Novel PAPR Reduction Technique Based On Conventional Partial Transmit Sequence (PTS)

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***Abstract*-- In this paper, a novel approach combining two well known signal processing techniques with traditional partial transmit sequence (PTS) has been proposed and analyzed. This includes convolutional code (CC) and repeating clipping filtering (RCF) techniques. The main objective is to reduce the peak-to-average power ratio (PAPR) of orthogonal frequency division multiplexed (OFDM) signal. The proposed PAPR method is referred to as convolutional-repeating clipping filtering PTS technique (CRCF_PTS). Simulation results show that our proposed PAPR achieved better power reduction factor as compared to the conventional PTS technique (about 2.3 dB). In addition, the overall bit error rate (BER) of OFDM system has been evaluated with and without our proposed PAPR for different standard channel models (Additive Gaussian Noise and Rayleigh fading channels). The results show that our PAPR technique has insignificant slightly changes in the bit BER in case of fading channel model. Therefore, proposed CRCF_PTS technique is practically feasible for OFDM system with no additional processing time.**

***Index Term*-- OFDM, PTS, and PAPR reduction techniques**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is an attractive technique for Ultra- wideband wireless communication applications. However, a well- known problem of OFDM is the casual occurrence of high peak-to-average power ratio (PAPR) in the time domain signal [1]. This leads to non- linear distortion occurred at the output of power amplifier. Many methods have been developed in order to mitigate this main drawback. This includes: Golay and Reed-Muller coding [2-3], selective mapping (SLM) [4], partial transmit sequence (PTS) [5-6], filtering and clipping [7-8-9] and etc. All of these techniques can be classified to two main categories: linear and nonlinear. Usually, linear methods lead to increase in computational complexity of communication system. On the other hand, nonlinear methods increase the overall system BER. In fact, a good PAPR reduction technique is the one that compromise between complexity and the BER obtained at receiving end. In this paper a novel approach combining nonlinear and the linear methods, has been proposed, and referred to as clipping and filtering with partial transmit sequence denoted by *Convolutional Repeating Clipping Filtering _ PTS*. The main objective is to reduce the peak-to-average power ratio (PAPR) and to keep an acceptable BER of the OFDM system. Our proposed technique has been achieved a significant reduction in PAPR, and very slightly changes to the BER performance as compared to the original OFDM system. The rest of the paper is organized as follows: In Section II, a brief description of PAPR concept in OFDM system is explained. The novel Clipping and Filtering and PTS algorithm also, is introduced in this section. Simulation results of our proposed PAPR technique are presented in section III. Performance evaluation and analysis of OFDM system with and without the proposed CRCF_PTS technique are also presented in section III. Finally, the presented paper is concluded in section IV.

II. OFDM SYSTEM With PAPER PROBLEM

In contrast to the single carrier, OFDM technology summed up a number of sub carriers modulated by group of data symbol. Therefore, transmitted signal may have a relatively large peak power which leads to high PAPR. The PAPR can be defined as follows [10]:

$$\text{PAPR(dB)} = 10\log_{10}\frac{MAX_n\{|x_n|^2\}}{E\{|x_n|^2\}} \quad (1)$$

Where; X_n is time domain data symbol obtained via IFFT given as follows:

$$x_n = \frac{1}{N}\sum_{k=0}^{N-1} X_k \exp(nk\frac{2\pi}{N}) \quad (2)$$

Where: X_K: is frequency domain data symbol obtained at source output and to modulate sub-carrier number k. In case of BPSK $X_K = \{1,-1\}$ whereas in case of QPSK modulation, $X_K = \{1,-1, j, -j\}$. N: is the total number of sub-carriers.

In OFDM system, N sub-carriers are summed with phase shifts as given in equation (2) in order to maintain orthogonality in frequency domain. In this case, the signal peak Power is N times greater than the mean power (in the worst case) which could be described as follows [10]:

$$(\text{PAPR})_{\max} = 10\log_{10}\text{N} \quad (3)$$

For example, if the number of sub-channels varies between 64 and 256, upper limit of the $(\text{PAPR})_{\max}$ value in OFDM system varies between 18dB and 24dB.

The normalized complex base band symbols are of OFDM is given by [10]:

$$x(t) = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x_n e^{(jn\Delta f t)} \quad (4)$$

Where, x_n represents the modulated symbols of the n[th] sub-carrier, and Δf is frequency spacing between successive sub-carriers. According to the Central limit theorem, as long as the number of sub carriers N Large enough, you can determine the real and imaginary parts of x(t). In this case, they follow Gaussian distribution, the zero Mean, and 0.5 variance (real and imaginary separately parts half of the entire signal). The cumulative distribution function (CCDF) has been used in our simulation to evaluate the PAPR of OFDM symbols. In general, a complementary formula of CCDF given by [10]:

$$P\{PAPR > z\} = 1 - P\{PAPR \leq z\} = 1 - (1 - e^{-z})^N \qquad (5)$$

Where, z represents a specific threshold power to evaluate the PAPR in OFDM.

