

Improved PTS Method with New Weighting Factor Technique for FBMC-OQAM systems

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Abstract— Filter bank multi-carrier (FBMC) with offset quadrature amplitude modulation (OQAM) has been regarded as one of the candidates for next generation broadband wireless communication systems. Similar to OFDM systems, one of the major drawbacks in FBMC-OQAM systems is high peak-to-average power ratio (PAPR). To overcome this problem, Partial Transmit Sequence (PTS) method is a well-known method which can reduce the peak-to-average ratio (PAPR) for a multicarrier modulation signal. The PTS method can improve PAPR reduction performance very well as increasing the number of predetermined discrete phase factors and number of clusters. However, the side information is proportioned increasing as increased number of predetermined discrete phase factors or/and clusters that it is required to inform to the receiver for recovering the original data. In this paper, we propose the new discrete phase factor pattern which can improved the PAPR reduction performance better than conventional PTS method. This paper presents various computer simulation results to verify the effectiveness of proposed method.

Keywords— FBMC-OQAM, PAPR, PTS and Phydys Filter

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is the modulation technique adopted in long term evolution (LTE) 4G cellular network standards. Other future wireless standards, the new modulation technique with high transmission data rate and high spectrum utilization have need proposed for the next generation mobile systems. One of the most attractive modulation technique is the Filter Bank Multi-Carrier with Offset Quadrature Amplitude Modulation (FBMC-OQAM).

FBMC-OQAM is considered to be a candidate radio waveform in future 5th Generation mobile standards [1-3]. This modulation scheme possesses many good features, such as excellent frequency localization in addition to very low side lobes in its power spectral density (PSD), robustness to phase noise and frequency offsets. This modulation achieves

orthogonality between the adjacent sub channels which leads to less adjacent channel interference.

One of the major drawbacks in FBMC-OQAM systems is high peak-to-average power ratio (PAPR) similar as OFDM signal[4],[5]. The high PAPR problem is inherent in any multicarrier modulation system which leads to the requirement of amplifiers and ADC/DACs with high dynamic range. So, the reduction of PAPR is a main requirement for efficient high data rate communication system. In OFDM systems, the distribution of PAPR property has been derived by theoretical approaches, and various methods have been proposed to solve the PAPR problem, such as the selective mapping (SLM)[6] and partial transmit sequence (PTS) [7],[8].

The PTS approach is well known method as a distortion less technique based on combining signal sub-blocks or clusters, which are multiplied by weighting factors. Although the PAPR performance can be improved by multiplying the optimum weighting factor, the weighting factor employed at the transmitter is required to inform to the receiver as side information. In the PTS method, the PAPR reduction performance can be improved as increasing the number of clusters or weighting factor. However, the computation complexity and the size of side information increase exponentially.

In this paper, we propose a new determination method of weighting factor for the PTS method. The proposed method can show the better PAPR reduction performance than that for the conventional PTS method without any incensement of the size of side information and system complexity.

This paper is organized as follows. Section II firstly presents both the FBMC-OQAM and OFDM system model, which to be used in the following evaluations. Section III presents phenomenon of PAPR distribution for the output of inverse discrete Fourier transform in the time domain signal. Section IV presents the determination method of weighting factor for the proposed method. Section V presents the various computer

simulation results to verify the effectiveness of the proposed method as comparing with the conventional PTS method, conventional OFDM and conventional FBMC-OQAM, and we draw some conclusions in Section VI.

II. SYSTEM MODEL

Figure 1 shows the block diagram of OFDM and FBMC-OQAM system. The FBMC-OQAM system will be used for explain the detail proposed method and OFDM system will be used for evaluation reference of computer simulation. Consider a FBMC-OQAM system, where M complex input symbols need to be transmitted over N sub-carriers. In a OQAM modulation, we transmit real symbols at interval $T/2$. where, T is the time period of a FBMC-OQAM symbol.

