Proposed Combined PTS with Clipping and Filtering Technique for PAPR Reduction in OFDM System

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ABSTRACT

One of the major drawbacks of OFDM is high Peak-to-Average Power Ratio (PAPR) which can result in poor power efficiency and serious distortion in the transmitter amplifier. In this paper, the advantages of two different approaches to PAPR reduction are exploited in order to reduce the PAPR more significantly. The first approach is based on clipping and filtering which provides a high PAPR reduction at the cost of signal distortion. The second approach (Partial Transmit Sequence PTS or Selected Mapping SLM methods) results in no distortion. The performance of the three proposed combined methods(Clipping And Filtering with PTS scheme, SLM with Clipping And Filtering scheme, and PTS with Clipping And Filtering scheme)are evaluated on the PAPR distribution function and on the Bit Error Rate as a function of Signal to Noise Ratio in Additive White Gaussian Noise Channel. The simulation results show that the proposed PTS with Clipping And Filtering scheme provides more PAPR reduction without degradation in the BER performance as compared to the other two proposed scheme (Clipping And Filtering with PTS scheme and SLM with Clipping And Filtering scheme). The simulation results of PAPR reduction and BER performances are simulated using MATLAB R2009a computer simulation software.

Keywords: PAPR, OFDM , Clipping And Filtering , SLM , PTS , 32QAM Modulation

مقترح دمج طريقة سلسلة النقل الجزئيةِ مع طريقة القطع والترشيح لتقليل القمّةُ العاليةُ لمعدل نسبةِ القدرة لنظام التعدد ألتقسيمي الترددي المتعامد

الخلاصة

إحدى العوائق الرئيسيةِ للتعدد ألتقسيمي الترددي المتعامد (OFDM) هي القمّةُ العاليةُ لمعدل نسبةِ القدرة (PAPR) التي يُمْكِنُ أنْ تُؤدّي إلى كفاءةِ قدرة قليلة وتشويهِ متتالي في مضخّم المرسلَ. في هذه البحثِ، تم استخدم ميزات طريقتين مختلفتين لتُخفّض قيمة (PAPR) بصورة كبيرة . الطريقة الأولى مستندة على clipping and filtering لتوليد تخفيض عالي في (PAPR) مقابل ارتفاع في تكلفة تشويه الإشارة. اما الطريقة الثانية مستندة على (PTS or SLM) والتي لا تُؤدّي إلـى أي تشويهِ. إنّ أداءَ طرق الجمع الثلاثة المقترحة ,Clipping And Filtering with PTS scheme)

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SLM with Clipping And Filtering scheme, and PTS with Clipping And Filtering scheme) مُقَيَّمُ على وظيفةِ توزيعِ (PAPR) وعلى معدل نسبة خطأِ البت كدالة لنسبة الاشارة الى الضوضاء لقناة ضوضاءِ كاوسي. ان نَتائِجَ المحاكاةَ أظهرت بأنّ الطريقــة المُقتَرَحَــة (PTS with Clipping And Filtering scheme) خفضَت (PAPR) بصورة كبيــرة دون ان تسبب تدهور في اداء احتمالية خطأ البت (BER) بالمقارنة مع طــريقتين جديــدتين مقتــرحتين .(Clipping And Filtering with PTS scheme and SLM with Clipping And Filtering scheme) نتائج المحاكاة لتخفيض القمّة العاليةُ لمعدل نسبةِ القدرة (PAPR) ومعــدل نسبة خطأِ البت (BER) تمت باستخدام الحاسبة عن طريق برامج المحاكاة بالحاسوبِ MATLAB R2009a

INTRODUCTION

In Orthogonal Frequency Division Multiplexing (OFDM) system, the input data symbols are first passed through serial to parallel converter, forming a complex vector of size N. We call the vector as $X = [X_0, X_1, ..., X_{N-1}]^T$. After IFFT the signal can be written as equation (1).

