

NEW IMPROVED CLIPPING AND FILTERING TECHNIQUE ALGORITHM FOR PEAK-TO-AVERAGE POWER RATIO REDUCTION OF OFDM SIGNALS

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ABSTRACT

This paper is focused in the domain of PAPR reduction of OFDM signals. The main idea is to use a combination of data interleaving with clipping and filtering and use of optimum clipping Ratio (γ) in order to increase the overall performance of the system and the PAPR, BER is evaluated in AWGN channel. The main advantage of the proposed combination lies in reducing PAPR and significantly reduction in BER in the presence of AWGN channel. Moreover, the Clipped OFDM symbols obtained by our optimized Clipping and Filtering method have less in-band signal distortion and lower out-of-band radiation than the existing method.

Keywords: Clipping and filtering, OFDM, PAPR, optimum clipping Ratio.

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a promising modulation radio access scheme for future wireless communication systems because of its inherent immunity to multipath interference due to a low symbol rate, the use of a cyclic prefix, and its affinity to different transmission bandwidth arrangements. OFDM has already been adopted as a radio access scheme for several of the latest cellular system specifications such as the long-term evolution (LTE) system in the 3GPP (3rd Generation Partnership Project) [1].

One of the major drawbacks of the OFDM signal based on multicarrier transmission is the high peak-to-average power ratio (PAPR) of the transmission signal. If the peak transmission power is limited, e.g., by regulations, the average transmission power that is allowed for an OFDM signal is reduced relative to that for a single-carrier transmission. This in turn reduces the range of the OFDM signal transmission. Moreover, to prevent spectral growth of the OFDM signal in the form of intermodulation among subcarriers and out-band radiation, the transmit power amplifier must be operated in its linear region. This means that the OFDM signal requires a large input backoff and this result in inefficient power conversion.

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In this paper we focus on PAPR reduction techniques based on nonlinear functions. Two well-known examples are clipping techniques which use a clipping function for PAPR reduction and filtering techniques which use at the transmitter side for PAPR reduction [2, 3]. However, since the OFDM signal consists of a number of independently modulated subcarriers, it produces severer peak-to-average power ratio (PAPR) than single-carrier signals. The large PAPR of the signal causes clipping when the signal is passed through the non-linear amplifier. Such clipping produces clipping noise that will result in performance degradation. In addition, clipping will also cause spectral re-growth in out-of-band which may cause interference to other systems. So in the recent decade, numerous solutions and improved algorithms have already been proposed to reduce PAPR [4, 5]. The large PAPR will cause the error rate performance loss is the clipping noise generated by clipping when the signal is passed through a non-linear amplifier. The nonlinear distortion causes both in-band and out-of-band interference of signal. The in-band interference increases the BER of the received signal through warping of the signal constellation and intermodulation, while the out-of-band interference causes adjacent channel interference through spectral spreading [6].

2. SOME BASICS OF OFDM AND PAPR

In OFDM, the signal samples are grouped in blocks of N symbols, $\{X_n, n = 0, 1, \dots, N - 1\}$, which are modulating one of a set of N subcarriers, $\{f_n, n = 0, 1, \dots, N - 1\}$. These subcarriers are chosen to be orthogonal, that is $f_n = n \cdot f$, where $f = 1/T$, and T is the OFDM symbol period. The resulting signal can be written as: [12]

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t} \quad (1)$$

In order to avoid the intersymbol interference (ISI) generated by the multipath channels, a Cyclic Prefix (CP-corresponding to a guard interval) is added to the signal. After Digital-to-Analogue (D/A) conversion the signal is modulated to a carrier frequency and applied to a high-powered amplifier (HPA) which drives the antenna load. At the receiver, after demodulation, the CP will be removed, the symbols being evaluated for a time interval of $[0, T]$.

Time domain samples of the low-pass OFDM signals in the complex domain are appreciatively Gaussian distributed due to statistical independence of carriers. The weighted sums of random variables which forms peaks in the signal, causes the PAPR problem. The expression of the PAPR for a given OFDM signal block is given by:

$$PAPR(x) = \frac{\max(|x(t)|^2)}{E(|x(t)|^2)} \quad (2)$$

Where $E[.]$ denotes the expectation operator.