$$X_{m,n} = R_m^n + j.I_m^n, 0 \leq n \leq N-1, 0 \leq m-1 \quad (1)$$

where, R_m^n and I_m^n are the real and imaginary parts of the M -th symbol over N -th sub-carrier, respectively. The input symbols in M -th data block can be grouped as a vector as shown below,

$$X_m = (X_{m,0}, X_{m,1}, \dots, X_{m,N-1})^T, 0 \leq m \leq M-1 \quad (2)$$

where, $[\]^T$, denotes the transpose operation. The OQAM mapping of the complex input symbol vectors $\{X_m\}_{m=0}^{M-1}$ into real symbol $\{a_{m',n}\}_{m'=0}^{2M-1}$ is done as shown the flowing equation,

$$s(t) = \sum_{m'=0}^{2M-1} \sum_{n=0}^{N-1} a_{m',n} h(t - m'T/2) e^{j\frac{2\pi}{T}nt} e^{j\phi_{m',n}} \quad (3)$$

where $h(t)$ is the impulse response of the prototype filter, $a_{m',n}$ is a real symbol mapped from complex $X_{m,n}$ with m varying from 0 to $M-1$, as follows

$$m' = \begin{cases} 2m & m' \text{ is even} \\ 2m+1 & m' \text{ is odd} \end{cases} \quad (4)$$

$$a_{m',n} = \begin{cases} (1-\rho).R_m^n + \rho.I_m^n & m' \text{ is even} \\ \rho.R_m^n + (1-\rho).I_m^n & m' \text{ is odd} \end{cases} \quad (5)$$

where $\rho \in \{0,1\}$ and is defined as n modulo 2. The mathematical significance of this time-staggering rule appears in [6] that has got a phase term $\phi_{m',n}$, which is set to be

$\frac{\pi}{2}(m'+n) - \pi m'n$ without loss of generality. PHYDYAS. In this

paper, we have chosen to use PHYDYAS filter as the prototype filter. The design of this filter is based on frequency sampling technique. The analytical parameters involved in this filter design are the number of sub-carriers N , the overlapping factor K , the roll-off and the length of the filter, $L = KN$ with desired values $F(k/L)$ where $k = 0,1,2 \dots L-1$

$$F_0 = 1, F_1 = 0.97196, F_2 = 1/\sqrt{2} \quad (6)$$

$$F_3 = \sqrt{1-F_1^2}, F_l = 0, 4 < l < L-1$$

The impulse response of the PHYDYAS filter is given as below,

$$h(t) = \begin{cases} \frac{1}{\sqrt{A}} [1 + 2 \sum_{l=1}^{K-1} (-1)^l F_l \cos(\frac{2\pi lt}{KT})] & t \in [0, KT] \\ 0 & \text{elsewhere} \end{cases} \quad (7)$$

where the normalization constant, $A = KT \left[1 + 2 \sum_{l=1}^{K-1} F_l^2 \right]$

In Fig. 1, we can have a glance of the impulse responses for both OFDM which has a rectangular shape and FBMC-OQAM that uses a PHYDYAS filter. We can notice that unlike the OFDM, the impulse response of the PHYDYAS filter has duration that spans over $4T$.

Let $\gamma_{m',n}(t)$ be a time and frequency shifted version of $h(t)$. Then, we can rewrite Equation (3) as follows:

$$s_{m',n}^{(v)}(t) = \sum_{m'=0}^{2M-1} \sum_{n=0}^{N-1} a_{m',n}^{(v)} h(t - m'T/2) e^{j\frac{2\pi}{T}nt} e^{j\phi_{m',n}} \quad (8)$$

$$= \sum_{m'=0}^{2M-1} \sum_{n=0}^{N-1} a_{m',n}^{(v)} \gamma_{m',n}(t)$$

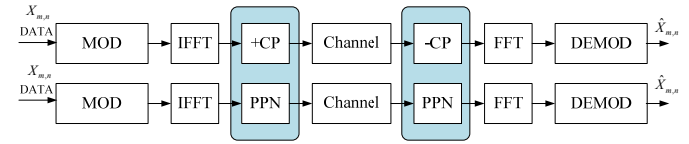


Figure 1. OFDM and FBMC Block Diagram

For a continuous time base-band signal $s(t)$ in Eq.(3) that is transmitted during a symbol period T . The PAPR performance includes summation of overlap signal, which is defined equation as below,

$$PAPR_{s(t)} = \frac{\max_{0 \leq t \leq T} |s(t)|^2}{\frac{1}{T} \int_0^T |s(t)|^2 dt} \quad (9)$$

