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A PAPR Reduction Scheme based on Improved PTS with ABC Algorithm for OFDM Signal

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***Abstract*—A high PAPR is well known as the serious problem of OFDM system because of a huge degradation of its signal quality, especially in the non-linear channel. From the reason, many PAPR reduction schemes have been proposed for solving this problem. The Partial Transmit Sequence (PTS) scheme is one of the PAPR reduction schemes which can improve the PAPR performance effectively. However, its computational complexity would be increased which is proportional to the increasing number of symbol clusters in the optimum PAPR value for a PAPR reduction process. To solve this problem, this paper proposes the PAPR reduction scheme based on the improved PTS with Artificial Bee Colony (ABC) algorithm for OFDM system. The potential capability of the proposed scheme is the PAPR reduction performance with low computational complexity which leads to the improvement of signal quality in the OFDM system. The excellent PAPR reduction performance with the low computational complexity of the proposed scheme has been verified by the computer simulations in this paper.**

***Index Terms*—high PAPR, OFDM, PAPR reduction scheme; improved PTS; ABC algorithm**

I. Introduction

The Orthogonal Frequency Division Multiplexing (OFDM) technique is the most popular technique for wireless communication because of its advantages such as the robustness to the multi-path channel, the efficient usage of the communication bandwidth, and so on. Many transmission standards in the wireless communication system [1-4] have taken the OFDM technique such as WLAN (Wireless LAN), DTV (Digital Television Broadcasting System) and mobile communication system in the next generation i.e 4G, 5G etc. From these reasons, the various signal quality improvement schemes based on OFDM technique have been proposed by many researchers such as the channel estimation scheme [5-6], the equalization scheme [7], etc.. However, the high Peak to Average Power Ratio (PAPR) is the main problem of using OFDM technique which is cause of Bit-Error-Rate (BER) degradation and Spectrum frequency expansion in the non-linear channel.

From the PAPR problem as mentioned in the previous paragraph, many PAPR reduction schemes have been proposed [8-12] such as clipping and filtering, selected mapping (SLM), partial transmit sequence (PTS) schemes and so on. These proposed PAPR reduction schemes could solve the PAPR problem which can improve the signal quality performance. The PTS scheme is a popular scheme which can achieve better PAPR performance by dividing each symbol into V clusters and multiplying each cluster by the optimum weighting factors. Although its PAPR reduction performance could be improved, its high computational complexity in the optimum PAPR value for the PAPR reduction process is a concerned issue for discussion in many recent papers.

From this issue, this paper focuses on the enhancement of PAPR reduction performance without the increase of the computational complexity. To satisfy the requirements, this paper proposes the PAPR reduction scheme based on the improved PTS (IPTS) with a weighting factor determination by using Artificial Bee Colony (ABC) algorithm. The silent features of the proposed scheme are to reduce PAPR by splitting each symbol cluster in half and multiplying each period of the cluster by two different weighting factors and to decrease the computational complexity by applying the ABC algorithm to generate the weighting factor.

The remainder of this paper is organized as follows: Section II gives a brief overview of the OFDM signal with PAPR properties in the non-linear channel. Section III presents the idea of proposed PAPR reduction scheme with low computational complexity. Then, the computer simulation results are presented in Section IV. Finally, Section V concludes this paper.

II. The OFDM Signal with PAPR Properties

The OFDM system which is considered in this paper is shown by the block diagram in Figure 1. In the figure, by using the IFFT processing the information data signal $X_{m,n}$ at n-th subcarrier of m-th symbol is transformed between the frequency and time domains at the transmitter. The information signal in time domain after N-point IFFT processing can be expressed as,

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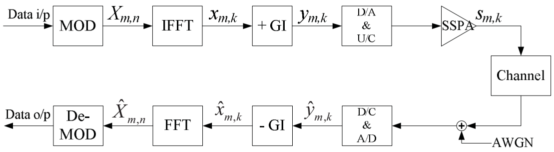

Fig.1 Block diagram of OFDM system.

$$x_{m,k}=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}X_{m,n}e^{j\frac{2\pi kn}{N}} \tag{1}$$

Meanwhile, the time domain signal $X_{m,n}$ is added by guard interval (GI) to be the output signal $y_{m,k}$ at k-th sampling point of m-th symbol. Then, $y_{m,k}$ is fed into the digital to analog and uplink converters respectively. Finally, the transmitted signal after amplified by the non-linear Solid State Power Amplifier (SSPA) with AM/AM conversion can be given by,

$$s_{m,k}=F\left[\left|y_{m,k}\right|\right]e^{j\{\arg(y_{m,k})\}} \tag{2}$$

where the conversion characteristic of amplifier is represented by $F[\ ]$. At the receiver, the received signal $\hat{y}_{m,k}$ after the downlink and analog to digital converters respectively is removed the GI and then it is converted into the frequency domain before demodulation.