3. CONVENTIONAL CLIPPING AND FILTERING

Clipping and Filtering is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal.

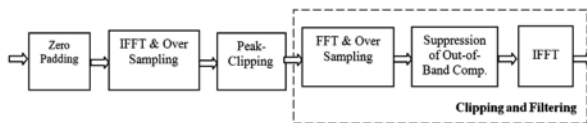


Figure 1: Block Diagram of Conventional Clipping and Filtering Technique

Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed. [12]

$$B(x) = \begin{cases} x & |x| \leq A \\ Ae^{j\phi(x)} & |x| > A \end{cases}$$

where, $B(x)$ = the value after clipping.

x = the initial signal value.

A = the threshold set by the user for clipping the signal.

3.1 Conventional Method Has the Following Drawbacks

- Clipping causes in-band signal distortion, resulting in BER performance degradation.
- Clipping also causes out-of-band radiation, which imposes out-of-band interference signals to adjacent channels. Although the out-of-band signals caused by clipping can be reduced by filtering, it may affect high-frequency components of in-band signal (aliasing) when the clipping is performed with the Nyquist sampling rate in the discrete-time domain. [12]
- However, if clipping is performed for the sufficiently-oversampled OFDM signals (e.g., $L \geq 4$) in the discrete-time domain before a low-pass filter (LPF) and the signal passes through a band-pass filter (BPF), the BER performance will be less degraded [7].
- Filtering the clipped signal can reduce out-of-band radiation at the cost of peak regrowth. The signal after filtering operation may exceed the clipping level specified for the clipping operation [8].

4. MODIFIED CF TECHNIQUE WITH OPTIMUM VALUE OF γ

However, the clipping introduces signal distortion resulting in adjacent channel emissions. This undesirable effect can be suppressed by low pass filtering of clipped signal that unfortunately further increases the PAPR. Armstrong [9] developed a method based on K -times repetition of the clipping and filtering process. Therefore both PAPR and adjacent spectral emissions are reduced, although the PAPR reduction is far from simple clipping case. The main drawback of repeated clipping and filtering method is its high complexity. For each frequency domain filtering, two FFT's are necessary. There is a need to compute $2K + 1$ FFT's in total. Recently a method named simplified clipping and filtering has been proposed [10]. Its performance in term of PAPR reduction attains the values provided by repeated clipping and filtering, however the complexity is significantly reduced. Only 2 FFT calculations are required for the PAPR reduction equivalent to iterative method using arbitrary K . In paper [11], authors used a combination of interleaving (adaptive symbol selection) with simple clipping followed by a filter increasing the PAPR.

5. PROPOSED OPTIMIZED CLIPPING AND FILTERING ALGORITHM

Figure 2 shows a block diagram of a PAPR reduction scheme using clipping and filtering where L is the oversampling factor and N is the number of subcarriers. In this scheme, the L -times oversampled discrete-time signal $x'[m]$ is generated from the IFFT of Equation (3),

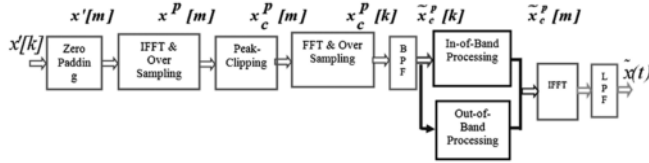


Figure 2: Proposed System Model

$$x'[k] = \begin{cases} x[k] & \text{for } 0 \leq k \leq N/2 \text{ and } NL - N/2 < k < NL \\ 0 & \text{elsewhere} \end{cases} \quad (3)$$

($x'[k]$ with $N(L-1)$ zero-padding in the frequency domain) and is then modulated with carrier frequency f_c to yield a passband signal $x^p[m]$. Let $x_c^p[m]$ denote the optimize clipped version of $x^p[m]$, which is expressed as

$$x_c^p[m] = \begin{cases} -A & x^p[m] \leq -A \\ x^p[m] & |x^p[m]| < A \\ A & x^p[m] \geq A \end{cases} \quad (4)$$

$$x_c^p[m] = \begin{cases} x^p[m] & \text{if } |x^p[m]| < A \\ \frac{x^p[m]}{A} & \text{otherwise} \end{cases} \quad (5)$$

Where A is the pre-specified clipping level. Here Equation (5) can be applied to both baseband complex-valued signals and passband real-valued signals, while Equation (4) can be applied only to the passband signals. Let us define the clipping ratio (CR) as the clipping level normalized by the RMS value s of OFDM signal, such that $CR = A/s$

It has been known that $s = \sqrt{N}$ and $s = \sqrt{N/2}$ in the baseband and passband OFDM signals with N subcarriers, respectively.