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2pn\Delta ft} \qquad 0 \le t \le NT \qquad ...(1)$$

where $j = \sqrt{-1}, \Delta f$ is sub-carrier spacing and NT is OFDM symbol period **[1]**. One of the major drawbacks of OFDM modulation is its high peak-to-average power ratio (PAPR). Large PAPRs occur when symbol phases line up so as to constructively form peaks in the time-domain signal. Since the peak transmission power is limited, either by regulatory or hardware constraints, the average power must be reduced, leading to a loss in performance relative to the constant amplitude modulation techniques**[2]**. The PAPR of an OFDM signal will be**[1,2]**

$$PAPR = \frac{\max \left| x(t) \right|^2}{E\left[\left| x(t) \right|^2 \right]} \qquad ...(2)$$

where $\max|x(t)|^2$ is the peak signal power and $E[|x(t)|^2]$ is the average signal power. According to Central Limit Theorem, x is approximately independently and identically distributed (i.i.d).Hence, When N is large. the complex Gaussian random variables with zero mean and variance $s^2 = E[|x_n(t)|^2]/2$. the complementary cumulative distributed function (CCDF) of PAPR; i.e., the probability that PAPR exceeds a certain threshold PAPR0 can be calculated as**[1,2]**

$$CCDF\,[PAPR\,(x(t))] = P_r\,(PAPR\ \mathbf{f}\ PAPR_0)$$
$$= 1-(1-e^{-PAPR_0})^N \qquad ...(3)$$

PAPR REDUCTION TECHNIQUES IN OFDM SYSTEMS

Amplitude Clipping And Filtering

This method is based on simple time domain signal limitation - clipping. Clipped signal $s_c(t)$ can be expressed by followings relationship**[3,4,5,6]**.

$$s_c(t) = \begin{cases} A.e^{jf(t)} & |s(t)| > A \\ s(t) & |s(t)| \le A \end{cases} \qquad ...(4)$$

where s_c (t) is the clipped signal, S(t) is the original signal, A is the clipping level and $f(t)$ is the phase of S(t)**[5,6]**

By this limitation, the peak values of signal are removed that results in PAPR reduction. However, the clipping introduces signal distortion resulting in adjacent channel emissions. This undesirable effect can be suppressed by lowpass filtering of clipped signal, that unfortunately further increases the PAPR. Repeated clipping and filtering described a method based on *K*-times repetition of the clipping and filtering process. The main drawback of repeated clipping and filtering method is its high complexity. For each frequency domain filtering, two FFT calculations are necessary. A method named simplified clipping and filtering SCAFBD gives almost the same PAPR reduction as repeated clipping and filtering, but the complexity is significantly reduced. Only 3 FFT's are required for the PAPR reduction equivalent to iterative method using arbitrary *K*. Finally, we have implemented into this method the block to bound distortion (BD) to ensure higher noise immunity of transmitted signal**[3,4,5,6,7]**. A block scheme of the SCAFBD method is shown in Fig(1).

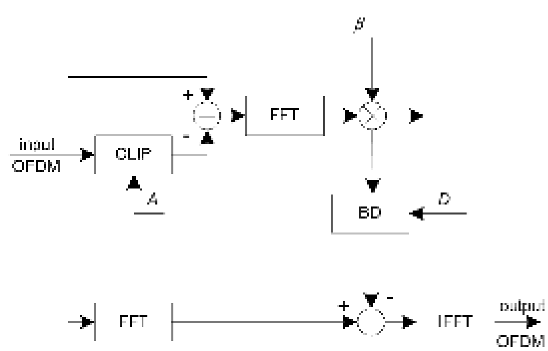


Figure (1) Block diagram of SCAFBD technique

Selected Mapping

SLM method is a kind of phase rotation methods. Phase rotated data of the lowest PAPR will be selected to transmit. Where U data sequence

