

A PAPR Reduction for FBMC-OQAM Signals using ABC-OPTS Scheme

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Abstract—Partial Transmit Sequence (PTS) scheme has been applied to the OFDM signal for solving the high PAPR problem which can achieve better PAPR performance. However, because of the structure of the FBMC-OQAM signal which is different from the OFDM signal, the PTS scheme is not suitable for the FBMC-OQAM signal. For this reason, this paper considers the PAPR reduction for FBMC-OQAM signal. This paper proposes an overlapped PTS (OPTS) with Artificial Bee Colony (ABC) algorithm. The silent features are to improve the PAPR by modifying the PTS scheme as OPTS scheme and less computational complexity in the PAPR optimization process by using the ABC algorithm. The PAPR reduction effectiveness of the proposed method has been confirmed by the simulation results in the paper.

Keywords—PTS, FBMC-OQAM, PAPR reduction; OPTS; ABC algorithm

I. INTRODUCTION

In wireless communications, the multicarrier modulation is the key to the transmission technique. One of the popular multicarrier modulation techniques is Orthogonal Frequency Division Multiplexing (OFDM) because of its potential capability as the robustness to the multi-path channel, high spectral efficiency, and so on. Many wireless communication services are taken by the OFDM system such as digital television and audio broadcasting system, wireless networks and the next generation mobile communications (i.e., 4G, 5G, etc.).

One of the limitations of the OFDM signal is the high out-of-band of the radiation [1] because of the guard interval (GI) insertion in the OFDM signal. To solve this issue, the filter bank multicarrier with offset quadrature amplitude (FBMC-OQAM) [2] technique has been proposed which can reduce the out-of-band of the radiation. Because the FBMC-OQAM signals no need the insertion of GI parts for the data transmission. However, the main

problem of the FBMC-OQAM signal which is the same as the OFDM signal is the higher Peak-to-Average Power Ratio (PAPR) of the data transmission in the time domain which leads to the distortion of the output signal of the non-linear channel. To solve this problem, many PAPR reduction schemes have been proposed [3-5] especially the PAPR reduction schemes which are proposed for the OFDM signals such as the PTS scheme. As the PTS scheme will optimize the PAPR value for each OFDM symbol independently, it is difficult to apply to FBMC-OQAM signals directly. Because of the structure of FBMC-OQAM signals, the overlapped symbol by the previous symbol will occur. For this reason, if the PTS scheme is applied to FBMC-OQAM directly, its PAPR performance is not effective.

In this paper, we propose an overlapped PTS scheme as OPTS scheme to improve the PAPR in FBMC-OQAM signals. For the proposed OPTS scheme, the PAPR optimization process is modified from the conventional PTS (CPTS) scheme, the overlapped signals by the previous symbol signals are considered to find the optimum PAPR value. As the huge computation complexity in the conventional PTS scheme especially when the cluster is larger, the artificial bee colony algorithm is applied to the proposed OPTS scheme so as to reduce the computational complexity in the PAPR optimization process.

The reminders of this paper are organized as follows: Section II presents the FBMC-OQAM signals with PAPR reduction. In Section III, the ABC-OPTS scheme is proposed for FBMC-OQAM signals. Then, Section IV shows the performance

evaluation results. Finally, Section V concludes this paper.

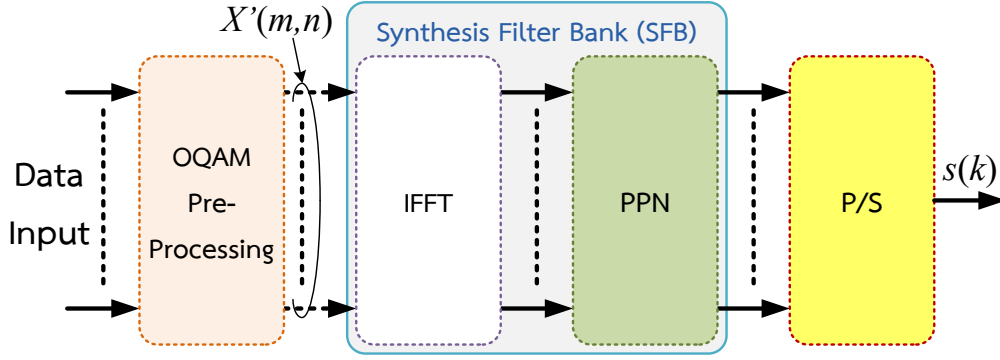


Figure 1. A block diagram of FBMC-OQAM transmitter.

