



PAPR Reduction in OFDM using Iterative Clipping and Filtering With Comparative Study of SLM and PTS

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Abstract: The rapid growth in multimedia –based applications has triggered a need for high data transmission rates and as a result demands on Orthogonal Frequency Division Multiplexing (OFDM) have increased that supports high data rates and high mobility. Amplitude of such signals consists of high peaks as they have large number of independent subcarriers. Efficient spectral usage and multipath delay spread tolerance are the main advantages of OFDM. Another advantage is that the modulation and demodulation can be implemented using inverse Fast Fourier Transformation (IFFT) and Fast Fourier Transformation (FFT) operations, which are computationally efficient. The major problem that arises in OFDM (multicarrier) system is the resulting in non-constant envelope with high peaks. Coherent addition of independent modulated subcarriers results in instantaneous power increase with respect to average power. This leads to high peaks in the received signal power due to destructive interference that leads to high Peak to Average Ratio (PAPR). Also some of the parameters like inter-symbol interference (ISI), inter-channel interference (ICI) and bandwidth increase the PAPR. Peak to Average Power Ratio must be minimized for valuable data transmission with high efficiency for OFDM communication system with limited resources. One of the effective techniques available to provide a high efficiency in PAPR reduction is to clip the high amplitude peak, so by clipping the signal, the spectral efficiency of the multicarrier signal is reduced. Hence, clipping could be effective technique with a very low complexity for PAPR reduction and filtering is carried out after clipping in order to eliminate unwanted frequencies by the clipping process.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), Iterative Clipping and Filtering (ICF).

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is an attractive technology that is based on multicarrier modulation techniques. It offers high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency. As a result for high data rate communication OFDM access technology has been chosen and is widely deployed in wireless communication standards as Digital Video Broad casting (DVB) and for mobile Wi-Max. In a simple OFDM generator, N subcarriers are transmitted in 1 bit of information each, by turning on and off at time intervals T in the digital domain by using the Fast Fourier Transform (FFT) and its counterpart, the inverse Fast Fourier Transform (IFFT). These mathematical operations are widely used for transforming data between the time-domain and frequency-domain. There are many challenging issues that are unresolved in OFDM. Peak to Average Ratio is one of the major problems of transmitted OFDM signal. Many techniques are proposed to solve the problem of PAPR occurring in the OFDM signals while transmission that include Clipping, Companding, Coding, Interleaving, Selective Mapping[3], Partial Transmit Sequence, Tone Reservation and Tone Injection. Performance degradation in terms of BER as compared to original OFDM signal occurs in many of these techniques. Among all these techniques Iterative Clipping and Filtering (ICF) procedure may be the simplest technique to approach a specified PAPR threshold in the processed OFDM symbols. In time domain clipping causes out-of band spectral re-growth and in-band distortion that latter causes degradation in BER performance of OFDM symbols. In frequency domain Filtering minimizes the spectral re-growth but can generate large time domain peaks so the ICF needs much iteration to achieve the desired PAPR reduction.

II. Theoretical Methods

A. OFDM symbol:

Let $c \in C^N$ be the frequency domain OFDM symbol and $\{c(i), i=1, \dots, N\}$ be the symbol value carried by the i-th sub-carrier. The time domain OFDM symbol, $x \in C^{lN}$ corresponding to c with l times oversampling can be expressed as

$$x(k) = 1/\sqrt{lN} \sum_{i=1}^N c(i)e^{j2\pi lNki} \quad (1)$$

Where $k=1 \dots l N$ is time index

$$c(i) = 1/\sqrt{LN} \sum_{k=1}^{LN} x(k) e^{j2\pi i k} \quad (2)$$

Where $i=1 \dots N$. Here for modulation and demodulation IFFT and FFT is implemented.

B. PAPR:

OFDM signal consists of a number of independently modulated sub-carriers that gives large PAPR when these are added coherently. When N signals are added with same phase produces peak power that is N times greater than the average power of signal. Thus has OFDM large PAPR that is very sensitive to nonlinearity of the high power amplifiers. In OFDM, block of N symbols $\{X, k=0,1,\dots,N-1\}$, is formed such that each symbols modulated a set of subcarriers, $\{f, k=0,1,\dots,n-1\}$. The N subcarriers are selected such that they are orthogonal, that is, $f_k f_{k'} = D$, where $Df = 1/NT$ and T is original time period.

The resulting signal is given as:

$$x(t) = \sum_{n=0}^{N-1} x^n e^{j2\pi f_n t} \quad (3)$$

PAPR is given by:

$$PAPR = \max |x(t)|^2 / E[|x(t)|^2] \quad (4)$$

Where $E[|x(t)|^2]$ denotes expectation operator.

