

Performance Evaluation of PAPR Reduction with SER and BER by Modified Clipping & Filtering in 3GPP LTE Downlink

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ABSTRACT

This paper work focuses on performance analysis of PAPR reduction of orthogonal frequency division multiplexing (OFDM) using amplitude clipping & filtering based design. Now a days one of the most proficient multi-carrier transmission techniques widely used today is orthogonal frequency division multiplexing (OFDM) which has been implemented by the next generation wireless communication technology: Long Term Evolution (LTE). Extra robustness to multipath fading and impulse noise is provided OFDM. It eliminates inter symbol interference (ISI) & inter carrier interference (ICI) with certain procedure. Therefore peak to average power ratio (PAPR) is the basic problem with OFDM. However in this paper we proposed a reduction procedure of the PAPR by using clipping and filtering. Here we use a composed high pass, low pass & Chebyshev band pass filter II after amplitude clipping to reduce the PAPR. The performance of the system in terms of bit error rate (BER) and symbol error rate (SER) is also investigated as a new filter based clipping method is proposed. Our proposed clipping method with and composed high pass the Chebyshev bandpass filter II in PAPR performance of the system with a little compromise of BER & SER showing the significant improvement in Quadrature Amplitude Modulation (QAM).

Keywords: OFDM, LTE, Chebyshev, BER, Clipping and Filtering(CF).

1. INTRODUCTION

One of the latest steps towards the 4th generation (4G) of radio technologies is Long term evolution (LTE) which has been designed to increase the capacity and speed of mobile telephone networks. Data usage & voice communication has grown fast now days in those networks where 3GPP High Speed Packet Access (HSPA) was introduced indicating that the users find using the network connection like broadband wireless data. 3GPP Long Term Evolution (LTE) has been designed to provide high data capacity in data delivery at a comparatively lower cost.

But these services require highly reliable data transmission over most of the time in very unfriendly environment. Most of these transmission systems have to face much degradation such as large noise, multipath, interference, attenuation, nonlinearities, time variance and must meet the finite constraints like crest factor & power limitation. Most commonly used technique in multi-carrier modulation is Orthogonal Frequency Division Multiplexing (OFDM) which has become very popular in wireless communication. But its large envelope fluctuation which is quantified as Peak to Average Power Ratio (PAPR) is the major disadvantage of OFDM transmission. In order to operate in a perfectly linear region, the operating power must be kept below the available power. For this reason, power amplifier is used at the transmitter. A lot of algorithms have been developed for the reduction of this PAPR. All of them have their own advantages and disadvantages [2]. Moreover, the data rate is reduced by the Coding scheme which is undesirable. In case of applying the Partial Transmit Sequence (PTS)[11] and Selected Mapping (SLM) techniques, these are more complex than that of CF technique. If another technique named Tone Reservation (TR) is considered, it also allows the data rate loss with more likelihood of increasing power. As well as the techniques such as Active Constellation Extension (ACE) and the Tone Injection (TI) [12] having criteria of increasing power will be unexpected in case of power constraint environment. The Selected Mapping is one of the most commonly chosen techniques because of its simplicity for implementation which bears no distortion in the transmitted signal. It has been described first in [2] i.e. to be known as the classical SLM technique which contains one of the disadvantages like sending the extra Side Information (SI) index along with the transmitted OFDM signal. A special technique described in [1] can be used to avoid this issue. However using complex matrix sequence [13] doesn't give the desired PAPR reduction.



In previous research works, a linear-phase FIR filter using the Parks-McClellan algorithm was used in the composed filtering [7]. Existing method [9] uses the band pass filter. But, using our proposed special type of composed filter, significant improvement was observed in the case of PAPR reduction.

The rest of this paper is organized as follows: section 2 deals with basic OFDM technique and PAPR calculation, Clipping and Filtering technique in section 3, section 4 proposed clipping and filtering technique, in section 4 explains design and simulation and this paper is concluded with the last part.