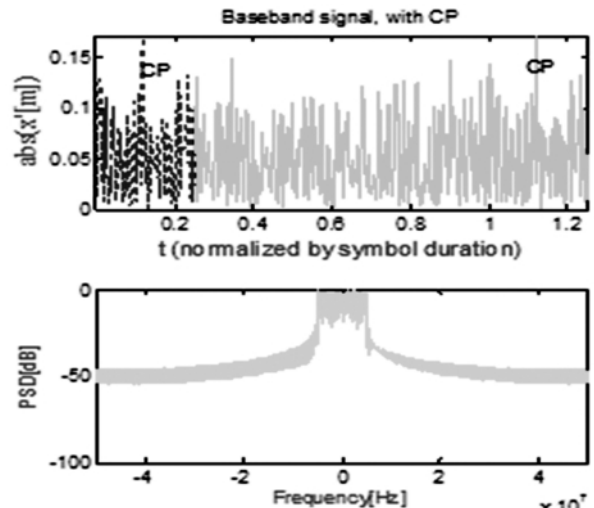
6. PARAMETERS OF PROPOSED MODEL AND SIMULATION

Table 1 shows the values of parameters used in the QPSK/OFDM system for analyzing the performance of proposed Optimize Clipping and Filtering Model in Figure 2 shows the impulse response and frequency response of the (equiripple) finite-duration impulse response (FIR) BPF used in the simulation where the sampling frequency $f_s = 10$ MHz, the stopband and passband edge frequency vectors are [1.5, 2.7] [MHz] and [1.6, 2.6] [MHz], respectively, and the number of taps is set to 104 such that the stopband attenuation is about 40dB. Figure 3 shows the results of proposed algorithm for OFDM signals with the parameter values listed in Table 1 Figures 3 (a)-(d) show the histograms as probability density functions (PDFs) and power spectra of the oversampled baseband OFDM signal, the corresponding passband signal $x^p[m]$, the passband

optimize clipped signal $x_c^p[m]$, and its filtered signal $\tilde{x}_c^p[m]$. It can be seen from Figure 3 (b) that the OFDM signal approximately follows a Gaussian distribution. Meanwhile, Figure 3(c) shows that the amplitude of the clipped signal is distributed below the clipping level. Finally, it can be seen from Figure 3(d) that the filtered signal shows its peak value beyond the optimize clipping level. Comparing Figure 3(c) to Figure 3(d), it can also be seen that the out-of-band spectrum increases after clipping, but decreases again after filtering. Figure 4(a) shows the CCDFs of crest factor (CF) for the optimize clipped and filtered OFDM signals. Recall that the CCDF of CF can be considered as the distribution of PAPR since CF is the square root of PAPR. It can be seen from this figure that the PAPR of the OFDM signal decreases significantly after clipping and increases a little after filtering if we choose optimize clipping ratio then the greater the PAPR reduction effect shown in Figure 4(a) and Figure 4(b) shows the PAPR analysis and BER performance when optimize clipping and filtering technique is used. It can be seen from this figure that the BER performance becomes best as if we choose optimize clipping ratio.