$X^{(u)} = [X_0^{(u)}, X_1^{(u)},..., X_{N-1}^{(u)}]^T$ of length N (u = 0,1,..., U-1) are generated by multiplying original input $X = [X_0, X_1,..., X_{N-1}]^T$ component-wise with predetermined phase sequences $P^{(u)}$, whose length is also equal to N. Then, IFFT is applied to each sequence for transforming the signal from the frequency domain to the time domain. usually $P^{(u)}$ selected from {±1} for avoiding the complexity for complex multiplications. The modified data for the uth phase sequence $X^{(u)} = [X_0 P_{u,0}, X_1 P_{u,1},..., X_{N-1} P_{u,N-1}]^T, u = 0,1,2,..., U-1$. After the PAPR comparisons among the U data sequence $x^{(u)}$, the optimal mapped one $\hat{x}$ with the minimum PAPR is selected for transmission**[1,3,4,8]**.

$$\hat{x} = \underset{0 \le u \le U}{\arg\min} [\, PAPR\ (x^{(u)})] \qquad ...(5)$$

Figure (2) show the Block diagram of SLM technique without explicit side information.**[1]**

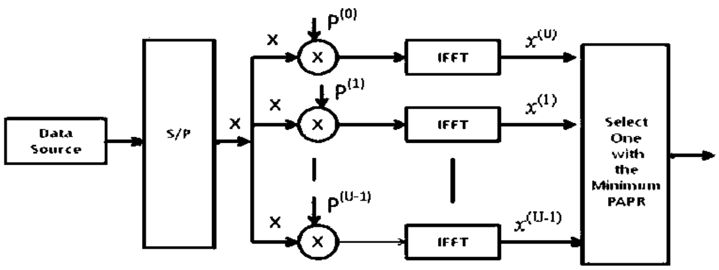


Figure (2) Block diagram of SLM technique

The amount of PAPR reduction for SLM depends on the number of phase sequences U and the design of the phase Sequences **[3,4,6,8].**

THE PARTIAL TRANSMIT SEQUENCE

In the PTS technique, input data block **X** is partitioned in M disjoint sub – blocks $X_m = [X_{m,0}, X_{m,1}, \ldots, X_{m,N-1}]^T, m = 1, 2, \ldots, M$ such that $\sum_{m=1}^{M} X_m = X$ and the sub – blocks are combined to minimize the PAPR in the time domain. The L times oversampled time domain signal of $\mathbf{X}_m$, m = 1, 2, …, M, is obtained by taking the IDFT of length NL on $\mathbf{X}_m$ concatenated with $(L – 1)N$ zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{jf_m}, m = 1,2,..., M$, are introduced to combine the PTSs. The set of phase factors is denoted a vector $b = [b_1, b_2,..., b_M]^T$ The time domain signal after combining is given by**[2,4,9]**

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

where $x'(b) = [x'_0(b), x'_1(b), ..., x'_{NL-1}(b)]^T$. The objective is to find the set of phase factors that minimizes the PAPR[2,4,9]. Minimization of PAPR is related to the minimization of $\max_{0 \le k \le NL-1} \left| x'_k(b) \right|$.Fig(3) shows the block diagram of the PTS technique**[3,4]**.

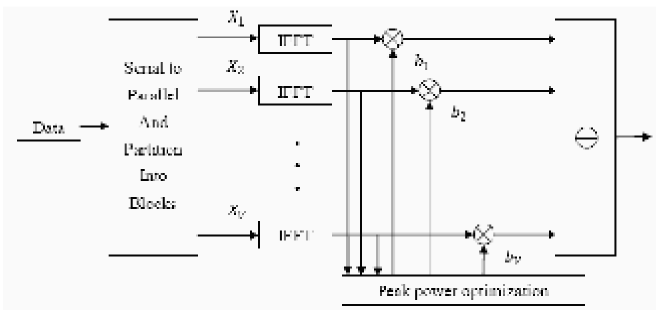


Figure (3) Block diagram of the PTS technique.