The PAPR of the OFDM signal which is performed in this paper can be defined by dividing the maximum power of OFDM signal by the averaged power of OFDM signal which is given by,

$$PAPR=\frac{\underset{0\le k\le N-1}{Max}\left[\left|y_{m,k}\right|^2\right]}{\underset{0\le k\le N-1}{Average}\left[\left|y_{m,k}\right|^2\right]} \tag{3}$$

III. Overview on Proposed PAPR Reduction Scheme with Low Computational Complexity

In order to reduce the larger PAPR of OFDM signal, this section shows the proposed PAPR reduction scheme based on improved PTS with Artificial Bee Colony algorithm.

A. PAPR reduction by using PTS scheme[9]

Figure 2 shows the structure of PTS scheme. In the figure, data signal $X^v_{m,n}$ will be obtained by dividing the modulation data $X_{m,n}$ by V clusters ($1\le v\le V-1$). To find the optimum PAPR value, N-point IFFT signal $x^v_{m,k}$ of each cluster is multiplying by the weighting factor $e^{j\phi^v_{m,k}}$ which can be defined by $e^{j\phi^v_{m,k}}\in\left\{\frac{2\pi l}{W}\middle| l=0,...,W-1\right\}$ where W is the number of discrete phases. The output signal $y_{m,k}$ can be given by,

$$y_{m,k}=\sum_{v=1}^{V}x^v_{m,k}\cdot e^{j\phi^v_{m,k}} \tag{4}$$

From (4), the optimum weighting factor $e^{j\phi^v_{m,k}}$ for multiplying the time domain information data after IFFT process at each cluster will be calculated by the following equation,

$$\tilde{V}=\min_{0\le l\le W-1}\left\{\max_{0\le k\le N-1}\left|\sum_{v=1}^{V}x^v_{m,k}\cdot e^{j\phi^v_{m,k}}\right|\right\} \tag{5}$$

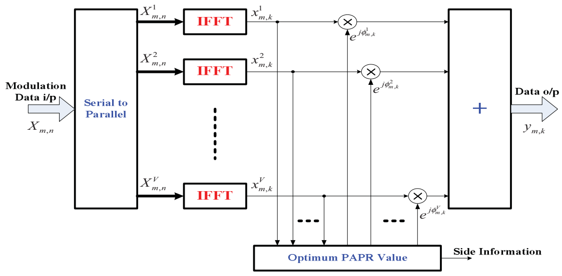

Fig.2 The structure of conventional PTS scheme.

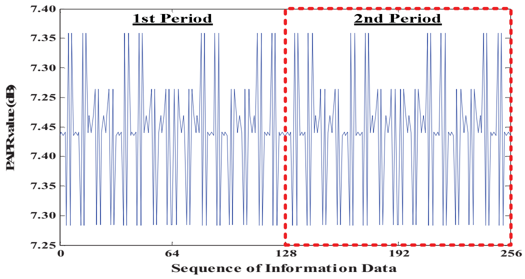

Fig.3 PAPR values of time domain OFDM signal.

where $\tilde{V}$ is the optimized argument to obtain the phase coefficient which can reduce to the lowest PAPR value.

For the distribution of PAPR, the possible number of PAPR values could be calculated by,

$$N_{PAPR}=\left[Modulation\ Level\right]^M \tag{6}$$

where M is the number of data subcarrier and Modulation Level $=2^{data-bit}$ (i.e data-bit: 2 bits for QPSK, 4 bits for 16QAM etc.). From (6), the possible number of PAPR values correspond to the number of data subcarriers. Therefore, by using the PTS scheme it is very difficult to find its optimum weighting factor in the PAPR reduction process when increasing M data subcarriers because its N_{PAPR} would be increased proportionally.

