STUDY ON PAPR REDUCTION PERFORMANCE OF IPTS FOR FBMC SIGNALS IN THE NON-LINEAR CHANNEL.

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ABSTRACT

The Filter Bank Multi-carrier (FBMC) modulation with one of its variants Offset Quadrature Amplitude (OQAM) has increased considerably in the field of research for the next generation of future broadband wireless communication systems. However, one of the drawbacks of the FMBC signals is the Peak to Average Power Ratio (PAPR). To improved PAPR value, Partial Transmit Sequence (PTS) method can improve PAPR as increasing the number of predetermined discrete phase factors and the number of clusters. We study the Improved Partial Transmit Sequence (IPTS) method, which can reduce the PAPR for a multicarrier modulation signal. In OQAM based FBMC (OQAM-FBMC) under the non-linear channel. In this paper, we investigate a PAPR method to reduce the PAPR and the computation complexity by using the IPTS method when applying to the OQAM-FBMC system. The results reveal that the IPTS in the performance of PAPR reduction and Bit Error Rate (BER) of the study scheme verified by using various computer simulations.

Keywords: FBMC, PAPR, PTS, IPTS, and Non-linear channel.

INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is the dominant scheme already adopted by various standards for wired and wireless communication systems, such as digital television and audio broadcasting, wireless area networks, and 4G mobile communication[1]. The main advantage of OFDM is the low cost of implementation. However, OFDM is not suitable considerably for massive networks in the Fifth-Generation (5G) because the limit of signals leads to high out-of-band (OOB) leakage and reduces the efficiency of messages for dynamic spectrum access[2]. So Filter Bank Multi-Carrier (FBMC) with Offset Quadrature Amplitude Modulation (OQAM) systems have been proposed recently, which can reduce the OOB when compared with OFDM signals[3].

FBMC signals have many advantages then OFDM signals. However, Both have the same high Peak-to-Average- Power ration (PAPR) of data transmission in the time domain which leads to has the significant fluctuation of the power signal that degrades the efficiency of non-linear High Power Amplifiers (HPA) bring the lower spectrum re-growth when of comparing with the ideal of Power Spectral Density (PSD) in the OFDM signals has higher spectrum re-growth then OQAM-FBMC signals [4].

So far, according to the characteristic of OQAM-FBMC signals, many techniques to solve the PAPR have proposed among Selected Mapping (SLM) [5], Tone Reservation (TR) [6], Partial Transmit Sequence (PTS) [7] and Segmental partial transmit sequence (S-PTS) [9]. However, all of the research results showed that it is not effective directly applied to the

OQAM-FBMC signals as it is for the OFDM signals because of the upsampling and overlapping signs of the inter-symbol interference (ISI).

The conventional PTS method in Offset-QAM based filter bank multi-carrier (OQAM-FBMC) can reduce PAPR value in the time domain, the addition combining signal sub-blocks or clusters, multiplied by weighting factors. The PAPR performance improved as increasing the number of groups of weighting factors. However, the weighting factor added at the transmitter is required to inform the receiver as side information increase and the computation complexity.

In this paper, we study and investigate the determination method of the weighting factor for the IPTS method. To reduce the high PAPR of OQAM-FBMC signals and system computation complexity, object to evaluate the efficiency of OQAM-FBMC signals, also the performance of Bit Error Rate (BER) in the non-linear channel when changing the Input Back Off (IBO) and Signal to Noise Ratio (SNR) respectively.

The remainder of the literature organized as follows: Section 2 presents an overview of conventional OQAM-FBMC signals with PAPR reduction and the phenomenon of PAPR distribution for the output of inverse discrete Fourier transform (IFFT) in the time domain signal. Next, section 3 presents the determination for the IPTS method of the weighting factor. Followed by Section 4, described the HPA model, exhibiting of amplitude and phase AM/AM and AM/PM conversion characteristics of non-linear amplifiers to evaluation the PSD. And Section 5, which shows the different simulation results when changing IBO and SNR in the non-linear channel to evaluate the high performance of the IPTS method for the OQAM-FBMC system. Finally, gives the conclusion of this work in Section 6.