2. BASIC OFDM TECHNIQUE AND PAPR CALCULATION

Orthogonal Frequency Division Multiplexing (OFDM) technique divides the frequency spectrum into sub-bands small enough so that the channel effects are constant (flat) over a given sub-band. After that a classical IQ (In phase Quadrature phase) modulation QPSK, M-QAM, BPSK, etc. are sent over the sub-band. If it can be designed correctly, all the fast changing effects of the channel will disappear during the transmission of a single symbol and thus will be treated as flat fading at the receiver. OFDM is a special form of multicarrier modulation (MCM) with densely spaced subcarriers with overlapping spectra allowing multiple-access. A large number of orthogonal subcarriers are used to carry data which are closely spaced. For each subcarrier, the data is divided into several parallel data streams or channels. Each subcarrier is modulated using a conventional modulation scheme like Phase Shift Keying (PSK) or Quadrature Amplitude Modulation (QAM) at a low symbol rate. In this case the total data rate is to be maintained similar to that of the conventional single carrier modulation scheme with the same bandwidth. For achieving high data rate and combating with multipath fading in Wireless Communications Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique. It is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. The different carriers are totally independent of one another which denotes that they are orthogonal to each other. By placing the carrier exactly at the nulls in the modulation spectra of each other these orthogonal carriers can be achieved as shown in the following Figure 1. Each carrier has an integer number of cycles over a symbol period denoting the orthogonally of the carriers. The spectrum of each carrier has a null at the centre frequency of each of the other carriers in the system due to this integer number of cycles which results in no interference between the carriers that allows them to be spaced as close as possible. The problem of overhead carrier spacing can be recovered that is required in Frequency Division

Multiplexing (FDM). For bandwidth efficiency [4] this multicarrier transmission scheme allows the overlapping of the spectra of subcarriers.

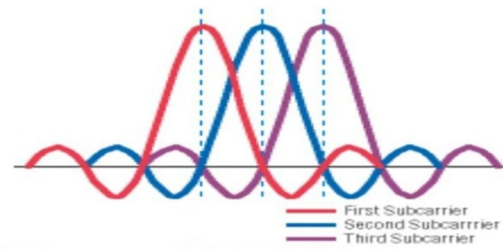


Fig. 1. OFDM Spectrum

As a result of incidence of large number of independently modulated sub-carriers in an OFDM system, as compared to the average of the total system, the peak value of the system may be very high. The coherent summation of N signals having same phase produces a peak which is N times the average signal [3]. In the design of both high power amplifier (HPA) and digital-to-analog (DAC) converter, PAPR is an vital factor in order to generate almost error-free (minimum errors) transmitted OFDM symbols.

In the transmitter, the linear power amplifiers are used in order to make sure that the Q-point must be in the linear region. The Q-point moves to the saturation region due to the high PAPR resulting in the clipping of signal peaks which generates in-band and out-off band distortion. The dynamic range of the power amplifier should be increased to keep the Q-point in the linear region which again reduces its efficiency and enhances the cost. Hence a trade-off exists between nonlinearity and efficiency. With the incensement of this dynamic range, the cost of power amplifier increases. As communication engineer our objective undergoes investigating the comparative performance analysis of different higher order modulation techniques by using amplitude clipping & filtering based design (signal distortion) to reduce PAPR.

The ratio between the maximum power & the average power is defined for the envelope of a baseband complex signal $\tilde{s}(t)$ i.e.[2]

$$\text{PAPR} = \frac{\text{Peak Power}}{\text{Average Power}} \quad (1)$$

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

For the complex pass band signal $s(t)$ we can also write this PAPR equation as follow:

$$\text{PAPR} \{ s(t) \} = \frac{\max |s(t)|^2}{E |s(t)|^2} \quad (3)$$

Now, equation (3) can be written as:

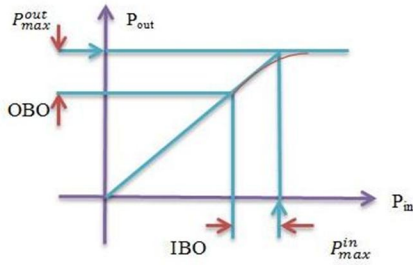


Fig. 2. Input Output characteristics of an HPA

$$\text{PAPR}\{s(t)\} = \frac{\max_{0 \leq t \leq NT} |s(t)|^2}{P_{\text{avg}}} = \frac{\max_{0 \leq t \leq NT} |s(t)|^2}{\frac{1}{T} \int_0^{NT} |s(t)|^2 dt} \quad (4)$$