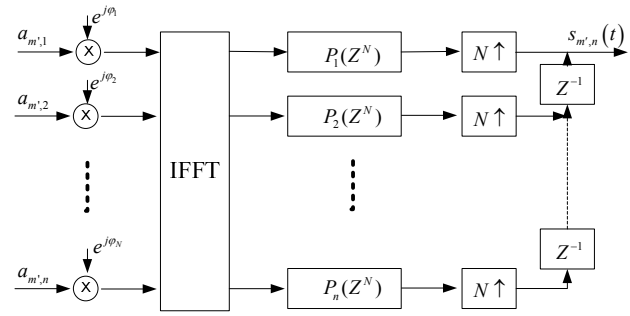


Figure 2. PPN at the Transmitter side

III. PAPR DISTRIBUTION

From this fact, the distribution of PAPR for the inverse discrete Fourier transform in the time domain signal given in (3) can be considered as i.i.d [9]. Gaussian. This means that the PAPR value given by (8) will be changed according to the pattern of input information data, employed modulation method and the number of sub-carriers. The possible number of PAPR values can be defined by the type of modulation method and the number of sub-carriers as show in flowing equation,

$$P_{Total} = (Mod)^M \quad (10)$$

where M is the number of sub-carriers and Mod represents the modulation levels which be decided by the type of modulation method. From (9), it can be observed that the possible number of PAPR performance becomes huge number. However, the output of inverse discrete Fourier transform in the time domain signal has the special characteristics which could be used to determine the weighting factor with PAPR reduction improvement for the PTS method.

In the following, we show the case of small number of sub-carriers for the purpose of simply explanations. The relation between PAPR value and data information can be depicted by using Fig. 3. In the figure, the modulation technique is QPSK and number of sub-carrier is 4 sub-carriers. The possible data information [0, 1, 2, 3] is mapped into complex number $[1+j, 1-j, -1+j$ and $-1-j]$, respectively. By using (9), the possible number of PAPR values is given by 256 (4^4). Fig. 3 shows the PAPR values for all data sequences of 256. From Fig.3, it can be observed that PAPR value has two periods between the first and the second and the PAPR values at the both sides are completely the same.

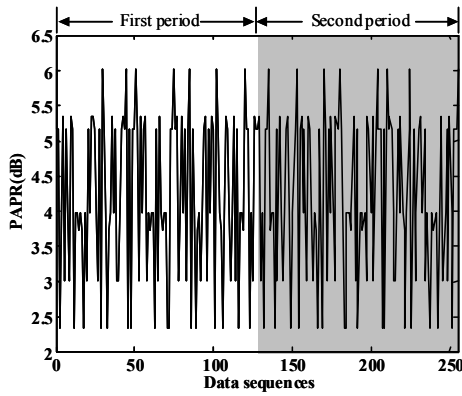


Figure 3. All PAPR performance of FBMC-OQAM signals in time domain when data sequences are changing.

After that the PAPR performance is reduced by using PTS method. All possible PAPR performances are 1-256 cases as shown in Fig. 3. The lowest PAPR was be selected from the multiplied weighting factor. From Fig. 3, it can be observed that PAPR performances have the same performance for 1-128 and 129-256, respectively. The new weighting factor for PTS method was proposed by using this special characteristic.

IV. PAPR REDUCTION BY USING PTS METHOD

A. Conventional PTS Method

Figure 2 shows the structure of FBMC-OQAM transmitter with the PTS method. In the PTS method, the data information in the frequency domain $a_{m',n}$ is partitioned into V clusters as $a_{m',n}^{(v)}$ ($1 \leq v \leq V$). All sub-carriers for each cluster are multiplied by the weighting factor, $b_{m',n}^{(v)} = e^{j\phi_{m',n}^{(v)}}$ so as to reduce the PAPR performance. Here, the phase value considered in each cluster is given by the following equation.

$$\phi_{m',n}^{(v)} \in \left\{ \frac{2\pi i}{W} \mid i = 0, \dots, W-1 \right\}. \quad (11)$$

where W is the number of predetermined discrete phase. After multiplying the weighting factor for each cluster, the sub-carrier vector is given by the following equation.