FBMC SYSTEM MODEL

Conventional OQAM-FBMC Signal and PAPR

In this section, we analyze the transmitted random data at the transmitter side of the OQAM-FBMC system, the complex random data shown below.

$$X_{m,n} = R_{m,n} + j.I_{m,n},\quad 0 \le n \le N-1,\quad 0 \le m \le M-1 \tag{1}$$

, where $R_{m,n}$ and $I_{m,n}$ represent random data in the real and imaginary parts of the $m-th$ symbol on the $n-th$ sub-carrier, respectively. The real and imaginary signals parts of the OQAM symbol are time delayed by $T/2$, where the T symbol period passed through the filter, which has the time-frequency conversion $h(t)$. The OQAM-FBMC modulated signal with M symbol expressed as

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

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

$$m' = \begin{cases} 2m & m'\,\text{is even} \\ 2m+1 & m'\,\text{is odd} \end{cases} \tag{3}$$

, where $\rho \in \{0,1\}$ is defined as n modulo 2. The phase offset of QAM taken by the delay as phase term $\varphi_{m',n}$, which is set to be $\frac{\pi}{2}(m'+n) - \pi m'n$ an as the following equation,

$$a_{m',\mathrm{n}} = \begin{cases} (1-\rho).R_m^n + \rho.I_m^n & m'\,\text{is even} \\ \rho.R_m^n + (1-\rho).I_m^n & m'\,\text{is odd} \end{cases} \tag{4}$$

The physical layer for dynamic spectrum access and cognitive radio (PHYDYAS) prototype filter employed in this paper. It explained by the comparison.

$$h(t) = \begin{cases} \frac{1}{\sqrt{A}}[1 + 2\sum_{l=1}^{K-1}(-1)^l F_k \cos\left(\frac{2\pi lt}{KT}\right)] & t \in [0, KT] \\ 0 & elsewhere \end{cases} \tag{5}$$

The PAPR evaluation is one of the schemes, which shows the fluctuation of the transmitted signal. The PAPR performance of OQAM-FBMC symbol is period T in the equation (2), which different the OFDM system is period *T*. The PAPR performance of OQAM-FBMC symbol is period *T* with a summation of overlap signal both previous, current and advance symbol as shown in figure 1. From figure 1, PAPR of conventional OQAM-FBMC system $s_{m',n}(t)$ signal symbol in period *T* is written by,

$$PAPR_{s_{m',n}(t)} = \frac{\max_{0 \le t \le T} \left|s_{m',n}(t)\right|^2}{\frac{1}{T}\int_0^T \left|s_{m',n}(t)\right|^2 .dt} \tag{6}$$

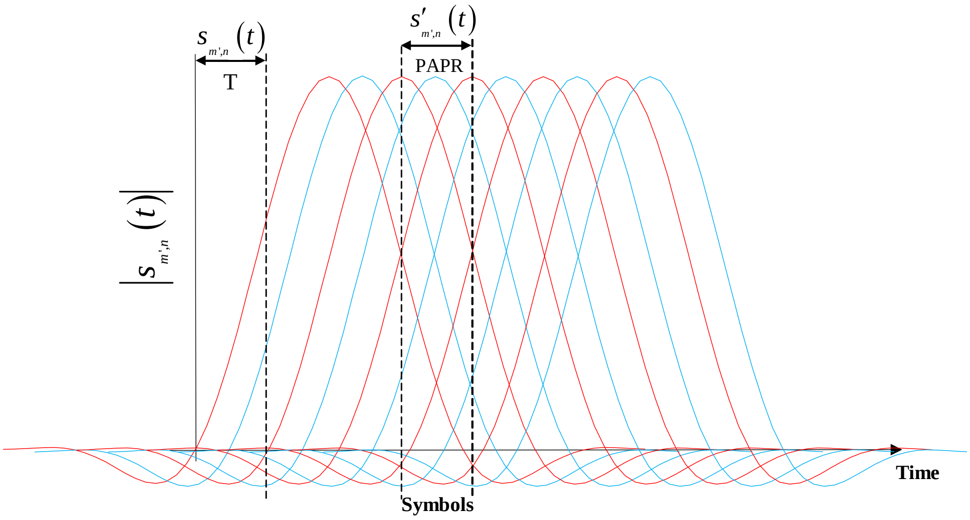

Fig.1. PAPR performance evaluation of the OQAM-FBMC is period *T*.