In the following, four information data sequences with 4 subcarriers (M=4) are inputted for the OFDM system and modulated by QPSK as $1+i, 1-i, -1+i$ and $-1-i$ respectively. By using the PTS scheme for PAPR reduction with 2 phases [0 and π], the PAPR values for all information sequences are calculated by (3) which are displayed in Figure 3. Meanwhile, its N_{PAPR} calculated by (6) is 4^4 or 256 values. From the Figure 3, it can be observed that there are the same PAPR values which can be separated by 2 periods as 1st and 2nd periods respectively. This means that the PAPR value can be calculated only one of two clusters. From this reason, the computational complexity by using the PTS scheme could be improved.

B. Improved PTS scheme[10]

From the characteristics of using the conventional PTS scheme as mentioned in the previous section, the conventional PTS is modified for PAPR performance enhancement by partitioned each cluster into 2 periods and multiplying each

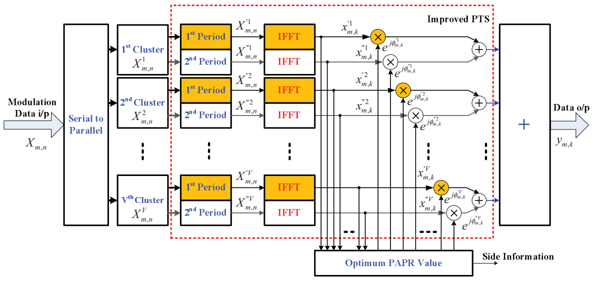

Fig.4 The PAPR reduction by using IPTS scheme.

period by different phase coefficients as shown in Figure 4. The output signal $y_{m,k}$ in the IPTS process can be given by,

$$y_{m,k} = \sum_{v=1}^{V}\left\{x'^{v}_{m,k} \cdot e^{j\phi'^{v}_{m,k}} + x''^{v}_{m,k} \cdot e^{j\phi''^{v}_{m,k}}\right\} \tag{7}$$

The phase coefficients $\phi'^{v}_{m,k}$ and $\phi''^{v}_{m,k}$ for weighting factors $e^{j\phi'^{v}_{m,k}}$ and $e^{j\phi''^{v}_{m,k}}$ in the improved PTS (IPTS) process can be expressed as,

$$\phi''^{v}_{m,k} = \frac{\phi'^{v}_{m,k}}{2} \quad \& \quad \phi'^{v}_{m,k} \in \left\{\tfrac{2\pi l}{W}\middle| l=0,\ldots,W-1\right\} \tag{8}$$

where $\phi'^{v}_{m,k}$ and $\phi''^{v}_{m,k}$ are the phase coefficients for 1st and 2nd periods respectively.

C. PAPR reduction with low computational complexity by using Artificial Bee Colony algorithm

To decrease the computational complexity of the PAPR reduction process in IPTS scheme. The ABC algorithm is applied for determining the weighting factors in the IPTS scheme which can achieve better the PAPR performance with low computational complexity. By applying the ABC algorithm, the phase coefficients can be produced by the following equation,

$$\phi'^{v}_{m,k}{}'(p,q) = \phi'^{v}_{m,k}(p,q) + \beta_{p,q}\left(\phi'^{v}_{m,k}(p,q) - \phi'^{v}_{m,k}(s,q)\right) \tag{9}$$

where p and s=1,2,…,SN when $p \neq q$, SN denotes the size of a randomly which is distributed the initial population and q is $\{1,2,\ldots,V\}$ as well as $\beta_{p,q}$ is a random number between [1,1] [11]. As $\phi'^{v}_{m,k}{}'(p,q)$ is the discrete coordinate, therefore, the selected phase coefficients when W=4 can be calculated by the phase coefficients in (9) which is given by,

$$\phi'^{v}_{m,k} = \begin{cases} \frac{\pi}{2}, & if \ \frac{\pi}{4} \le \phi'^{v}_{m,k}{}'(p,q) < \frac{3\pi}{4} \\ \pi, & if \ \frac{3\pi}{4} \le \phi'^{v}_{m,k}{}'(p,q) < \frac{5\pi}{4} \\ \frac{3\pi}{2}, & if \ \frac{5\pi}{4} \le \phi'^{v}_{m,k}{}'(p,q) < \frac{7\pi}{4} \\ 0, & if \quad else \end{cases} \tag{10}$$

From (8), it can be rewritten the relationship phase coefficients between $\phi'^{v}_{m,k}$ and $\phi''^{v}_{m,k}$ which can be given by [12],

$$\phi''^{v}_{m,k} = \lambda \cdot \phi'^{v}_{m,k} \tag{11}$$

where λ is the constant value.