II. Proposed method

A. Classic Clipping and Filtering method:

Much iteration are required to approach the specified PAPR threshold in the complementary cumulative distribution function (CCDF) when implemented with fixed rectangular window in frequency domain. CCDF of PAPR can be defined as probability that the PAPR exceeds the given threshold $CCDF = 1 - \Pr(PAPR \leq A)$

Clipping and Filtering

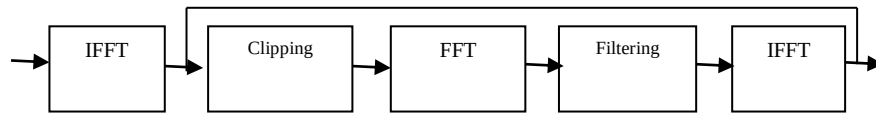


Figure1: Classic Iterative Clipping and Filtering [1]

The new OFDM symbol enters the ICF block in the first iteration ($i=1$). Clipping and Filtering is iteratively performed. Output x is produced in the I^{th} final iteration.

B. Proposed Scheme Using IFFT and FFT

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 signal having values higher than this predetermined value is clipped and the rest are allowed to pass through un-disturbed.

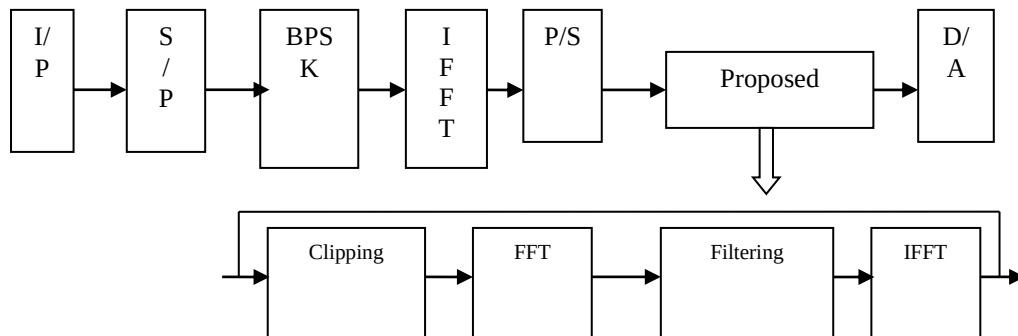


Figure 2: Proposed Clipping and Filtering method with IFFT and FFT [2]

III. Simulation and Result:

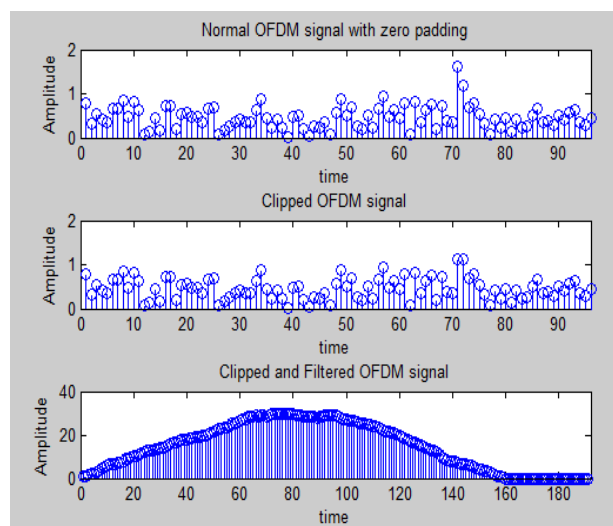


Figure 3: ICF using IFFT and FFT

Figure 3 depicts the number of transmitted symbols are 64, symbol size is 64 and length of signal is 1.5. Here the PAPR of normal OFDM is 24.0481 dB, PAPR of modified SLM OFDM is 15.3388 and PAPR of Clipped and Filtered OFDM signal is 9.8025. The efficiency of SLM technique is 36.2160 % and the efficiency of Clipped and Filtered OFDM signal is 59.238%. Thus the Clipping and Filtering technique provides more reduction in PAPR and provides efficiency more than SLM technique.