Here, P_{avg} denotes the average power of the complex pass band signal $s(t)$ & in the frequency domain it can be computed because Inverse Fast Fourier Transform (IFFT) is a unitary (scaled) transformation. For superior estimated the PAPR of continuous time OFDM signals, the OFDM signals samples are obtained by L times oversampling. The time domain samples which are L times oversampled are the NL point IFFT of the data block including (L-1)N zero-padding. As a result, the oversampled IFFT output can be expressed as the following equation:

$$X[n] = \frac{1}{\sqrt{N}} \left(\sum_{m=0}^{N-1} X_m e^{j \frac{2\pi n m}{NL}} \right) \quad (5)$$

3. CLIPPING AND FILTERING TECHNIQUE

For PAPR reduction in 3GPP LTE downlink system, one of the easiest techniques which can be followed is Amplitude Clipping of the signal and after that filtering the signal. To do limit the peak envelope or amplitude of the input signal a threshold value of the amplitude is made fixed here [5].

The CR or clipping ratio is defined as below:

$$\text{CR} = \frac{P}{\sigma} \quad (6)$$

Here, P denotes the amplitude of the signal and σ denotes the root mean squared value of the OFDM signal (unclipped). The clipping function is performed in digital time domain before the digital to analog (D/A) conversion and the process is described by the following equation:

$$k_x^c = \begin{cases} k_x & k_x \leq M \\ M e^{j\phi(k_x)} & k_x > M \end{cases} \quad (7)$$

where, k_x^c is the clipped signal, the transmitted signal is k_x , the amplitude and the phase of the transmitted signal, k_x is M and $\phi(k_x)$ respectively.

4. PROPOSED CLIPPING AND FILTERING TECHNIQUE

By indicating the second point of limitation [8], less BER degradation can be obtained and that is clipped signal passed through the band pass filter (BPF).

Clipped signal would pass through a high pass filter (HPF) [7] was the phenomenon for the former designed scheme for clipping & filtering method. In the figure 3, the proposed method is shown.

The input of the IFFT block is the interpolated signal introducing

$Q(Z-1)$ zeros in the middle of the original signal is expressed as:

$$b'[s] = \begin{cases} b[s] & \text{for } 0 \leq t \leq \frac{Q}{2}, QZ - \frac{Q}{2} < t < QZ \\ 0, & \text{Otherwise} \end{cases} \quad (8)$$

The Z-times oversampled discrete-time signal is generated in this system as the following equation:

$$B'[r] = \frac{1}{\sqrt{ZQ}} \sum_{t=0}^{ZQ-1} b'[s] \exp \left(\frac{j2\pi n \Delta f t}{ZQ} \right); r=0,1,\dots,Q(Z-1) \quad (9)$$

After that the above over-sampled-discrete time signal gets modulated with carrier frequency f_c , yielding a pass band signal $B^e[r]$

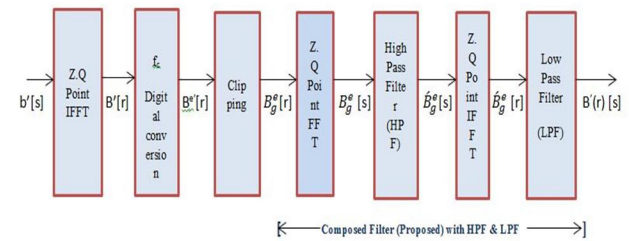


Fig. 3. Proposed Clipping and Filtering Block Diagram

Now, assuming $B_g^e[r]$ is the clipped version of $B^e[r]$ which is expressed as the following equation:

$$B_g^e[r] = \begin{cases} -M & B^e[r] \leq -M \\ B^e[r] & |B^e[r]| < M \\ M & B^e[r] \geq M \end{cases} \quad (10)$$