$$A_{m',n}^{(v)} = \sum_{v=1}^V b_{m',n}^{(v)} \cdot a_{m',n}^{(v)}. \quad (12)$$

where, $b_n^{(v)}$ is the weighting factors, which are required to inform the receiver as the side information. The set of weighting factor for V clusters are optimized in the time domain so as to achieve the better PAPR performance, by using the following equation.

$$s_{m',n}^{(v)}(t) = \sum_{m'=0}^{2M-1} \sum_{n=0}^{N-1} A_{m',n}^{(v)} \gamma_{m',n}^{(v)}(t). \quad (13)$$

The optimized PAPR performance can be given by the following equation.

$$\tilde{V} = \arg \min_{0 \leq w \leq W-1} \max_{0 \leq k \leq N-1} |s_{m',n}^{(v)}(t)|. \quad (14)$$

where $\tilde{V}$ is optimized argument that can reduce to the lowest PAPR performance.

B. Proposal of New Weighting Factor for PTS Method

To increase the potential capability of PAPR reduction for PTS method in FBMC-OQAM systems, we propose the new determination method of weighting factor for PTS method that can reduce the PAPR performance without increasing computation complexity. In the proposed method, the input data block is partitioned into the cluster as the same as conventional PTS method. The difference of proposed method is that each cluster is partitioned by first and second parts as shown in Fig. 6. The first and second parts of cluster employ the different weighting factor, which can express by the following equation.

$$A_{m',n}^{(v)} = \sum_{v=1}^V (b_{m',n}^{(v)} \cdot a_{m',n}^{(v)} + b_{m',n}^{(v')} \cdot a_{m',n}^{(v')}). \quad (15)$$

where $b^{(v)}$ and $b^{(v')}$ are weighting factors for the first and second parts at the v -th cluster, respectively. $a_{m',n}^{(v)}$ and $a_{m',n}^{(v')}$ are the data sub-carriers of first and second parts at the v -th cluster, respectively. The weighting factor of proposed method for both parts can be defined by $e^{j\phi_n^{(v)}}$ and $e^{j\phi_n^{(v')}}$, respectively which are given by the following equation.

$$\phi_n^{(v')} = \alpha \cdot \phi_n^{(v)}. \quad (16)$$

where ϕ_1' is the phase coefficient for the first part of clusters, and ϕ_2' is the phase coefficient for the second parts, α is the constant value and its optimum value to obtain the better PAPR is decided as 0-0.5 [10] from the computer simulation results when changing the various values of α and when α is 1. This means that the weighting factor for the second part of cluster becomes the same as conventional PTS method. From 11 and 14, it can be seen that the conventional and proposed PTS methods have the same number of weighting factor W .

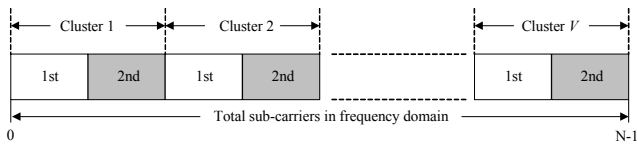


Figure 4. Structure of FBMC-OQAM symbol for proposed method in the frequency domain.

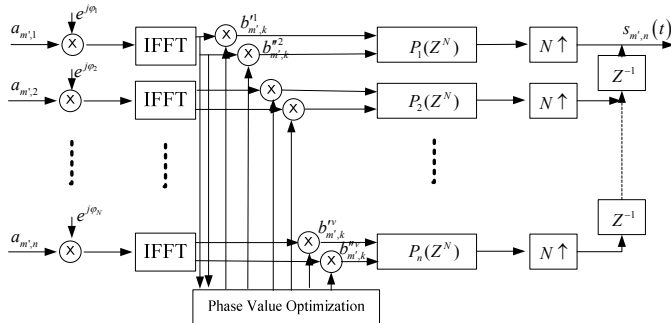


Figure 5. Structure of FBMC-OQAM transmitter with proposed PTS method

V. SIMULATION RESULTS

This section presents the various computer simulation results to verify the performance of proposed method. The simulation parameters can be shown as below table,