A. Clipping And Filtering Technique

In OFDM, signal contains high peaks (exceeding a certain threshold) will be applied to clipping and Filtering processes (CAF) as illustrated in fig. (1). In the Clipping part, when amplitude exceeds a certain threshold, the amplitude is hard-clipped while the phase is saved [13-14].

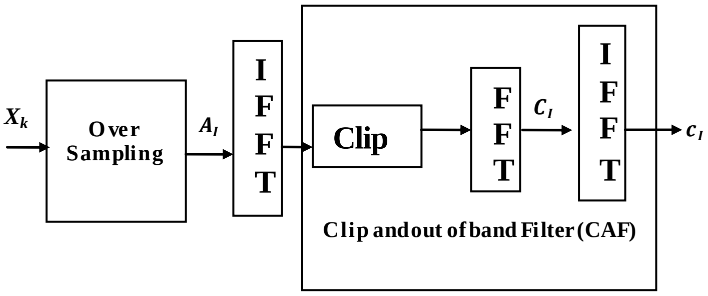

Fig.1. Repeating clipping and filtering technique

In fig., vector $A_l = [A\,0 \ldots\ldots A_{N-i}]$ obtained after oversampling stage is first transformed using an oversize inverse fast Fourier transformation (IFFT). For an oversampling factor denoted by IF, A_l is extended by adding N(IF − I) zeros in the middle of the vector. This results in a trigonometric interpolation of the signal time domain signal [I]. The interpolated signal is then clipped.

In this paper, hard-limiting is applied to the amplitude of the complex values at the IFFT output. However, any other form of nonlinearity could be used. The clipping ratio, CR, is defined as the ratio of the clipping level value to the root mean square value of the unclipped signal. The clipping is followed by filtering to reduce out-of band power. The filter consists of two FFT operations. The forward FFT transforms the clipped signal back into the discrete frequency domain resulting in vector C_l. The in- band discrete frequency components of $[C_{0,i,\ldots\ldots}, C_{N/2-1,i}, C_{NI1-N/2+1,i,\ldots} C_{NI1-1,i}]$, are passed unchanged to the inputs of the second IFFT while the out-of-band components $[C_{N/2+1,i\ldots\ldots} C_{NI1-N/2,i}]$ are nulled. In systems where some band- edge subcarriers are unused the components corresponding to these are also nulled. The resulting filter is a time-dependent filter, which passes in-band and rejects out-of-band discrete-frequency components. This means that it causes no distortion to the in-band OFDM signal. Since the filter operates on a symbol-by-symbol basis, it causes no Inter-symbol interference. The filtering does cause some peak to re-growth. Clipping method sets a clipping threshold, when the amplitude of the signals over the threshold, then cut the high peak power. According to the system acquirement, the following function has been used to calculate the clipping ratio. PAPR0=10logCR, where, PAPR0 is the threshold value, and CR is the clipping ratio. Due to the relation between PAPR0 and the system BER, PAPR0 is selected to be inverse ratio to BER. In this case, proper threshold value should be selected carefully.

B. Proposed PAPR rdeuction Method

The Block diagram of conventional PTS is shown in Fig.2. The basic principles of practical partial transmit sequence (PTS) is as follows. First of all, we use vector data X to define the symbols. Second, divided this vector into M groups, denoted by $\{X_m, m=1, 2\ldots M\}$. Then the M group summed up as follows [12-15]:

$$X'(b) = \sum_{m=1}^{M} b_m X_m \qquad (6)$$

Where, $\{b_m, m=1, 2\ldots M\}$ is the weighted coefficient, so that $b_m = e^{j\varphi_m}$, $\varphi_m \in [0,2\pi]$ which are considered auxiliary information. Then we adopt IDFT (Inverse Discrete Fourier Transform) to $X'(b)$, so we obtain $x'_b = \text{IDFT}\{X'(b)\}$. Referred to the IDFT instruction, we use of M separate IDFT given as follows [12-15]:

$$x'_{(b)} = \sum_{m=1}^{M} b_m . IDFT\{X_M\} = \sum_{m=1}^{M} b_m X_m \qquad (7)$$