PROPOSED THREE COMBINED METHODS FOR PAPR REDUCTION IN OFDM SYSTEMS

In this paper, the proposed three combined methods are based on a concatenation between any two from the above-mentioned methods (the first proposed method is a concatenation between Clipping And Filtering with PTS method, the second proposed method is a concatenation between SLM with Clipping And Filtering method while the third proposed method is a concatenation between PTS with Clipping And Filtering method).

In the first proposed combined method, the signal is first processed by Clipping And Filtering PAPR reduction method. Due to amplitude clipping the distortion is observed in the system which can be viewed as another source of noise. The signal at the output of the Clipping And Filtering method has a lower PAPR but it is distorted. In order to further reduce in the PAPR, the signal is then processed using PTS distortionless method.

In the second and third proposed combined method, the PAPR of input OFDM signal is first reduced using PTS or SLM distortionless methods. The ability of PAPR reduction in SLM depends on the number of phase factors and the design of the phase factors which is limited in order to limit the complexity while the number of signal alternatives generated through the PTS used for the PAPR reduction is limited in order to limit the complexity. This is also motivated by the fact that the PAPR reduction often does not grow linearly with the increased number of alternatives. The resulting signal after SLM or PTS method has a lower PAPR and is not distorted. In order to further reduction in PAPR, the signal is then processed using Clipping And

Filtering PAPR reduction method which is further reduces in the PAPR and the cost of signal distortions can be controlled by the Clipping And Filtering method parameters.

CRITERIA FOR SELECTION OF PAPR REDUCTION TECHNIQUE

As in everyday life, we must pay some costs for PAPR reduction. There are many factors that should be considered before a specific PAPR reduction technique is chosen. These factors include PAPR reduction capability, power increase in transmit signal, BER increase at the receiver, loss in data rate, computational complexity increase.**[3,4]**

SIMULATION AND RESULTS

Here all Simulation results of OFDM PAPR reduction have been verified in MATLAB R2009a and the evaluation of the proposal three Combined methods are presented and compared for 32QAM mapping as modulation scheme for each sub-carrier (N=64 or N=256) to produce different CCDF performance curves where CCDF means that the probability of an OFDM frame exceeding a given PAPR when the x-axis represents the combined PAPR thresholds while the y-axis represents the probability of CCDF or probability of PAPR grater than threshold. The BER performance will be evaluated under the effect of Additive White Gaussian Noise (AWGN).We used 10^5 randomly distributed symbols to produce all of the graphs.

SIMULATION RESULTS OF PROPOSED CLIPPING AND FILTERING WITH PTS METHOD

For the proposed Clipping And Filtering with PTS scheme. The signal is first processed by Clipping And Filtering PAPR reduction method then the output signal processed using PTS distortionless method. For the iterated Clipping And Filtering technique, the Amplitude clipping distortion falls in both in band and out of band. Out of band radiation can be reduced by filtering after clipping but this may result in some peak re-growth. So in the simulation, it can be used five iterative clipping and frequency domain filtering to avoid peak re-growth with eight Oversampling factor. While for PTS technique, we used four sub-blocks (V = 4) with QPSK phase factor rotation(W=4).

The results of the proposed scheme shown in Fig(4) for sub-carrier N=64 and in Fig(5) for sub-carrier N=256.

From Fig(4) and Fig(5), it is shown that the proposed scheme achieves more PAPR reduction than the conventional clipping and filtering method. Moreover, this figure also shows that the PAPR of the proposed scheme is slightly lower than that of the conventional PTS method