Here, the pre-specified clipping level is M. The signals are passed through the proposed Composed Filter after

clipping. A set of FFT-IFFT operations are performed in the filter, where after the FFT function the filtering operation occurs in the frequency domain. The FFT function transforms the clipped signal, $B_g^e[r]$ into the frequency domain & results in the term $b_g^e[s]$. The information components of $b_g^e[s]$ are then passed through a high pass filter (HPF) generating $\hat{B}_g^e[s]$. This filtered signal is then passed through the unchanged condition of IFFT block. Here, the out-of-band radiation that fell in the zeros is set back to zero. The signal is transformed in to time domain by The IFFT block of the filter and thus obtain $\hat{B}_g^e[r]$. After a low pass filtering our desired signal is $B^*[r](s)$.

5. DESIGN AND SIMULATION

The observations were actually based on only QAM modulation. Table 1 shows the values of parameters used in the simulation for analysing the performance of clipping and filtering technique. It can be seen from the simulations results that it is possible for clipping and filtering scheme to reduce peak to average power ratio (PAPR). Simulation is done in the QAM modulation scheme i.e. 4-QAM has been used in OFDM generation which is very effective modulation techniques in 4G technologies having a bandwidth conserving modulation technique. The number of sub-carriers N is randomly having a sampling frequency of $F_s = 8$ MHz, satisfies the condition of orthogonality. PAPR(dB) of the original OFDM is computed by oversampling the number of sub-carriers K by the oversampling factor of $L=8$ while $L=4$ is enough, by insertion of $(L-1)$ N zeros to reduce the ISI. Complementary Cumulative Distribution Function (CCDF) of PAPR is the measure of probability that how much higher is the PAPR value in comparison to PAPR (dB) is calculated by Monte-Carlo simulation.

Table 1: Parameter used for simulation

Bandwidth, BW	1 MHz
Over Sampling Factor, Z	8
Sampling Frequency, f_s	1 MHz
Carrier Frequency, f_c	12 MHz
Cyclic Prefix Size	16
No. of Subcarrier/FFT Size, N	256
Clipping Ratio	0.6,0.8,1.0,1.2,1.4,1.6
Modulation	16-QAM

It can be seen from the simulations results that it is possible for clipping and filtering scheme to reduce peak to average power ratio (PAPR). Simulation is done in the way, QAM modulation scheme i.e. 16-QAM has been

used in OFDM generation which is very effective modulation techniques in 4G technologies having a bandwidth conserving modulation technique. The number of sub-carriers N is randomly having a sampling frequency of $F_s = 8$ MHz, satisfies the condition of orthogonality. PAPR(db) of the original OFDM is computed by oversampling the number of sub-carriers N by the oversampling factor of $Z=8$ while $Z=4$ is enough, by insertion of $(Z-1)$ N zeros to reduce the ISI. Complementary Cumulative Distribution Function (CCDF) of PAPR is the measure of probability that how much higher is the PAPR value in comparison to PAPR (db) is calculated by Monte-Carlo simulation.

Figure 8 shows the existing PAPR calculation for filtering and clipping and the BER performance.[10]

In Figure (3)-(7) is given the Random Signal Bits, Modulated Signal(Transmitted),Received Signal, Scattered Demodulated Signal & Received Random bits for 16-QAM. Figure (8) to (10) shows the unclipped and without CP of Passband and Baseband signal before clipping and filtering and after clipping & filtering with proposed filtering of the signal of different clipping ratio's. Symbol Error Rate of different QAM modulation and for 16-QAM in simulated condition is given in Figure (17) to (18). Figure 15 shows the PAPR reduction for proposed filtering technique.