PAPR Distribution

The distribution of PAPR signals in the time domain signal given for (2) it represented as Gaussian. Messages changed according to the pattern of data input signals. The possible number of PAPR values defined by the type of modulation method and the number of sub-carrier shown bellows.

$$P_{Total} = \left(Mod\right)^{M} \tag{7}$$

The Mod denotes the sum of modulation levels, which be depend on the number of modulation methods. The output of IFFT in the time domain signal has characteristics that could determine the weighting factor with reduction improvement for the PTS method. In the figure 2, QPSK modulation have the number of sub-carrier is 4, the possible data information [0, 1, 2, 3] replace into complex number [1+j, 1-j, -1+j and -1-j], respectively. For the data sequences of all 256, the PAPR value has two periods between the first and the second, and the PAPR at both sides are all most the same. The lowest PAPR selected from the multiplied weighting factor form characteristic of the same performance weighting factor for the PTS method.

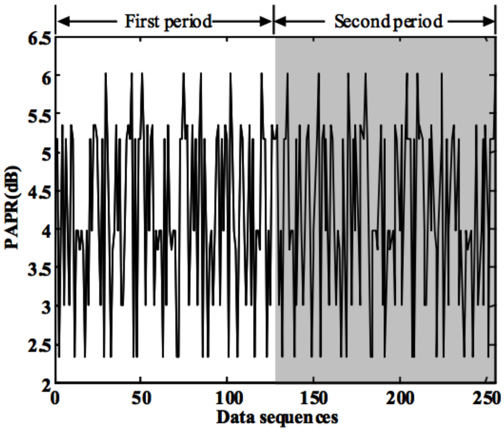

Fig.2. PAPR period data sequence of OQAM-FBMC signals in the time domain

A.Conventional PTS Method

In the PTS method, the signals in the frequency domain are partition into each cluster, and sub-carriers in each group are multiplied by the weighting factor to reduce PAPR value. Therefore the phase value represented in each group can be shown in the equation below.

$$\varphi^{(v)}_{m',n} \in \left\{ \frac{2\pi i}{W} \right\}, i = 0, \ldots, W - 1 \tag{8}$$

Where W is the number of predetermined discrete phases, when multiplying the weighting factor for each cluster, sub-carrier written as the following equation.

$$A^{(v)}_{m',n} = \sum_{v=1}^{V} b^{v}_{m',n} \cdot a^{v}_{m',n} \tag{9}$$

Where the weighting factors are required to inform the receiver as the side information (SI), the number of V cluster are optimized in the time domain to achieve the better PAPR performance by using as the following equation.

$$s^{(v)}_{m',n}\left(t\right) = \sum_{m'=0}^{2M-1} \sum_{n=0}^{N-1} A^{v}_{m',n} g_{m',n(t)} \tag{10}$$

The optimized PAPR performance given by the following equation.

$$\overset{\square}{V} = \arg\min_{0 \le w \le W-1} \max_{0 \le k \le N-1} \left| s^{(v)}_{m',n}(t) \right|$$

(11)

B.Impact of PAPR on OQAM-FBMC by using IPTS Method

IPTS method can reduce the PAPR performance without increasing computation complexity, and the input data block is partition into each cluster as the same as the conventional PTS method. The future of the IPTS method is cluster can be partitioned by the first and second parts as shown in Fig. 3. that can express by the following equation.

$$A^{(v)}_{m',n} = \sum_{v=1}^{V} \left(b'^{v}_{m',n} \cdot a'^{v}_{m',n} + b''^{v}_{m',n} \cdot a''^{v}_{m',n} \right) \quad (12)$$

Where the different weighting factor for the first and the second parts v and the sub-carrier for the fist and second part also respectively

$$f'^{(v)}_{n} = a \cdot f^{n(v)}_{n} \quad (13)$$

Where phase coefficient for the first and the second parts, and constant value and optimum value to obtain the better PAPR is decided as 0-0.5 from the computer simulation results when changing the various cost, it observes the conventional PTS, and IPTS method has the same number of weighting factor w.