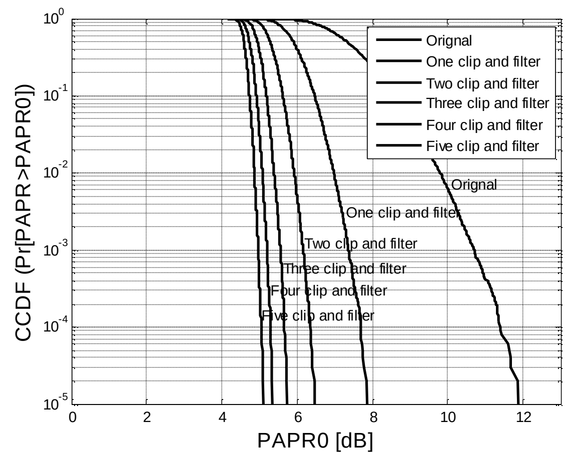


Figure (4) Proposed combining Clipping And Filtering with PTS scheme for OFDM system with 32QAM modulation and N=64 , V=4 , W = 4(QPSK phase factor rotation) , Oversampling factor =8 and number of iteration = 5.

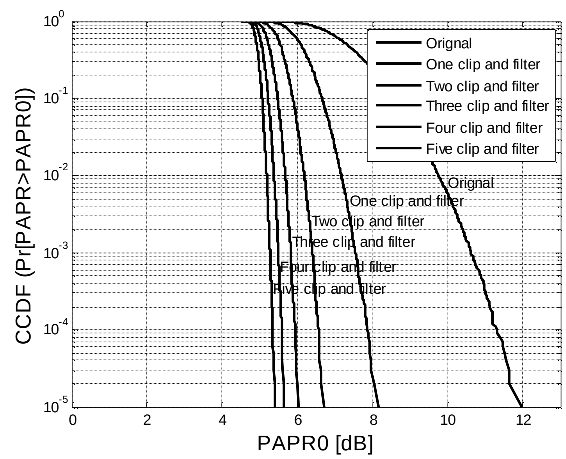
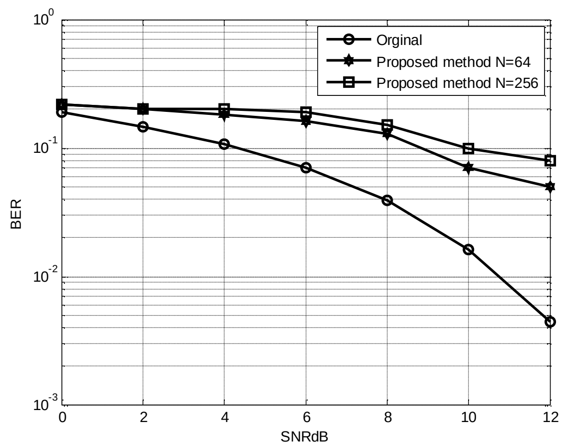


Figure (5) Proposed combining Clipping And Filtering with PTS scheme for OFDM system with 32QAM modulation and N=256 , V=4 , W = 4(QPSK phase factor rotation) , Oversampling factor =8 and number of iteration = 5.

From the previous two figures, as the iterative clipping and filtering are increased the PAPR CCDF curve decrease and the PAPR CCDF curves are increased when N increase.

Fig(6) shows the BER performance of the proposed combining Clipping And Filtering with PTS PAPR reduction scheme for OFDM system with 32QAM modulation and for N=64 and N=256. From the figure we observe high degradation BER performance of the proposed scheme after five iteration and the simulation results reveal that the proposed scheme provides a poor BER performance when of the number of subcarriers are increased.



Figure(6) BER performance for the proposed combining Clipping And Filtering with PTS scheme for OFDM system with 32QAM modulation and N=64 and N=256

SIMULATION RESULTS OF PROPOSED SLM WITH CLIPPING AND FILTERING METHOD

For the proposed SLM with Clipping And Filtering scheme. The signal is first processed by SLM distortionless method then the output signal processed using Clipping And Filtering PAPR reduction method. SLM scheme is relatively significant method since it can obtain better PAPR by modifying the OFDM signal without distortion. Selecting of proper phase sequences used to achieve good PAPR reduction is very important in SLM technique. The ability of PAPR reduction in SLM depends on the number of phase factors and the design of the phase factors. It was demonstrated that the side information in SLM does not need to be transmitted, but, can instead be blindly detected at the receiver with negligible increase in BER. The only cost of SLM is in additional processing. Because the PAR of each of D phase sequence/data combinations must be found. In this simulation. For the SLM technique, we used Oversampling factor = 8 with QPSK phase factor rotation and the number of route = 4. While for iterative Clipping And Filtering technique, we used Oversampling factor = 8 and number of iteration = 5.