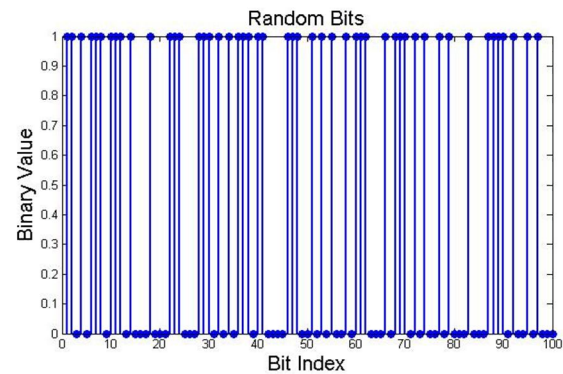


Fig. 3. Random Transmitted bits for 16-QAM

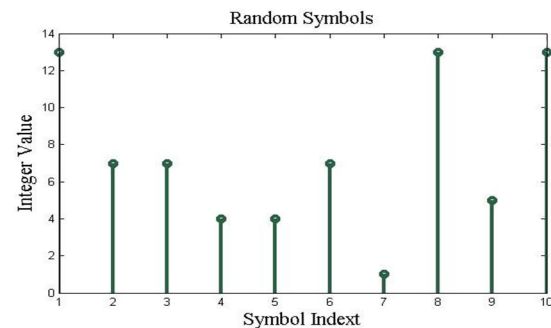


Fig. 4. Random Transmitted Symbols for 16-QAM

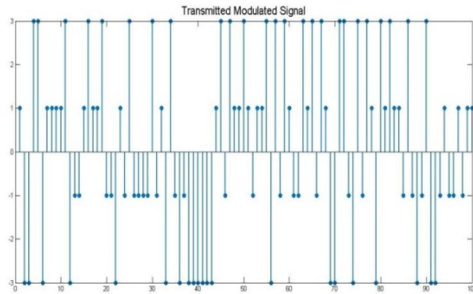


Fig. 5. Modulated Transmitted Signals for 16-QAM

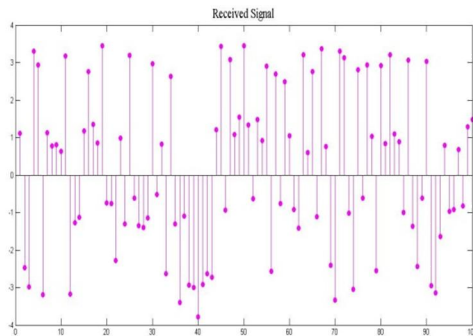


Fig. 6. Received Signal for 16-QAM

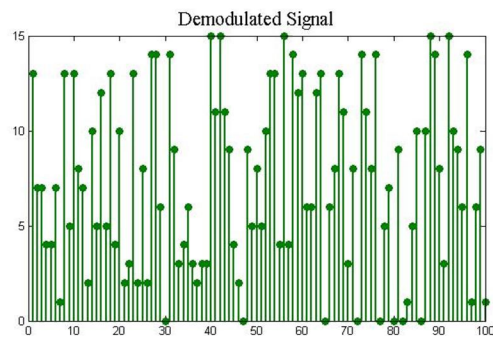
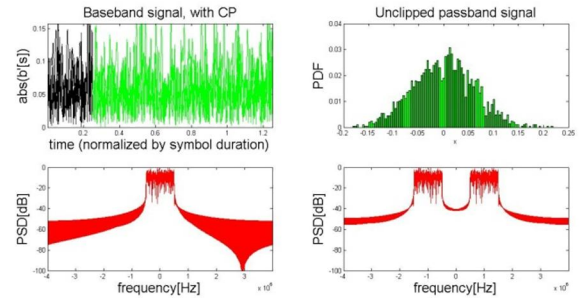
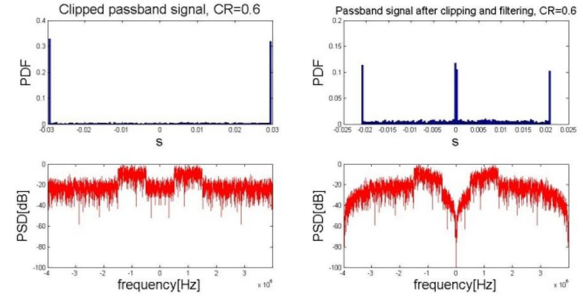


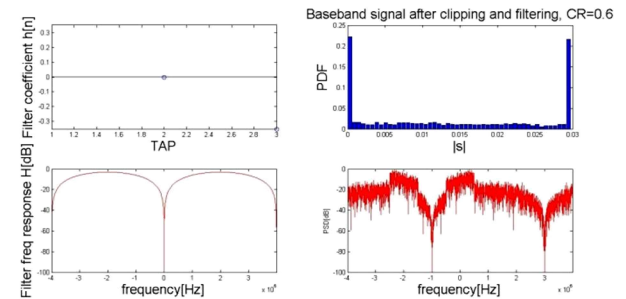
Fig. 7. Signal after Demodulation for 16-QAM



a.



b.



c.