II. FBMC-OQAM SYSTEM AND PAPR

A. FBMC-OQAM Signal

Figure 1 shows the structure of FBMC-OQAM transmitter. In the FBMC-OQAM transmitter, the modulation data can be given by,

$$X'(m,n) = \text{Re}\{X(m,n)\} + j \text{Im}\{X(m,n)\}, \quad (1)$$

where $X'(m,n)$ is the modulation data at the m -th symbol ($1 \leq m \leq L$) and the n -th subcarrier ($0 \leq n \leq M-1$) including real $\text{Re}\{X(m,n)\}$ and imaginary $\text{Im}\{X(m,n)\}$ parts of $X(m,n)$ symbol respectively. L is the number of OQAM symbols and M is the number of subcarriers.

The imaginary $\text{Im}\{X(m,n)\}$ part of the $X(m,n)$ symbol is shifted by $\frac{T}{2}$ to right from the real $\text{Re}\{X(m,n)\}$ part of the $X(m,n)$ symbol as shown in Fig.2. The OQAM symbols are converted into the time-domain by IFFT with N -points then process by the polyphase network (PPN) [6].

The time domain transmitted signal $s(k)$ at the k -th sample can be given by,

$$s(k) = \sum_{m=1}^L \sum_{n=0}^{M-1} \left\{ \text{Re}\{X(m,n)\} h(k - (m-1)T) + j \text{Im}\{X(m,n)\} h(k - (m-1)T - \frac{T}{2}) e^{-j\pi n} \right\} e^{j\frac{2\pi nk}{T}}, \quad (2)$$

where $h(k - (m-1)T - \frac{T}{2})$ is the impulse response of the PHYDYAS prototype filter [7].

B. PAPR

The Peak-to-Average Power Ratio (PAPR) of the continuous time multicarrier signal can be defined by,

$$PAPR\{s(k)\} = \frac{\text{Max}_{qT \leq k \leq (q+1)T} |s(k)|^2}{E[|s(k)|^2]} \quad (3)$$

where $q = 0, 1, \dots, M + K - 1$, K is the overlapping factor which is the ratio between the impulse response of filter duration and T symbol period. $E[\cdot]$ represents the expectation operator.

To observe the PAPR reduction, the complementary cumulative distribution function (CCDF) is evaluated as the PAPR performance which can be given by,

$$CCDF(PAPR\{s(k)\}) = \Pr(PAPR\{s(k)\} > PAPR_{TH}) \quad (4)$$

where $PAPR_{TH}$ is the threshold of PAPR.

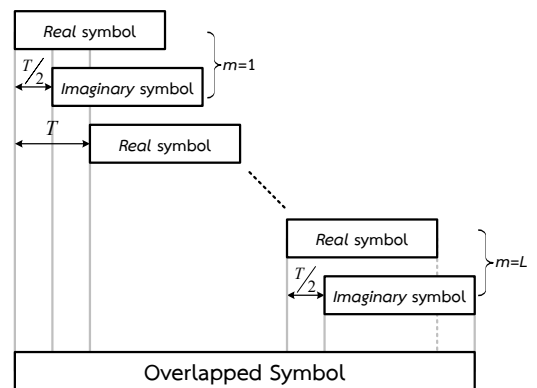


Figure 2. A structure of FBMC-OQAM symbol.

