequency division multiplexing (OFDM) is studied and analyzed. The Monte Carlo method, an important branch of computational algorithms, produces an experimental approximate solution from multiple experiments after the input data are generated randomly. In this paper, the Monte Carlo method is used to improve the large quantity of computation required for the partial transmit sequence. The simulation results show that the proposed method has great improvement in the high computation quantity for the partial transmit sequence technique while keeping the suboptimal PARP reduction performance.

I. INTRODUCTION

AlphaGo, an artificial intelligence program developed by Google DeepMind from 2015 to 2017 to play the Go game, caught the worldwide attention on artificial intelligence (AI) as it defeated a number of Go masters. The programming architecture of AlphaGo is based on the Monte Carlo tree search as its primary algorithm [1]. The Monte Carlo tress search is an algorithm derived from the Monte Carlo method. The Monte Carlo method is used to determine an experimentally approximate solution based on the statistic numeric analysis on samples of random distribution produced in a massive quantity. The Monte Carlo tree search, on the other hand, performs an experiment procedure by building a tree rather than carrying out an experiment randomly. As a result, the large quantity of computation required for the Monte Carlo method is simplified. The Monte Carlo method has been widely used in various fields of research [2-4], primarily for the study and analysis of simulation systems with random distribution, such as medical system and power grid. In several literatures, the Monte Carlo method was used to study the propagation of uncertainty in a quantitative imaging technique [3] or the lightning flashover rates in power lines [4]. Moreover, the probability distribution of Monte Carlo method was determined with the measurement of NAND devices and interpolation [5]. Based on the deployment of Monte Carlo method in these literature for the establishment and analysis of random systems, this paper is intended to study and analyze the peak-to-average power ratio (PAPR) issue in the orthogonal frequency division multiplexing (OFDM) system using the Monte Carlo method along with the partial transmit sequence (PTS) [6-7] so that the approach proposed serves to reduce the PAPR and quantity of computation required for searching.

II. THE PROPOSED METHOD

Assuming that an OFDM signal, $x(t)$, has a period, T, and N subcarriers, it is mathematically expressed as

$$x(t)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1}X_k e^{j\frac{2\pi k}{T}t},\ 0\le t\le T, \tag{1}$$

where $\mathbf{X}=\left(X_0,X_1,...,X_{N-1}\right)$, is the modulation symbol. The 16QAM modulation is selected for the modulation of the orthogonal frequency division multiplexing. An arbitrary 16QAM modulation signal is expressed mathematically as follows:

$$X_k=(\sqrt{2}j^{Q_1}+\frac{1}{\sqrt{2}}j^{Q_2})e^{j\frac{\pi}{4}},\{Q_1,Q_2\}\in Z_4 \tag{2}$$

First, for the purpose of the study, a data block after 16QAM modulation is divided into u subblocks with equal length N, $\overline{X}_i, 1\le i\le u,$ and the following is satisfied:

$$\sum_{i=1}^{u}\overline{X}_i=\mathbf{X} \text{ and } \overline{X}_i\cap\overline{X}_j=\phi\,, i\ne j \tag{3}$$

Then, the subblocks are converted into u PTSs using the Fourier transformation.

$$S_{\overline{X}_i}(t)=\sum_{k=1}^{N}\overline{X}_{i,k}\phi_k(t),\ 1\le i\le u \tag{4}$$

These PTSs are multiplied by a scrambling sequence consisting of only 1, $\mathbf{b}=(1,...,1)$, as the first candidate signal.

$$S_b(t)=\sum\nolimits_{i=1}^{u}b_i S_{\overline{X}_i}(t)=\sum\nolimits_{i=1}^{u}S_{\overline{X}_i}(t) \tag{5}$$

The PAPR of the signal is determined as a sample for the subsequent selection of transmission signal. Next, the number of scrambled phases generated, W-1, is determined by two factors: the number of groups, G_M and the number of samples, S_M, both of which shall satisfy

$$S_M\ge G_M \text{ and } W-1=G_M\times S_M\,.$$

On the other hand, the threshold PAPR_{TH} is used in this study to determine which PAPRs are smaller than PAPR_{TH}. For phase scrambling, the phase factor $b_i\in\{1,-1\}$ is provided in this paper as examples and generated randomly as uniform distribution. Assuming $q=1,...,G_M$, three conditions require attention when processing the S_M samples generated in the q^{th} group:

(a) If the PAPRs of the S_M samples are all greater than the threshold PAPR_{TH}, the phase scrambling change will be regenerated with uniform distribution for the S_M samples generated for the next group;

(b) If the PAPRs of the S_M samples are all smaller than or equal to the threshold $PAPR_{TH}$, the content of the scrambling sequence will be compared for the S_M samples. In addition to keeping the phase content after their intersections, the positions of different contents after their intersections have to be identified for phase scrambling in order to generate the S_M samples for the next group, where the change of phase scrambling is again generated randomly using uniform distribution.

(c) As in (b), it is assumed that B intersections are at the positions of different contents for the contents of S_M scrambling sequences. To further improve the performance of PAPR, a full search threshold B_{value} is defined and used in the proposed method. In simple terms, to generate all the possible results, the practice of (b) is executed when $B > B_{value}$, or the number of S_M samples in the next group will be 2^B.