Fig. 8 a)Unclipped, b)Clipped, c)Clipped & Filtering for CR=0.6

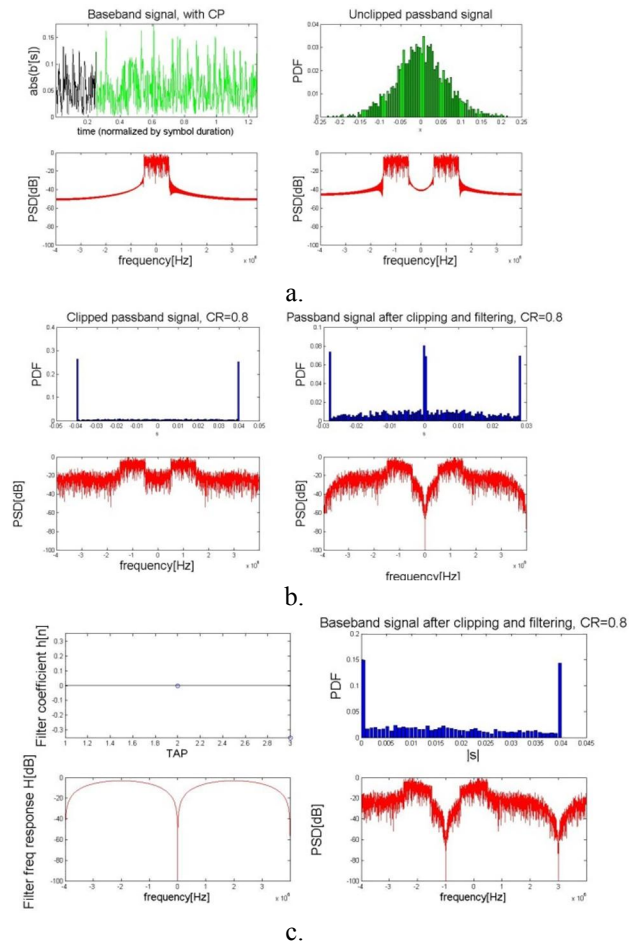


Fig. 9. a)Unclipped, b)Clipped, c)Clipped & Filtering for CR=0.8

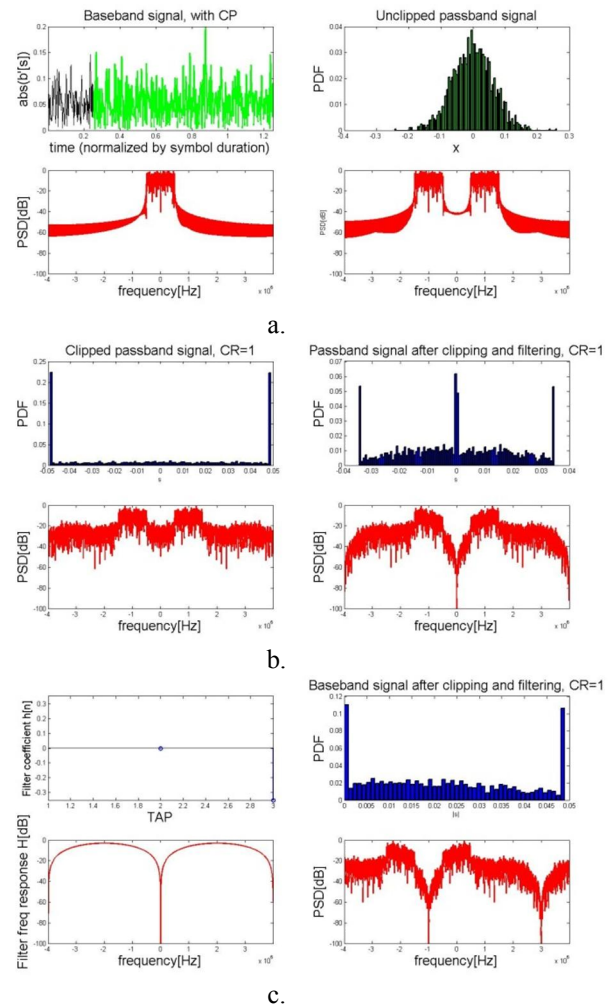