The results of the proposed scheme shown in Fig(7) for sub-carrier N=64 and in Fig(8) for sub-carrier N=256.

From Fig(7) and Fig(8), it is shown that the proposed SLM with Clipping And Filtering scheme achieves more PAPR reduction than the conventional SLM or conventional clipping and filtering method. Moreover, this figure also shows that the PAPR of the proposed scheme is slightly lower PAPR than the previous proposed Clipping And Filtering with PTS scheme

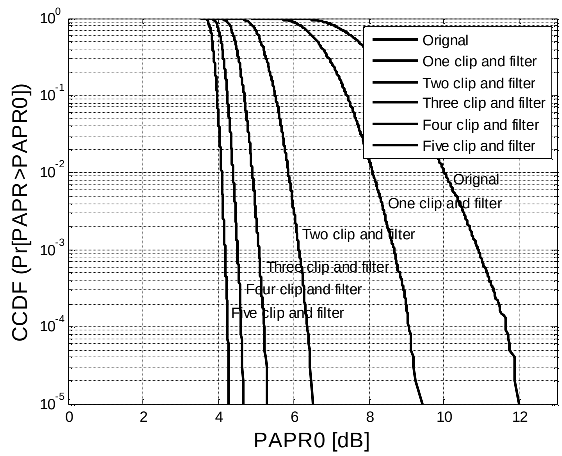
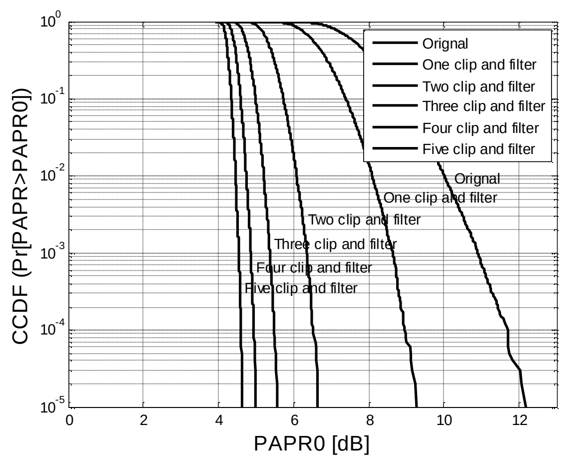


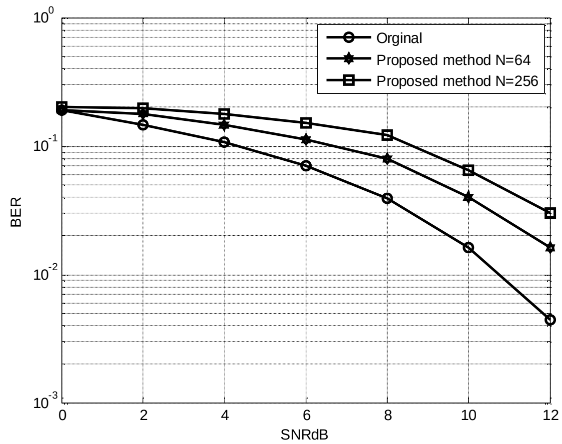
Figure (7) Proposed combining SLM with Clipping And Filtering scheme for OFDM system with 32QAM modulation , N=64 , Oversampling factor = 8 , QPSK phase factor rotation , number of route = 4 & number of iteration = 5



Figure(8) Proposed combining SLM with Clipping And Filtering scheme for OFDM system with 32QAM modulation, N=256 , Oversampling factor = 8 , QPSK phase factor rotation , number of route = 4 & number of iteration = 5

From the previous two figures, as the iterative clipping and filtering are increased the PAPR CCDF curve decrease and the PAPR CCDF curves are increased when N increase.