From (7) and (11), it can be confirmed that the PAPR performance of using IPTS scheme can be improved with keeping the same side information size as that of using PTS scheme. Meanwhile, by using (9) and (10) for generating the phase coefficients in the IPTS scheme, its computational complexity is corresponded to SN. The optimum λ value and SN to obtain the better PAPR value and the lower computational complexity respectively will be decided in the next section.

IV. SIMULATION RESULTS

Table I shows the parameters using in the computer simulation. By using these parameters, the various computer simulation results can confirm the effectiveness of the proposed scheme in this paper.

TABLE I. SIMULATION PARAMETERS.

Modulation technique for informantion data	16QAM
Demodulation	Coherent
OFDM occupied bandwidth	5MHz
N-points $IFFT$	256 and 512
M data subcarriers	64 and 128
V clusters per symbol	4
W weighting factor	4
SN randomly distribution size	128

Figure 5 shows the average of PAPR performance for the proposed scheme when changing λ value in (11). From the simulation, M subcarriers are taken by 64 and 128 respectively for comparison which thier oversampling ratios are 3, and SN is 128 as well as the adjacent type is considered. From the results, it can be seen that the proposed scheme can obtain the best PAPR performance when $\lambda = 0$. From this reason, the optimum λ value of using in the proposed scheme is 0.

Figure 6 shows the PAPR performance for the PAPR reduction schemes with the Adjacent and Interleved [13]. In the simulation, the Complementary Cumulative Distribution Function (CCDF) is evaluated to show when changing the $PAPR_o$ (dB). From the figure, it can be seen that the proposed schemes with SN=128 can achieve better PAPR performance at 10^{-1} of the CCDF than the conventional PTS scheme by 0.3 dB and 0.2 dB approximately in case of adjacent and interleaved types respectively. Here it should be noted that the Bit Error Rate (BER) performance is depended on the PAPR performance at 10^{-1} of the CCDF. From this reason, it can be expected that the proposed scheme would be better the BER performance than the conventional PTS scheme

Furthermore, the computational complexity of the PAPR reduction schemes at 10^{-1} of the CCDF can be given by the following equation,

$$\begin{aligned} PTS_{comp} &= \frac{M}{V} \cdot W^{V} \\ Proposed_{comp} &= \frac{1}{2} \cdot (1+\lambda)\frac{M}{V} \cdot SN \end{aligned} \tag{12}$$

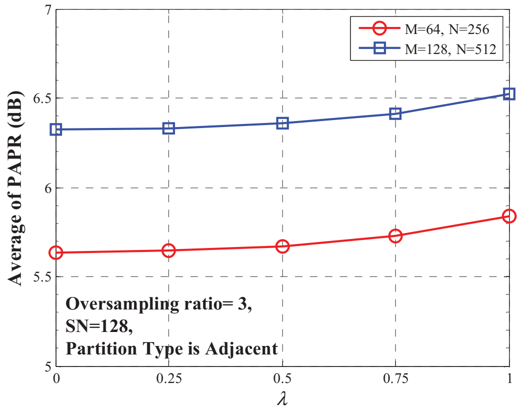

Fig. 5 Average of PAPR performance when changing λ in (11).

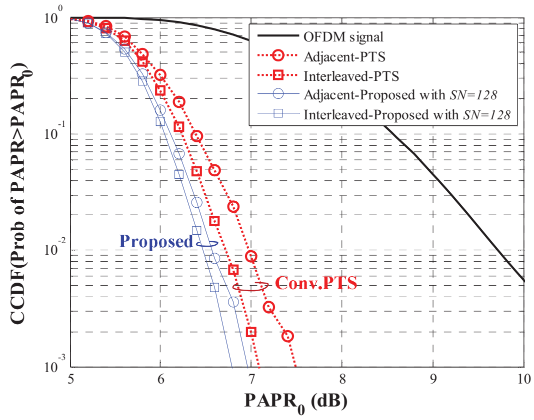

Fig. 6 PAPR Performance of proposed scheme by using adjacent with $\lambda = 0$.

TABLE II. COMPUTATIONAL COMPLEXITY BETWEEN PROPOSED AND CONVENTIONAL SCHEMES.