Fig. 10. a)Unclipped, b)Clipped, c)Clipped & Filtering for CR=1.0

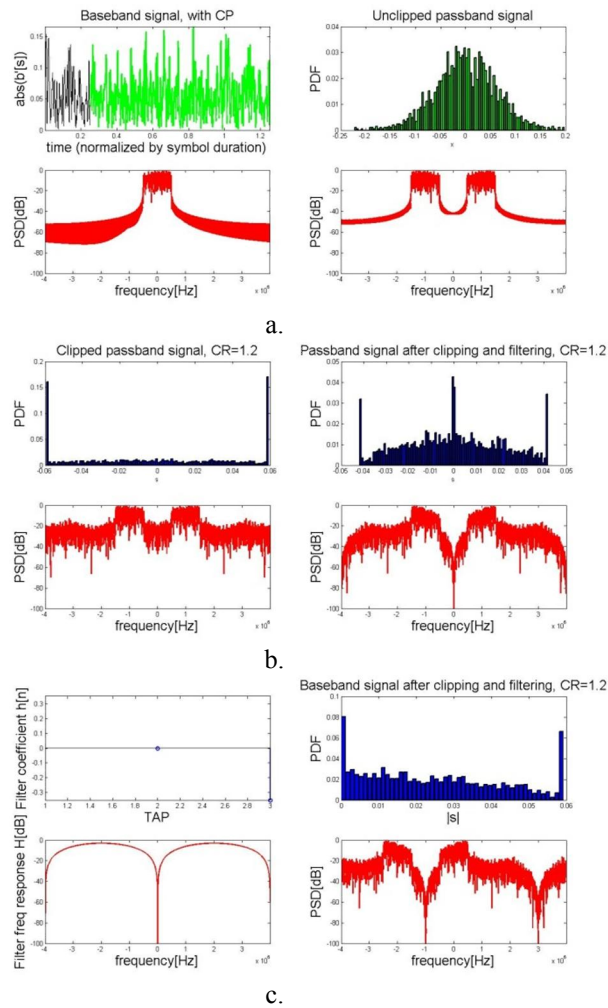


Fig. 11. a)Unclipped, b)Clipped, c)Clipped & Filtering for CR=1.2

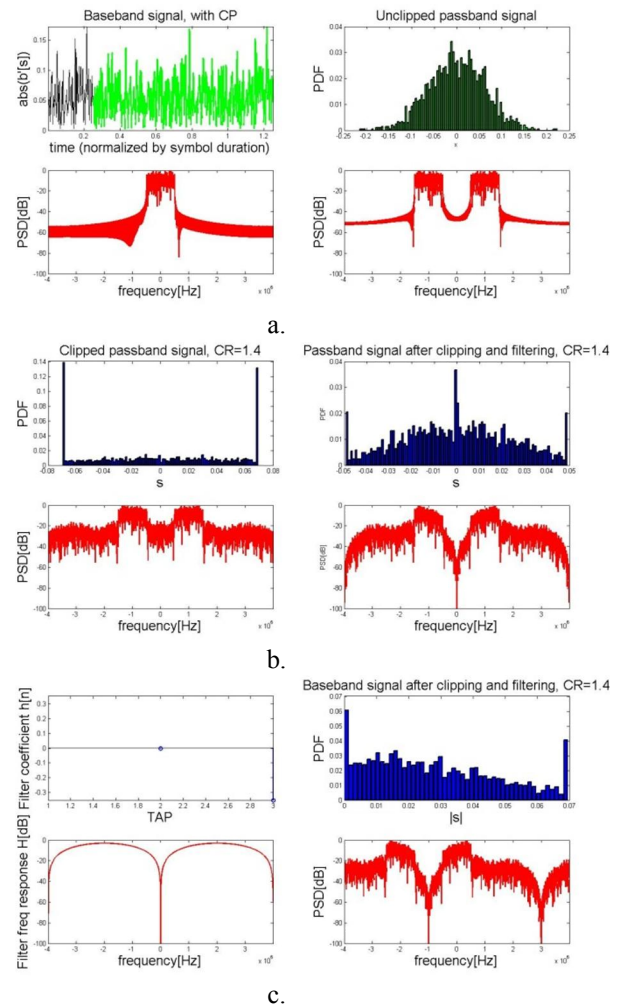


Fig. 12. a)Unclipped, b)Clipped, c)Clipped & Filtering for CR=1.4