Fig (9) show the BER performance of the proposed combining SLM with Clipping and Filtering PAPR reduction scheme for OFDM system with 32QAM modulation and for N=64 and N=256. From this figure, also we observe high degradation BER performance of the proposed scheme after five iteration and the simulation results reveal that the proposed scheme provides a poor BER performance when of the number of subcarriers are increased



Figure(9) BER performance for the proposed combining SLM with Clipping And Filtering scheme for OFDM system with 32QAM modulation for N=64 and N=256

SIMULATION RESULTS OF PROPOSED PTS WITH CLIPPING AND FILTERING METHOD

From the second proposed method, The SLM requires the transmission of the side information to indicate the used masking pattern, It needs multiple IFFT operation, Detection of the making pattern is needed for recovery of data stream from the received signal. Also, the selection of the symbol with the minimum PAPR involves large computational complexity and fails to utilize the range of the power amplifiers effectively.

In the proposed PTS with Clipping And Filtering scheme. The signal is first processed by PTS distortionless method then the output signal processed using Clipping And Filtering PAPR reduction method. PTS is important probabilistic scheme for PAPR reduction, the alternative OFDM signals generated by PTS are interdependent. PTS divides the frequency vector into some subblocks before applying the phase transformation. Therefore, some of the complexity of the serval full IFFT operations can be avoided in PTS, so that it is more advantageous than SLM if the amount of computational complexity is limited. Also it is demonstrated that the PAPR reduction in PTS performs better than that of SLM. In this simulation, we used the number of sub-blocks V = 4 and W = 4(QPSK phase factor rotation) for PTS technique. While, we used Oversampling factor = 8 and number of iteration = 5 for iterative Clipping And Filtering method.

The results of the proposed scheme are shown in Fig(10) for sub-carrier N=64 and in Fig(11) for sub-carrier N=256From Fig(10) and Fig(11), it is shown that the proposed scheme achieves more PAPR reduction than the conventional PTS or conventional clipping and filtering method. Moreover, the proposed PTS with

Clipping And Filtering scheme is slightly lower PAPR reduction than the previous two proposed PAPR reduction (Clipping And Filtering with PTS and SLM with Clipping And Filtering)scheme

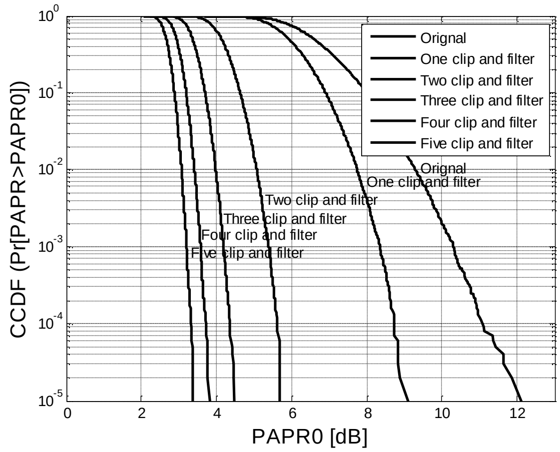


Figure (10) Proposed combining PTS with Clipping And Filtering scheme for OFDM system with 32QAM modulation and N=64 , V=4 , W = 4(QPSK phase factor rotation) , Oversampling factor = 8 and number of iteration = 5.

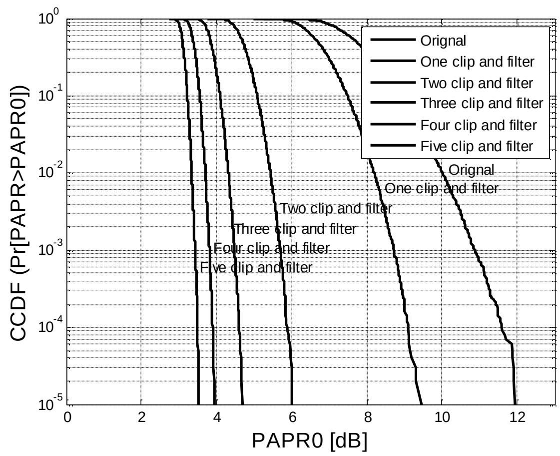


Figure (11) Proposed combining PTS with Clipping And Filtering scheme for OFDM system with 32QAM modulation and N=256 , V=4 , W = 4(QPSK phase factor rotation) Oversampling factor = 8 and number of iteration = 5.