Choose appropriate weighted-coefficients $\{b_m\ m=1, 2\ldots M\}$ corresponding to minimum PAPR of sequence $\boldsymbol{x'}_{(\boldsymbol{b})}$ described as follows [12-15]:

$$\{b_1, b_2, \ldots, b_m\} = \underset{\{b_1, b_2, \ldots, b_m\}}{argmin} \left(\max_{1\leq n\leq N} \left|\sum_{m=1}^{M} b_m . X_m\right|\right)^2 \qquad (8)$$

Where, argument (.) represents the sentence condition which makes the function to achieve the minimum value. Thus we use *M-1* IDFT to search the optimized weight coefficients $\{b_m\}$, and to achieve the purpose of reducing the PAPR value in OFDM system.

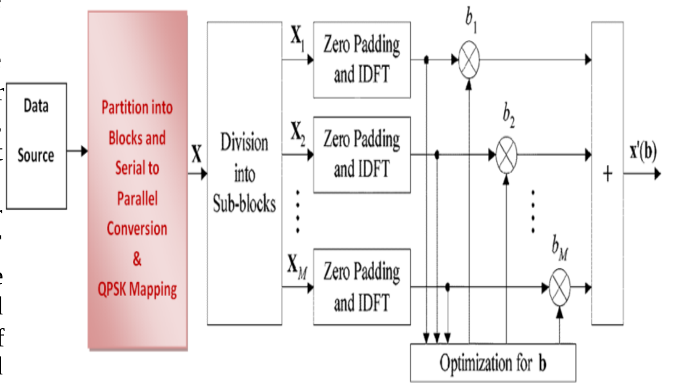

Fig. 2. Conventional PTS Principle

In the proposed OFDM system, we have combined the use of convolutional code and RCF (Repeating Clipping and Filtering) as shown in Fig.3. The main idea of the proposed PAPR method (CRCF_PTS) is to use three main signal processing steps to reduce the PAPR value. First is to use the convolution code with the OFDM transmitter. Second, the merit of nonlinear clipping method is used to cut the high power value of these minority symbols. Third, a filter module is added after clipping process to reject the out-of-band signals. Finally, a conventional PTS module is applied to the clipped and filtered symbols. Stages of OFDM transceiver with the proposed CRCF_PTS is illustrated in Fig.4.

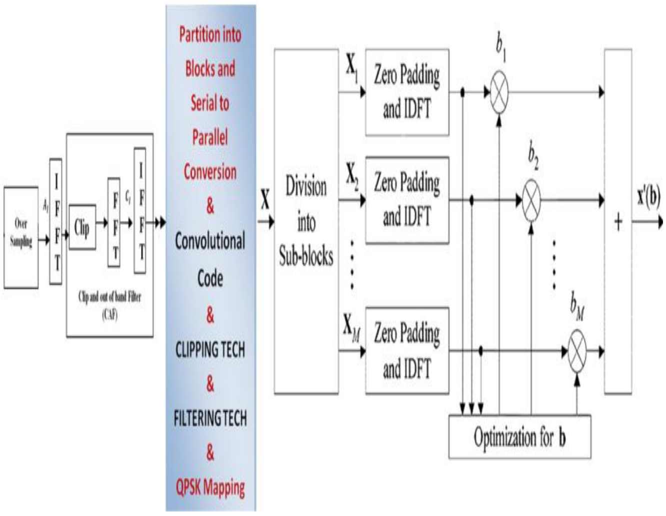

Fig. 3. CRCF_ PTS Block diagram

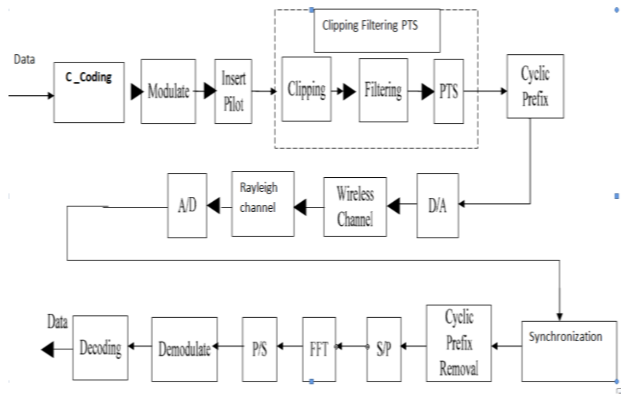

Fig. 4. Proposed PAPR technique (CRCF_PTS) for OFDM system

III. SIMULATION ASSUMPTIONS AND RESULTS

The major simulation parameters of OFDM system have been assumed as follow. FFT point is 64 (i.e. 64-subcarriers), modulation technique is QPSK, , 16-symbols cyclic prefix, and convolutional code with code rate 1/3. Two channel models have been assumed. AWGN channel and multipath fading channel model (3 paths, frequency selective, Doppler shift=20Hz, Rayleigh). In case of fading channel, maximal ratio channel equalizer is assumed. In addition, other parameters including oversampling factor (IF=1 &2), number of iterations (n = 4), clipping ratio (CR= 6dB), and number of PTS groups (V = 4) have been considered in our simulation. The overall performance of OFDM system has been evaluated and investigated with and without the proposed PAPR approach (CRCF_ PTS). The simulation results are shown in Fig.5 through Fig.8.