Table 1
Parameters Used for Simulation of Proposed Optimize Clipping and Filtering Model

Parameters	Value
Bandwidth, BW	1MHz
Oversampling Factor, L	10
Sampling Frequency, $f_s = BW.L$	10 MHz
Carrier Frequency, f_c	4 MHz
FFT Size, N	256
Number of Interval samples (CP)	64
Modulation order	QPSK
Clipping Ratio (CR)	0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0

(a) Baseband Signal $x'[m]$ and its Power Spectrum

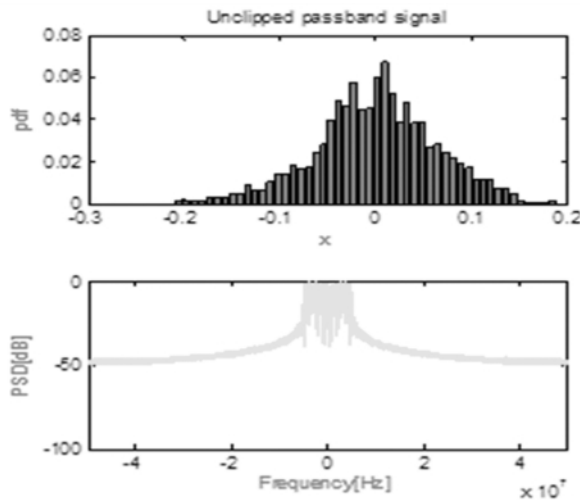
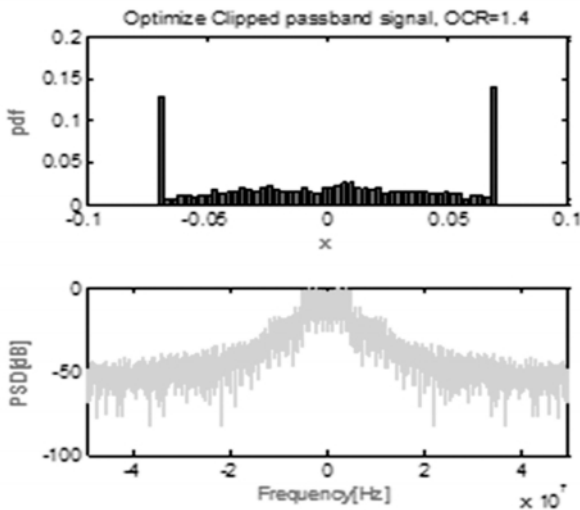
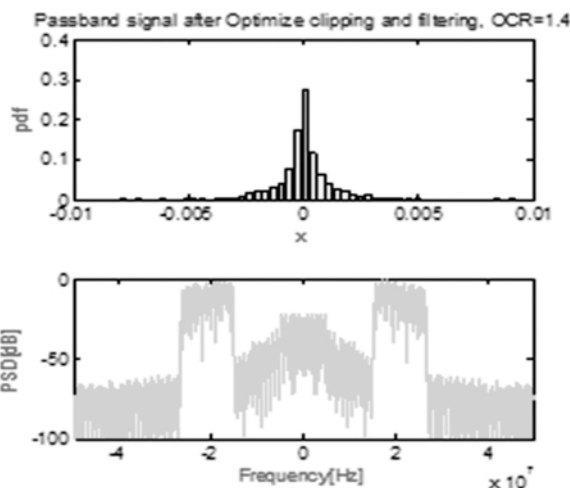
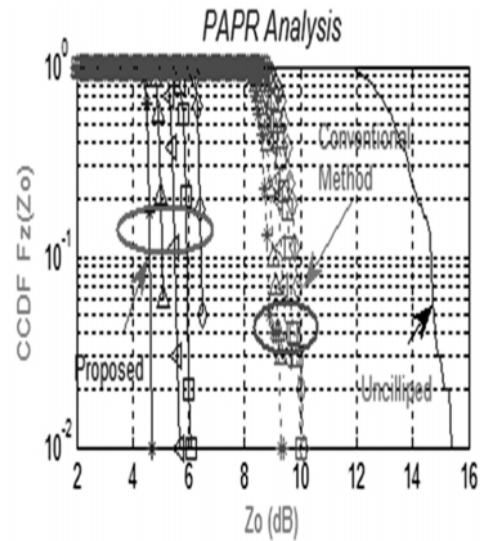
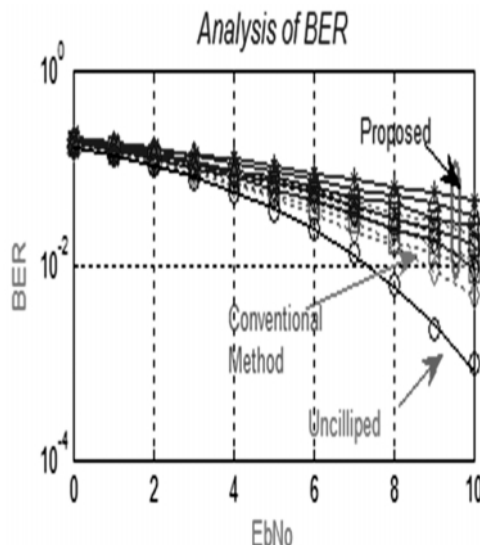
(b) Pdf and Power Spectrum of the Passband signal $x^p[m]$ (c) Pdf and Power Spectrum of the Optimize Clipping Signal $\hat{x}_c^p[m]$ (d) Pdf and Power Spectrum of the Filtered Signal $\hat{x}_c^p[m]$