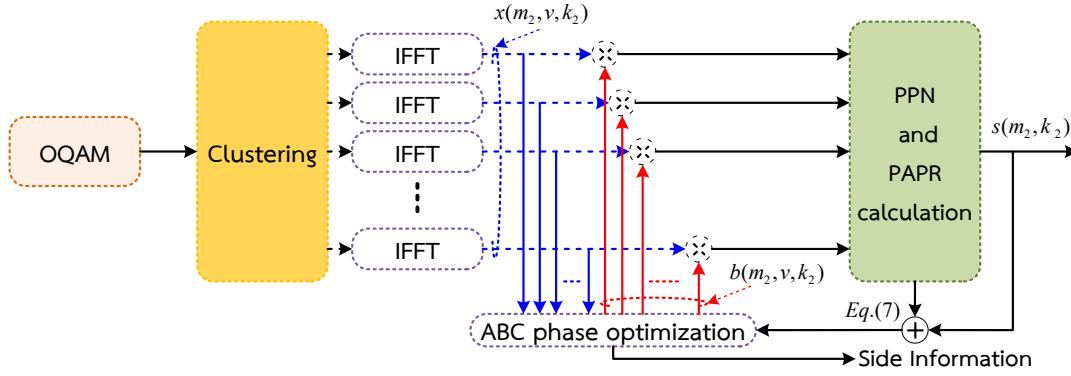


Figure 3. FBMC-OQAM with PAPR reduction by using the proposed OPTS scheme

III. PROPOSAL OF ABC-OPTS METHOD

A. Overlapped PTS (OPTS) Technique

The Partial Transmit Sequence (PTS) scheme[6] is one of the popular solutions for solving the larger PAPR which is the main problem in the multicarrier signal. In the basic concept of the PTS scheme, the modulation data will be divided into V clusters then each cluster is multiplied by a weighting factor in PAPR optimization process which can be express as,

$$s(m_1, k_1) = \sum_{v=1}^V \{b(m_1, v, k_1) \cdot x(m_1, v, k_1)\}, \quad (5)$$

and

$$b = \min_{b_v} \left\{ \max \left| \sum_{v=1}^V \{b(m_1, v, k_1) \cdot x(m_1, v, k_1)\} \right| \right\} \quad (6)$$

where $s(m_1, k_1)$ is the time domain transmit signal after PAPR optimization with PTS scheme at the m_1 -th symbol ($1 \leq m_1 \leq L$) and the k_1 -th sample ($0 \leq k_1 \leq T$) and $b(m_1, v, k_1)$ is weighting factor at v -th cluster. Equation (5) and (6), it can be shown that each symbol has optimized its PAPR value independently. However, the overlapped symbol by the previous symbol in the FBMC signal always occurs as shown in Fig. 2. From this reason, it is very difficult in PAPR optimization by applying the PTS scheme directly. To solve this issue, the PTS scheme is modified as overlapped PTS (OPTS) scheme to apply for PAPR optimization process in the FBMC signal with 4 up-sampling as shown in Fig.3 which can be given by,

$$s(m_2, k_2) = s(m_2 - 1, k_2 + \frac{T}{2}) + \sum_{v=1}^V \{b(m_2, v, k_2) \cdot x(m_2, v, k_2)\}, \quad (7)$$

where $s(m_2, k_2)$ is the overlapped time domain transmit signal after PAPR optimization by OPTS scheme at the m_2 -th symbol ($1 \leq m_2 \leq 4L$) and the k_2 -th sample ($0 \leq k_2 \leq 4T - 1$). Then the weighting factor b of proposed OPTS scheme can be considered by the following equation

$$b = \min_{b_v} \left\{ \max \left| \sum_{v=1}^V \left\{ s(m_2 - 1, k_2 + \frac{T}{2}) + \sum_{v=1}^V \{b(m_2, v, k_2) \cdot x(m_2, v, k_2)\} \right\} \right| \right\} \quad (8)$$

B. Artificial Bee Colony (ABC) Algorithm for PAPR optimization

As the computational complexity of the conventional PTS scheme is too high due to the finding of phase optimization which is W^{V-1} possible phase factors [9], especially when the number of the cluster becomes larger. To solve this problem, the Artificial Bee Colony algorithm [10] is applied to the proposed OPTS scheme as ABC-OPTS scheme so as to use for searching the optimum phase.

In the ABC-OPTS scheme, a weighting factor as a food source position is denoted by $\mathbf{b}_q = [b(q, v)]^T$, $v = 1, 2, \dots, V$ and $q = 1, 2, \dots, SN$ which can be determined the fitness value of its PAPR solution by the following equation,

$$fitness(\mathbf{b}_q) = \frac{1}{1 + PAPR(\mathbf{b}_q)}, \quad (9)$$

where SN is the size of a food source position $\mathbf{b}_q$, which is the initial population with a random distribution.