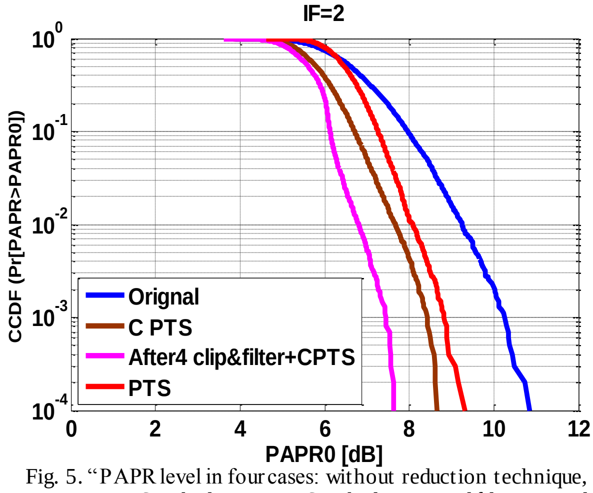

Fig. 5. "PAPR level in four cases: without reduction technique, PTS with clipping, PTS with clipping and filtering, and original PTS"

This lead to one or two clipping and filtering stages at maximum would be enough. The result presented in Fig.5 shows PAPR level obtained at four cases: without PAPR reduction technique, with traditional PTS, with PTS and clipping, and using PTS with clipping and filtering. Fig.5 shows CCDF of PARP versus reference PARP denoted by $(PAPR)_0$ using CRCF_PTS technique. It is clear from this fig.; a reduction of about 2.5 dB has been achieved by the proposed PAPR however, increasing the number of repeating stages added insignificant power reduction.

Next set of curves shown in fig. 6 illustrate the effect of clipping and filtering number of stages in the proposed PAPR reduction technique denoted by CRCF PTS. As shown in this fig., PAPR is decreased by increasing number of cascaded clipping and filtering stages following PTS algorithm. From this fig. it is very clear that the lowest PAPR is obtained by applying proposed PAPR reduction technique when compared with the other three cases.

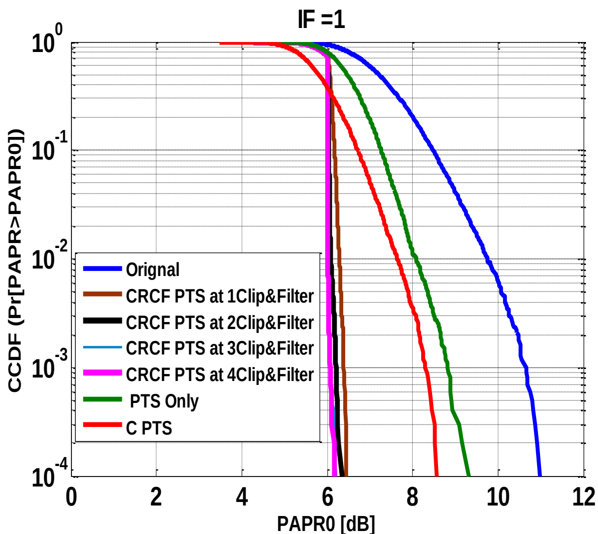

Fig. 6. Effect of filtering and clipping stages number on PAPR level compared with the same cases presented in Fig.5

In the next set of fig.s shown in fig. 7, the effect of oversampling order IF on the PAPR level is handled. As illustrated in this fig., by using IF = 1 obtained PAPR level will be lower than case of applying IF = 2. The reason is because of reduction happen in the average value of OFDM transmitted symbol when the number of zero padding increases. Complete OFDM transceiver, with stages shown in fig. 4, has been simulated and obtained results are presented in Fig.8. A pilot signal has been inserted to help us exactly recover the data at the receive part. Repeating clipping and Filtering is used with PTS (CRCF_PTS) method to process the modulated sequence, and then add cyclic prefix to eliminate the interference between each OFDM sub-carriers. After D/A conversion, the signal is sent into the wireless channel. The main drawback of PAPR reduction is the negative effect on BER performance, but actually in our case the proposed PAPR reduction technique didn't affect on BER level in both fading and noisy only channel cases. Summarization of simulation results of our novel technique has been presented in Table I.