TABLE 1. SIMULATION PARAMETERS

Methods	OFDM/ FBMC-OQAM
Modulation	OQPSK/16OQAM/64OQAM
Demodulation	Coherent
Allocated bandwidth	5MHz
Number of FFT points	256
Number of sub-carriers	64
Number of cluster (V)	4
Number of discrete phase (W)	4
Overlapping factor(K)	4
Prototype filter	Phydyas Filter (PF)

This figure 6 shows the PAPR performance for the conventional OFDM and conventional FBMC-OQAM when employs the PAPR reduction method by using PTS and Improved PTS (I-PTS) methods, respectively. The modulation techniques are 16QAM and 16OQAM. The PAPR performance for the conventional OFDM and conventional FBMC-OQAM was also calculated by using computer simulation as shown in the figure 6 as the purpose of comparison.

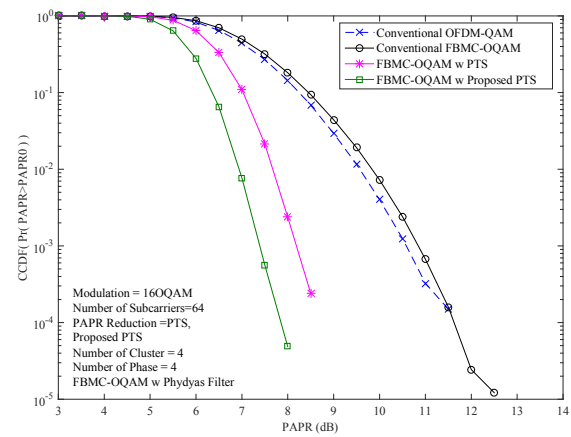


Figure 6. Comparision PAPR performance between conventional and proposed method for FBMC signal.

In the figure, the PAPR performance is evaluated by using the Complementary Cumulative Distribution Function (CCDF). The total sub-carrier is 64, number of cluster is 4 clusters and number of discrete phase is 4 phases. α is tokened by zero. From these figures, it can be observed that proposed PTS methods show the better PAPR performance compared with conventional PTS method. We proposed the new weighting factor technique in which each cluster is divided two parts. The weighting factors for the 1st and 2nd parts have the predetermined relationship so as to keep the same size of side information. From the various computer simulation results, we confirmed that the proposed method shows the better PAPR performance and the same computation complexity with keeping the same size of side information as compared with the conventional PTS method.

This figure 7 shows the PAPR performance when modulation technique is changed by OQPSK, 16OQAM and 64 OQAM, respectively. The simulation result shows that the porposed method can works all modulation techniques with keep the same PAPR reduction performance.

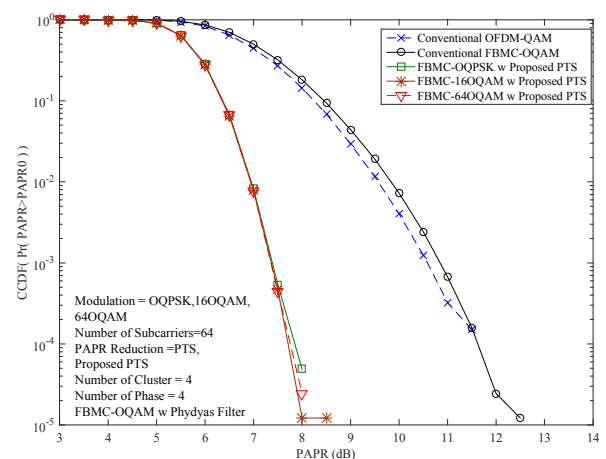


Figure 7. Comparision PAPR performance when chaning the modulation techniques.

VI. CONCLUSIONS

In this paper, we proposed the New Weighting Factor Technique for PTS method in the FBMC-OQAM system. The

feature of proposed new weighting factor technique is to employ the special characteristics of output of inverse discrete Fourier transform in the time domain signal, which PAPR value is changed cyclically according to the pattern of input data sequence.

From this reason, the proposed method uses the relationship between first and second cluster, which keeps the same the side information and achieves better the PAPR reduction performance. The simulation results confirm that the FBMC-OQAM system can be used the proposed New Weighting Factor based on PTS method without increasing the computation complexity and number of side information.

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