The weighting factor which is calculated from the candidate food source position by each employed bee can be produced by,

$$b'(q, v) = b(q, v) + \phi(q, v) \{b(q, v) - b(p, v)\} \quad (10)$$

where $p = 1, 2, \dots, SN$ and $q \neq p$. $\phi(q, v)$ is a random number between $[-1, 1]$. Because of $b'(q, v)$ is the discrete phase, therefore (10) can be considered in case of $W = 2$ by the following equation,

$$b'(q, v) = \begin{cases} 1, & \text{if } \frac{\pi}{4} \leq b'(q, v) < \frac{5\pi}{4} \\ -1, & \text{else} \end{cases} \quad (11)$$

A food source which is selected by each onlooker bee can be calculated by,

$$O_q = \frac{fitness(\mathbf{b}_q)}{\sum_{q=1}^{SN} fitness(\mathbf{b}_q)}, \quad (12)$$

In case of unable to get better values which are considered by the number of cycles, it can be selected the weighting factor by,

$$b(q, v) = b(\min, v) + rand * \{b(\max, v) - b(\min, v)\} \quad (13)$$

where $rand$ is the random number between $[0, 1]$.

IV. PERFORMANCE EVALUATION

This section presents the effectiveness of the proposed ABC-OPTS scheme by the computer simulation results which are evaluated by the parameter listed by Table 1.

Figure 4 shows the PAPR performance of the proposed ABC-OPTS scheme. In the simulation, $SN = 20$ and 40 , $Limit = 5$, and it which is the number of cycles = 20 are used for the proposed ABC-OPTS scheme respectively. From the Fig.5, At $CCDF = 10^{-1}$, the PAPR of original FBMC is 9dB.

TABLE 1. SIMULATION PARAMETERS

Parameters	Information
Modulation technique	OQPSK
Demodulation	Coherent
OFDM occupied bandwidth	5MHz
N -points IFFT	256
M data subcarriers	64
V clusters	16
W discrete phases	2
Prototype filter	PHYDYAS

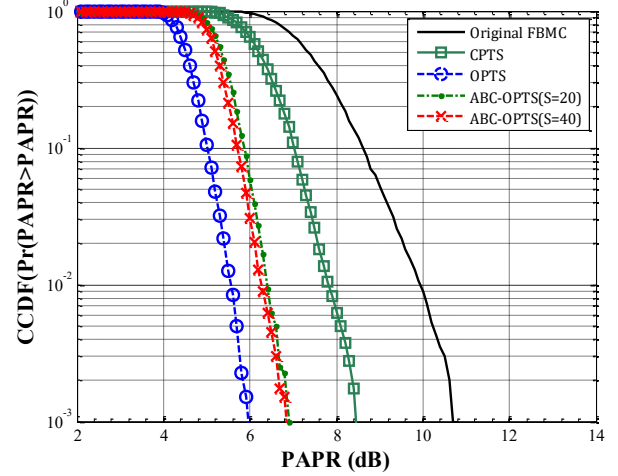


Figure 4. PAPR Performance of proposed ABC-OPTS scheme with $it=20$ and $Lim=5$

TABLE 2. COMPUTATIONAL COMPLEXITY FOR DIFFERENT PAPR REDUCTION METHODS

Methods	Computational Complexity	PAPR at $CCDF = 10^{-1}$
CPTS	$W^{V-1} = 2^{(16-1)} = 32,768$	7.2dB
OPTS		5.2dB
ABC-OPTS	$it * SN = 20 * 20 = 400$	5.8dB
	$it * SN = 20 * 40 = 800$	5.7dB

The PAPR by CPTS and OPTS with the computational complexity $W^{V-1} = 2^{16-1} = 32,768$ are 7.2dB and 5.2dB respectively. The PAPR by the proposed ABC-OPTS with $SN = 20$ and 40 are approximately 5.8dB and 5.7dB respectively. There are 0.6dB and 0.5dB gap between the PAPR by OPTS and the proposed ABC-OPTS with $SN=20$ and 40 respectively. However, from the comparison of the computational complexity in Table 2, it can be seen that the computational complexity of the proposed ABC-OPTS with $SN=20$ and 40 , and $it=20$, are only 400 or $\frac{400}{32,768} \times 100 = 1.22\%$ and 800 or $\frac{800}{32,768} \times 100 = 2.44\%$ of that by CPTS and OPTS schemes respectively.

V. CONCLUSIONS

This paper proposed the PAPR reduction scheme by the overlapped PTS with Artificial Bee Colony algorithm as ABC-OPTS scheme for FBMC-OQAM signals. The silent features are to improve the PAPR by OPTS scheme and to reduce the computational complexity in the PAPR optimization process by using the ABC algorithm. From these simulation results, it can be shown that the proposed ABC-OPTS scheme can improve the PAPR performance with the less computational complexity for the FBMC-OQAM signal.

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