Fig (12) shows the BER performance of the proposed combining PTS with Clipping And Filtering PAPR reduction scheme for OFDM system with 32QAM modulation and for N=64 and N=256. From the figure we confirm that the BER performance of the proposed scheme is almost equal to that of the conventional OFDM system and the simulation results reveal that the proposed scheme provides a good BER performance regardless of the number of subcarriers and modulation orders.

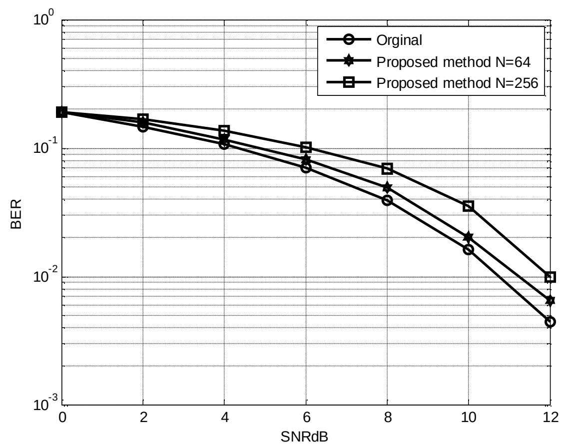


Figure (12) BER performance for the proposed combining PTS with Clipping And Filtering scheme for OFDM system with 32QAM modulation for N=64 and N=256

Table(1) show the PAPR in dB for the three proposed scheme at 10^{-5} CCDF and for five Iterative Clipping And Filtering for different sub-carrier (N=64 and N=256)

Table(1) PAPR in dB for three proposed PAPR methods at 10^{-5} CCDF

Iterative number for Clipping And Filtering method	Clipping And Filtering with PTS scheme		SLM with Clipping And Filtering scheme		PTS with Clipping And Filtering scheme	
	N=64	N=256	N=64	N=256	N=64	N=256
First iteration	7.9	8.1	9.4	9.42	9	9.4
Second iteration	6.4	6.7	6.4	6.6	5.7	6
Third iteration	5.85	6	5.2	5.6	4.5	4.7
Fourth iteration	5.45	5.7	4.5	5	3.85	4
Fifth iteration	5.2	5.45	4.2	4.6	3.5	3.7

As a compared between three proposed OFDM PAPR reduction scheme, it is required to have a PAPR reduction scheme which are achieves a good trade-off between the PAPR reduction and BER performance. Therefore, the Proposed PTS With Clipping And Filtering scheme is the better proposed scheme than the other two proposed scheme which is give lowest possible value of PAPR while keeping a minimal level BER.

CONCLUSIONS

In this paper, a combination of three PAPR reduction schemes are proposed (Clipping And Filtering with PTS scheme, SLM with Clipping And Filtering scheme and PTS with Clipping And Filtering method) are presented. The performance of the proposed schemes are evaluated by simulation on OFDM signals with different data subcarriers (N=64 and N=256) for 32QAM modulation. The simulation results show that the Proposed PTS With Clipping And Filtering scheme is the better proposed scheme between three proposed PAPR reduction scheme which gives lowest possible value of PAPR while keeping a minimal level BER. In the case of a lower number of subcarriers(N=64), the PAPR reduction provides good results in terms of both PAPR reduction and BER improvement in the nonlinear channel. While, for the signal with a very high number of subcarriers(N=256), the PAPR reduction is also evident but is not manifested by any BER improvement.

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