<table>
<tr><th colspan="2">Schemes</th><th>PAPR value (dB) CCDF at 10^{-1}</th><th>Complexity in Eq.(12) (M=64)</th><th>Improvement from PTS (%)</th></tr>
<tr><td colspan="2">Adjacent-PTS</td><td>6.40</td><td rowspan="2">4,096</td><td rowspan="2">100</td></tr>
<tr><td colspan="2">Interleaved-PTS</td><td>6.25</td></tr>
<tr><td>Adjacent-Proposed</td><td rowspan="2">SN=128, $\lambda = 0$</td><td>6.10</td><td rowspan="2">1,024</td><td rowspan="2">25</td></tr>
<tr><td>Interleaved-Proposed</td><td>6.05</td></tr>
</table>

From Table II, it can be seen that the proposed scheme can perform better the PAPR performance at 10^{-1} of the CCDF than the conventional PTS scheme with only 25 percent calculated by (12) for the computational complexity of the PAPR reduction performance process which improves from the conventional PTS scheme. From both results in Figure 6 and Table II, it can be concluded that the proposed scheme provides much better PAPR performance with low computational complexity compared with the conventional PTS scheme.

V. CONCLUSIONS

This paper proposed the PAPR reduction scheme based on the improved PTS with Artificial Bee Colony algorithm for OFDM signal. To obtain the optimum weighting factor for achieving better the PAPR performance, the relationship between phase coefficients in the 1st and 2nd periods respectively is also considered by changing the λ values. From the computer simulation results, it can be shown that the proposed PAPR reduction scheme based on the improved PTS with Artificial Bee Colony algorithm outperforms that with the conventional PTS scheme significantly both for the PAPR performance and the computational complexity.

REFERENCES

[1] IEEE LAN/MAN Committee, "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE, 2007.

[2] IEEE WAN Committee, "Air Interface for Broadband Wireless Access Systems," IEEE, 2009.

[3] ETSI DVB-T2 Committee, "Frame Structure Channel Coding and Modulation for a second Generation Digital Terrestial Television Broadcasting System (DVB-T2)," ETSI, May 2008.

[4] E.Dahlman, S.Stefan, J.Skold and P.Beming, "3G Evolution: HSPA and LTE for Mobile Broadband," Elsevier Ltd., 2nd, 2008.

[5] Z.Sheng, H.D.Tuan, H.H.Nguyen and Y.Fang, "Pilot Optimization for Estimation of High-Mobility OFDM Channels,"IEEE Trans. On Vehicular Tech., Vol. 66, no. 10, pp. 8795-8806, Oct.2017.

[6] H.Wu, Y.Liu and K.Wang, "Analysis of DFT-Based Channel Estimation for Uplink Massive MIMO Systems," IEEE Comm. Lett., vol. 22, no. 2, pp. 328-331, Feb.2018.

[7] E.Vlachos, A.S.Lalos and K.Berberidis, "Low-Complexity OSIC Equalization for OFDM-Based Vehicular Communications," IEEE Trans. On Vehicular Tech., Vol. 66, no. 5, pp. 3765-3776, May 2017.

[8] J.Zhao, S.Ni and Y.Gong, "Peak-to-Average Power Ratio Reduction of FBMC/OQAM Signal using a Joint Optimization Scheme", IEEE Access, vol.5, pp.15810-15819, May 2017.

[9] H.S.Joo, K.H.Kim, J.S.No and D.J.Shin, "New PTS Schemes for PAPR Reduction of OFDM Signals without Side Information", IEEE Trans. On Broad., vol.63, no.3, pp.562-570, Sept.2017.

[10] P. Boonsrimuang, K.Mori, T. Paungma, and H. Kobayashi, "Proposal of improved PTS method for OFDM signal," in PIMRC2007, March, 2006.

[11] Y.Wang, W.Chen and C.Tellambura, "A PAPR reduction method based on Artificial Bee Colony algorithm for OFDM signals," IEEE Trans. Wireless Commun., vol. 9, no. 10, pp. 2994-2999, Aug. 2010.

[12] T.Mata, P.Boonsrimuang, P. Boonsrimuang and H. Kobayashi, "Proposal of improved PTS method for STBC MIMO-OFDM system," IEICE Trans. Commun., vol. E93-B, no. 10, pp. 2673-2676, Oct. 2010.

[13] J.Sarawong, T.Mata, P.Boonsrimuang and H. Kobayashi, "Interleaved Partitioning PTS with New Phase Factors for PAPR Reduction in OFDM Systems," ECTICON2011, May. 2011.