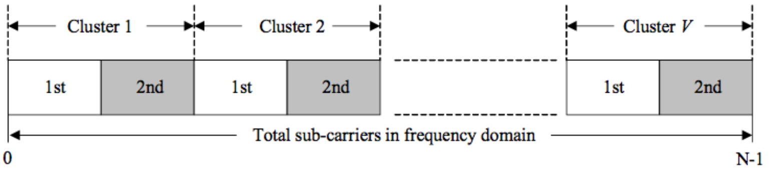

Fig.3. Structure of OQAM-FBMC symbol for IPTS method in the frequency domain

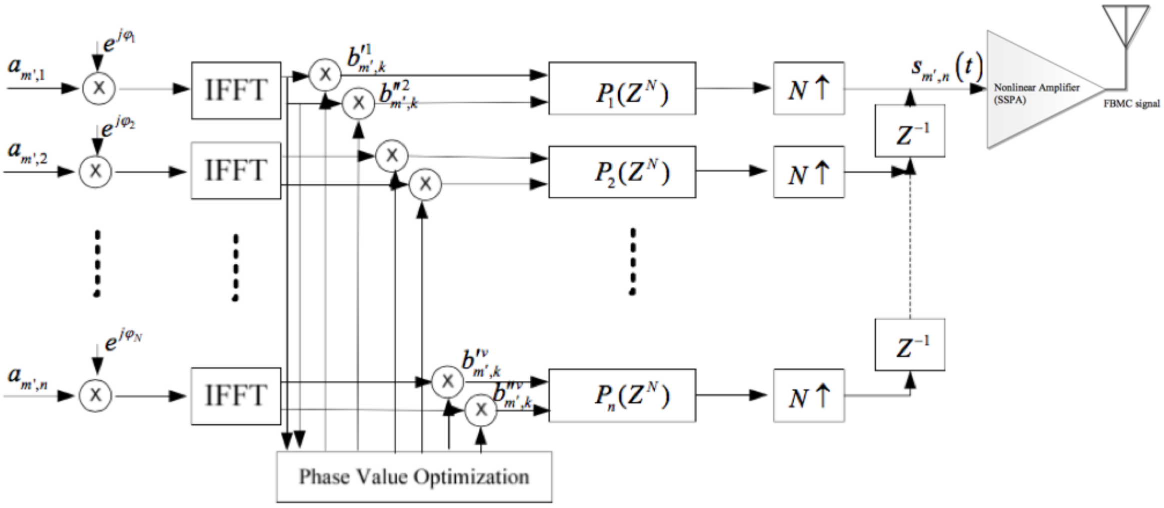

Fig.4. A simulation model of degrades the OQAM-FBMC system at the transmitter side with the IPTS method under the SSPA nonlinear amplifier.

High Power Amplifier model

The nonlinear amplifier is required by the transmitter to increase the transmitted signal power, which can increase the distance between the transmitter and receiver. However, the nonlinear amp has the nonlinear characteristic, which cut the peak of the OQAM-FBMC signal in the time domain. The essence of the nonlinear amplifier modeled by Rapp, which are shown by the following equation,

$$F_E(\rho) = \frac{\nu\rho}{\left[1+\left(\nu\rho / A_o\right)^{2p}\right]^{1/2p}} \tag{14}$$

$$\Phi_E(\rho) = \alpha_\phi \left(\frac{\nu\rho}{A_o}\right)^4 \tag{15}$$

, where $F_E(\rho)$ and $\Phi_E(\rho)$ are the AM-AM and AM-PM conversion characteristics of SSPA, respectively, ρ is the amplitude of the OQAM-FBMC signal, ν is the gain factor of SSPA amplifier, A_0 is the saturated output level of SSPA amplifier, p is the non-linear characteristic of SSPA amplifier and α_ϕ is phase displacement of SSPA amplifier. The Input Back-Off (IBO) or operation point of the SSPA amplifier can be defined by,

$$IBO = 10\log\frac{P_{in}}{P_0} \tag{16}$$

, where P_{in} is input power of the OQAM-FBMC signal and P_0 is the output power of the OQAM-FBMC message. The output power increased when IBO is near the saturation point of the power amplifier. On the other hand, the output power is decreasing when IBO is getting low.

SIMULATION RESULTS AND DISCUSSION

In this section represented the simulation parameters of OQAM-FBMC shown in table 1. The high-QAM modulation is taken by the 64-OQAM because it’s can easily observe the nonlinearity effect. And the non-linear characteristic of the SSPA amplifier in practice is made by 2. We clearly show the nonlinear effect for the OQAM-FBMC when the modulation is taken by High-OQAM more than OQPSK and 16OQAM.