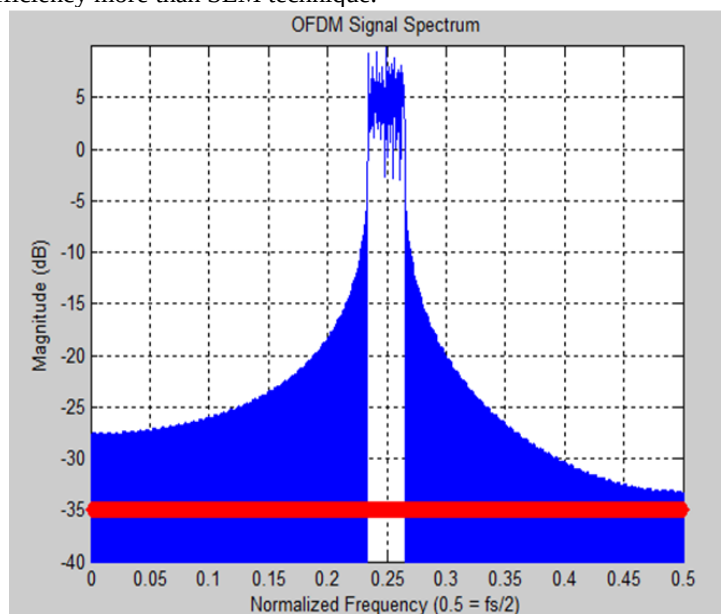


Figure 4: Normalized OFDM signal

The Figure 4 shows the simulation result of the OFDM spectrum is obtained through MATLAB simulation. For this simulation, the number of data bits transmitted is 12, carrier count 32, symbols per carrier 16 and SNR is 20. From the simulation results it is concluded that by carefully selecting the carrier spacing, the OFDM signal spectrum is made flat and the orthogonality among the sub-channels is guaranteed. The guard interval is added to maintain the orthogonality of the sub-carriers and to avoid inter symbol interference (ISI) and inter carrier interference (ICI). Since the spectra of the OFDM signal is not strictly band limited, linear distortion such as multipath cause each sub-channel to spread energy into the adjacent channels and consequently cause ISI. A simple solution is to increase the symbol duration or the number of carriers so that distortion becomes insignificant. Random data is taken and transmitted. The transmitted data is appended with cyclic prefix. This data is fed as input to the Modulator block. After the signal is modulated, it is fed as input to the IFFT block where the IFFT operation is performed and finally transmitted.

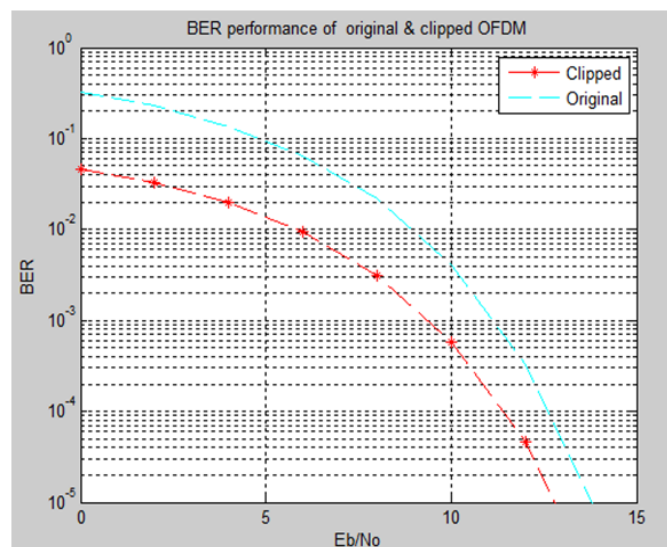


Figure 5: BER performance of OFDM over the range SNR

Figure.5 depicts the performance of BER versus SNR of original and Clipped OFDM signals with PAPR reduction based on the AWGN channel. The Clipped signal has PAPR of 12dB that for original signal has PAPR of 14dB.

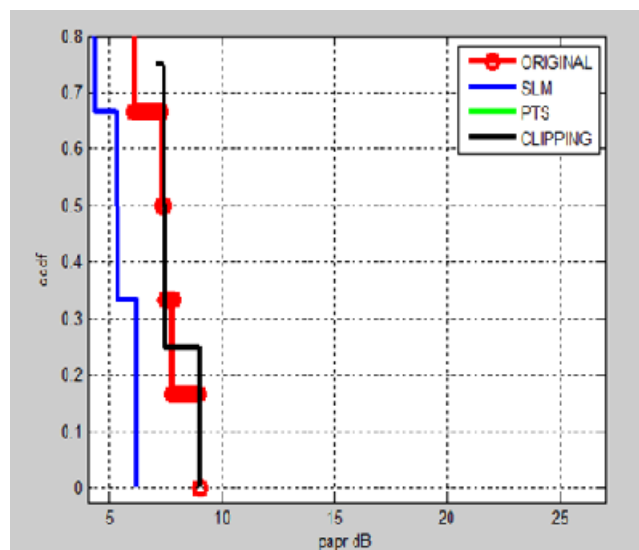


Figure 6: PAPR performance of original signal, PTS, Clipping and Filtering and SLM

IV. Conclusion

It is an undesirable condition of a signal as it will distort the transmitted signal at the receiver. It can be seen that the various techniques significantly reduce the PAPR performance. The Iterative Clipping and Filtering technique is better than the others as it reduces the most PAPR values. There are many techniques that can be implemented to reduce the PAPR in OFDM system. Each of them has its own advantages and disadvantages. It can be suggested that PAPR reduction technique must be employed as per the criterion for that specific system. Using the Clipping and Filtering technique original signal is directly obtained from the input sequence derived by the Clipping and Filtering technique using FFT/IFFT and iteratively performed. PAPR reduction is carried out with number of iterations. In the first iteration the new OFDM symbol enters the Clipping and Filtering block iteratively with FFT/IFFT technique, then clipping and filtering is iteratively performed. In the final iteration, the output is produced that contains PAPR reductions with a greater extend.

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Acknowledgement

With all respect and gratitude, we would like to thank all people who have helped us directly for this article. We are also thankful to Electronics Engineering Department of our Institute for providing lab and necessary tools.