For the selection of simulation parameters of OFDM, the number of subcarriers (*N*) is 512. For digital modulation, 16-QAM is selected as the primary modulation and 10,000 OFDM signals are used for statistical analysis. In the simulation, the 16QAM modulation signal is generated randomly with the probability density function of uniform distribution. On the other hand, for the selection of simulation parameters for PTS, the number of sub-blocks (*u*) is 16 and the changes of phase factor are {+1,-1}. Finally, for the selection of simulation parameters for the modified Monte Carlo method, the threshold ($PAPR_{TH}$) is {8,10,12} and that for quantity of searches (B_{value}) is 5, the number of groups (G_M) is 10 and number of samples (S_M) is {100,200,250}. A modified Monte Carlo method is proposed in this study as the phase generation mechanism for the traditional PTS with the introduction of two thresholds, the PAPR threshold and full search threshold. The proposed method generates phase factors in the same way that the Monte Carlo method is used to determine π. The PAPR threshold is used to simplify the quantity of computation required for the identification of phase factors. The full search threshold is used to improve the performance of the method proposed in terms of reducing PAPR. In Fig. 1, the signal with the smallest PAPR is selected as the transmission signal out of 2^{16} candidate signals for the traditional PTS. For the PTS with the use of modified Monte Carlo method, the transmission signal is selected out of $W = G_M \times S_M + 1$ candidate signals. According to Fig. 1, the PTS with modified Monte Carlo method does not perform as well as the traditional PTS in terms of the improvement of PAPR. However, it reduces the large quantity of searches required for the traditional PTS and the number of candidate signals drops from 2^{16} to *W*.

III. Conclusions

A modified Monte Carlo method is proposed in this study as the phase generation mechanism for the traditional PTS with the introduction of two thresholds, the PAPR threshold and full search threshold. The proposed method generates phase factors in the same way that the Monte Carlo method is used to determine π. The PAPR threshold is used to simplify the quantity of computation required for the identification of phase factors. The full search threshold is used to improve the performance of the proposed method in terms of reducing PAPR. The simulation result shows that the proposed method not only reduces the high quantity of computation required for the traditional PTS, but also has the suboptimal PAPR reduction performance.

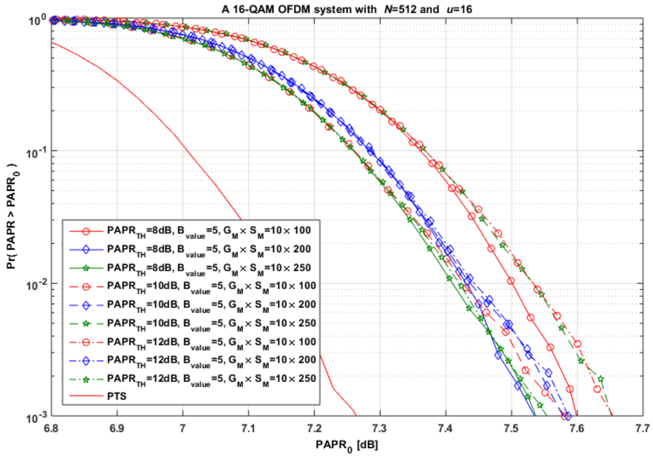

Fig. 1: PAPR improvement performance for the 16-QAM modulated OFDM with 512 subcarriers.

IV. References

[1] BBC News, "Artificial intelligence: Google's AlphaGo beats Go master Lee Se-dol," Retrieved 17 March 2016.

[2] D. P. Kroese, T. Brereton, T. Taimre and Z. I. Botev, "Why the Monte Carlo method is so important today," *Wiley Interdisciplinary Reviews: Computational Statistics*, vol.6, no.6, pp. 386-392, Jun. 2014.

[3] A. Arduino, M. Chiampi, F. Pennecchi, L. Zilberti and O. Bottauscio, "Monte Carlo Method for Uncertainty Propagation in Magnetic Resonance-Based Electric Properties Tomography," *IEEE Transactions on Magnetics*, vol. 53, no.11, June 2017.

[4] Sandro de Castro Assis, Wallace do Couto Boaventura and Jose Osvaldo Saldanha Paulino, "Lightning Performance of Transmission Line: Comparison IEEE Flash and Monte Carlo Method," *IEEE Latin America Transactions*, vol. 15, no.2, pp. 269 – 274, Feb. 2017.

[5] H. Li, "Modeling of Threshold Voltage Distribution in NAND Flash Memory: A Monte Carlo Method," *IEEE Transactions on Electron Devices*, vol. 63, no. 9, pp. 3527-3532, Sep. 2016.

[6] K. S. Lee, Y. J. Cho, J. Y. Woo, J. S. No and D. J. Shin, "Low-complexity PTS schemes using OFDM signal rotation and pre-exclusion of phase rotating vectors, "*IET Communications*, vol. 10, no.5, pp. 540 -547, March 2016.

[7] H. Liang, Z. Lin, H. Chen and C. Y. Yang, "A Modified Genetic Algorithm PTS Technique with Error Correction for PAPR Reduction in OFDM Systems," *in Proc. IEEE ISITA 2010*, Taichung, Taiwan, Oct. 2010.