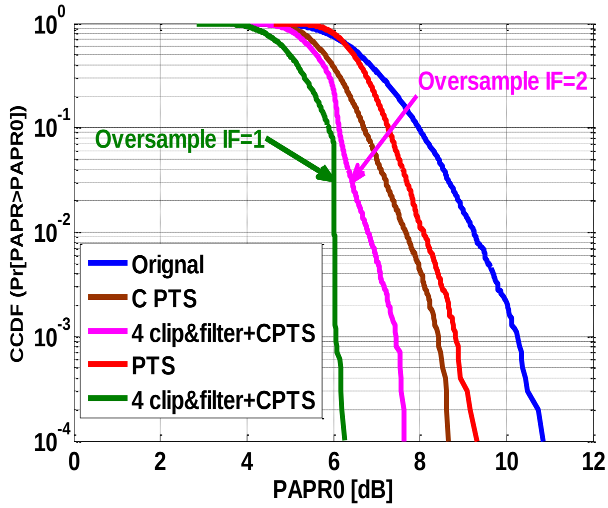

Fig. 7. PAPR level obtained by changing oversampling value IF=1, 2 compared with cases of study presented in Fig.5

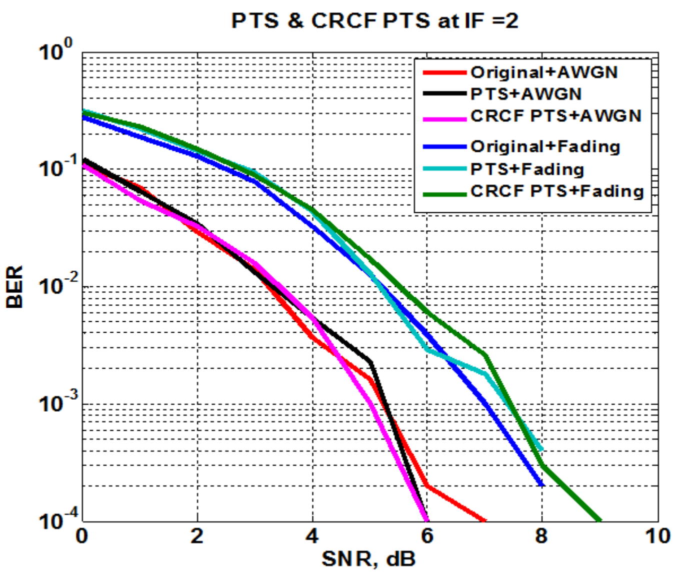

Fig. 8. BER performance versus variation in SNR for transmission over standard channel models

TABLE I
PAPR PARAMETERS IN DIFFERENT PAPR REDUCTION SITUATIONS

PAPR Parameter (In dB)	AFTER PTS	AFTER C_PTS	AFTER NEW Proposed (CRCAF_PTS) AT N=64 Oversample F=2		AFTER NEW Proposed (CRCF_PTS) AT N=64 Oversample F=1	
Mean (PAPR_Orignal) system	7.3051					
Mean(PAPR_After the reduction Technique)	6.5182	5.8549	After 4 CF	5.5743	After4 CF	5.0036
Variance (σ^2) (PAPR_Orignal)	0.3621	0.4389	1.0104		1.1255	
Variance (σ^2) (PAPR_After the reduction technique)	0.8167	0.9866	After 4CF	0.2694	After 4CF	0.3844
Power Reduction Factor (PRF) dB	0.7869	1.4502	1.7308		2.3015	
Percentage%	16.6%	28.4%	40.4%		41.2%	

IV. CONCLUSION

A novel PAPR reduction scheme based on repeating clipping and filtering, convolutional code, and conventional PTS has been proposed to reduce the peak- to- average power ratio of transmitted OFDM signal. Proposed PAPR reduction technique is denoted by (CRCF_PTS). Performance of CRCF_PTS has been evaluated using different clipping ratio and oversampling factor in case of AWGN and fading channel models. Simulation results showed that the proposed scheme resulted in system performance enhancement in terms of power reduction factor as well as BER. The presented PAPR technique provided an excellent power reduction with an acceptable additional processing delay for clipping and filtering technique as well as convolutional code. The presented PAPR method in this paper is strongly enhanced the OFDM system performance with acceptable complexity as well as processing time delay.

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