Table 1. List of simulation parameters of FBMC systems

Schemes	OQAM-FBMC
Modulation	64OQAM
Demodulation	Coherent
Allocated bandwidth	5MHz
Number of sub-carriers(*M*)	64 sub-carriers
Number of FFT points(*N*)	256 points
Up sampling factor(*K*)	4
Over Sampling	4
Prototype filter: PHYDYAS Filter (PF)	$F_0 = 1$, $F_1 = 0.97196$ $F_2 = 1/\sqrt{2}$ $F_3 = \sqrt{1-F_1^2}$
Number of clusters (V)	4
Number of discrete phases (W)	4
Nonlinear Amplifier (SSPA)	$A_0 = 1, v = 1, p = 6$ and $\alpha_\phi = 0.025$
IBO (dB)	-2 dB,-4dB,-6dB and -8dB
CNR(dB)	22dB, 24dB and 26dB

Figure 5 shows the comparison of the PAPR reduction performance evaluated by using the Complementary Cumulative Distribution Function (CCDF) and the modulation is 64-OQAM. The number of subcarriers (N) is 256. The number of clusters is 4, and the number of discrete phases is 4 phases. The PAPR performance of OQAM-FBMC with PAPR reduction schemes shows lower PAPR performance when compared with the conventional FBMC.

CCDF of PAPR performance shown the best PAPR reduction values PTS, PTS with Dispersive, and IPTS scheme, respectively. The proposed technique shows the improved PAPR performance when compared with conventional PTS technique.

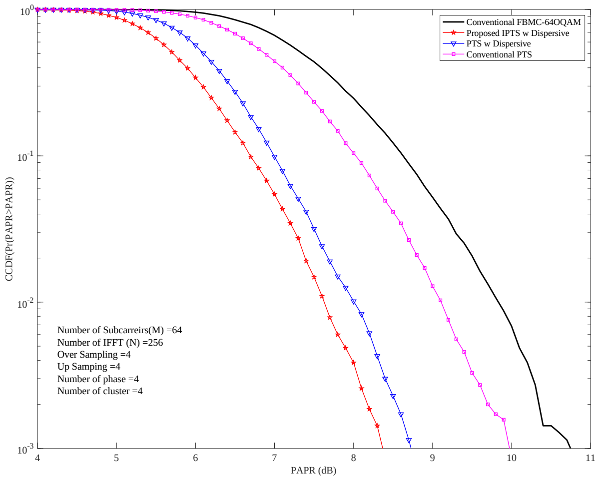

Fig. 5 Comparison PAPR performance between conventional PTS, PTS dispersive, and proposed IPTS

Figure 6 shows the BER performance of the OQAM-FBMC system when the SNR is changing. The output power of the nonlinear amplifier fixed when IBO by -2dB, -4dB, -6dB, and -8dB because we want to keep the same SNR in the X-axis. Form the simulation results show the BER performance degraded by the lower IBO. Because of the low intermodulation noise from the nonlinearity of the amplifier is generated by low PAPR. The low PAPR also avoids the intermodulation noise at the IBO. Figure 6 shows that the BER performance of IPTS is better than conventional.

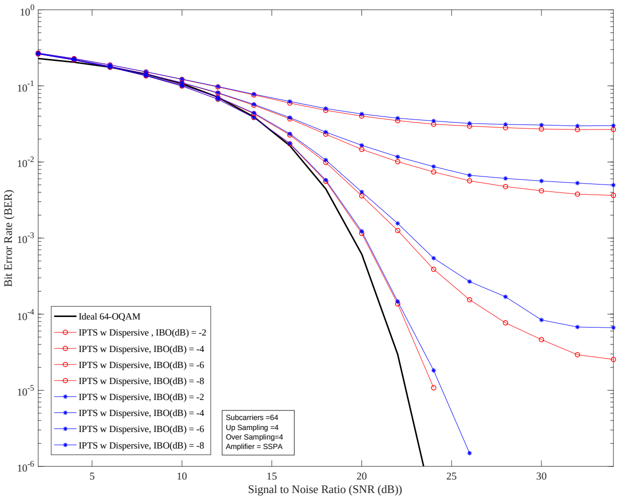

Fig. 6 BER performance versus SNR when IBO is changing.

CONCLUSION

The PAPR reduction schemes for the OFDM signal proposed. However, those PAPR reduction schemes cannot directly apply to the OQAM-FBMC because of the FBMC symbols are overlapped in the time domain. The efficient of PAPR reduction degraded by this reason. The weighting factor is employed to specify the characteristics of IFFT in the time domain signal, in which PAPR value is changed cyclically according to the pattern of the input data sequence. In this paper, the proposed IPTS achieves better PAPR performance without increasing the computation complexity and the number of side information. The BER performance of 64 QAM modulation is improved by low PAPR under the non-linear channel. The operation point of the non-linear amplifier also effects to the BER performance, which degrades from the intermodulation and AWGN noises. The proposed scheme can improve the BER performance that we verify the proposed using computer simulation.

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