Figure 3: Histogram (PDF's) and Power Spectral of OFDM Signal



(a) PAPR Distribution



(b) BER Performance

Figure 4: PAPR Distribution and BER Performance with Proposed Algorithm

7. CONCLUSION

In this paper, a new combined method for PAPR reduction of OFDM signals has been proposed. This method combines two basic PAPR reduction methods Interleaving and Repeated (or Simplified) clipping and filtering. The main advantage of the proposed combination lies in substantial BER reduction in AWGN channel. Another advantage of proposed method is lessening of in-band signal distortion and out-of-band distortion resulting in Improvement of BER performance. The disadvantage of the method is a need for side information transmission. Moreover the paper briefly discuss the influence of side information coding on total bit error probability. The goal of further research could be for example in elimination of side information transmission. The PAPR and BER can be further improved by using a new algorithm based on digital filtering.

REFERENCES

- [1] 3GPP TS36.300, Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description.
- [2] A.K. Gurung et. al. "Power Saving Analysis of Clipping and Filtering Method in OFDM Systems", *Telecommunication Networks and Applications Conference, ATNAC 2008, IEEE*, pp. 204-208.
- [3] H. Chan and A. Haimovich "An Iterative Method to Restore the Performance of Clipped and Filtered OFDM Signals", *Communications, 2003. ICC'03. IEEE International Conference*, 5, pp. 3438-3441.
- [4] D. Qing and Z. Hongsheng, "An Improved Algorithm to Reduce PAPR Based Clipping and Filtering", *Wireless Communications, Networking and Mobile Computing, 2008. WiCOM'08 International Conference*, pp. 1-4.
- [5] S.H. Leung et. al. "Algorithm for Repeated Clipping and Filtering in Peak-to-average Power Reduction for OFDM", *Electronics Letters*, 5th December 2002, **38(25)**, pp. 1726-1727.
- [6] K.D. Rao and T.S.N. Murthy, "Analysis of Effects of Clipping and Filtering on the Performance of MB-OFDM UWB Signals", *Proc. of the 2007 15th International Conference on Digital Signal Processing (DSP 2007), IEEE*, pp. 559-562.
- [7] Ochiai H. and Imai K. (Dec. 2000). "On Clipping for Peak Power Reduction of OFDM Signals". *IEEE GTC*, **2**, pp. 731-735.
- [8] Han S.H. and Lee J.H. (2005). "An Overview of Peak-to-average Power Ratio Reduction Techniques for Multicarrier Transmission". *IEEE Wireless Commun.*, **12(2)**, 56-65.
- [9] J. Armstrong, "Peak-to-average Power Reduction for OFDM by Repeated Clipping and Frequency Domain Filtering", *Electronics Letters* 28th February 2002, **38(5)**, pp. 246-247.
- [10] L. Wang, Ch. Tellambura, "A Simplified Clipping and Filtering Technique for PAR Reduction in OFDM Systems", *IEEE Signal Processing Letters*, **12(5)**, June 2005, pp. 453-456.
- [11] H. Ochai, H. Imai, "Performance of the Deliberate Clipping with Adaptive Symbol Selection for Strictly Band-Limited OFDM Systems", *IEEE Journal on Selected Areas in Communications*, **18(11)**, November 2000, pp. 2270-2277.
- [12] Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung-Gu Kang, "MIMO-OFDM Wireless Communications with MATLAB", pp. 230-270, Jhon Wiley and sons (Asia) Pte Ltd.