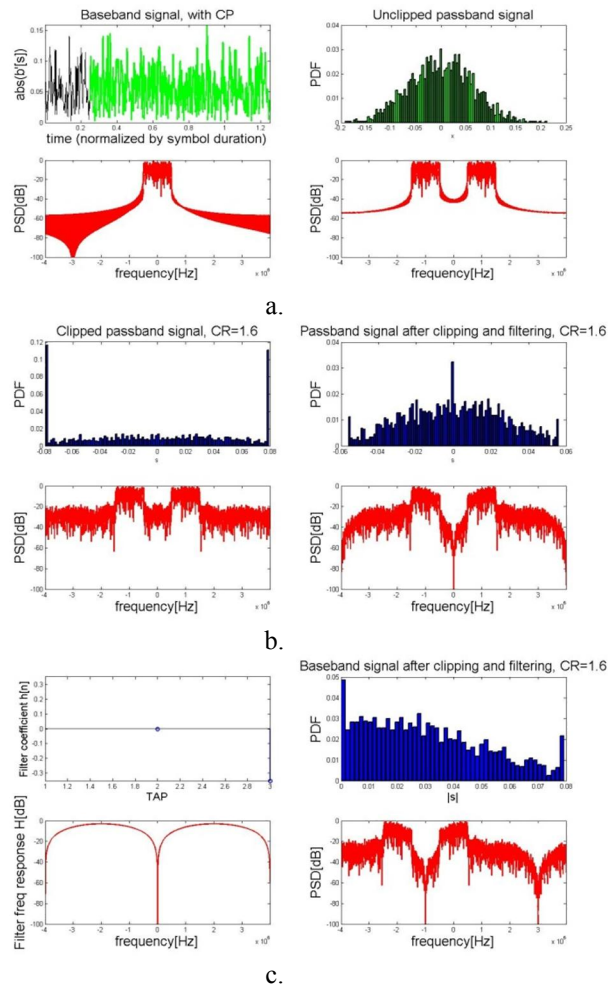


Fig. 13. a)Unclipped, b)Clipped, c)Clipped & Filtering for CR=1.6

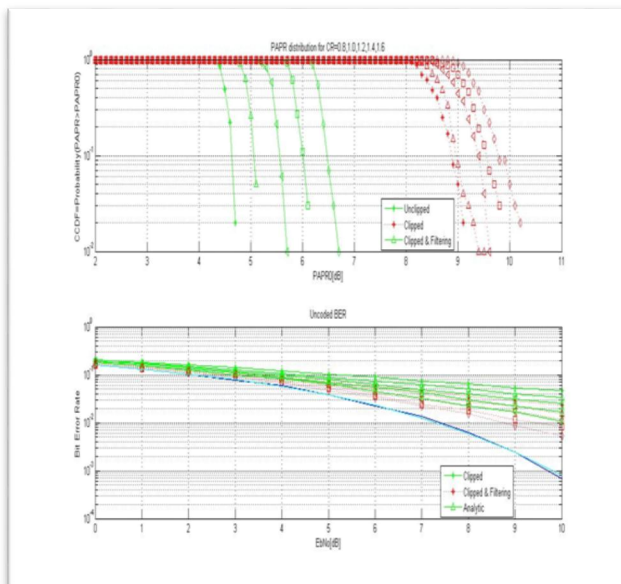


Fig. 14. Existing Method for PAPR Reduction for clipping and Filtering

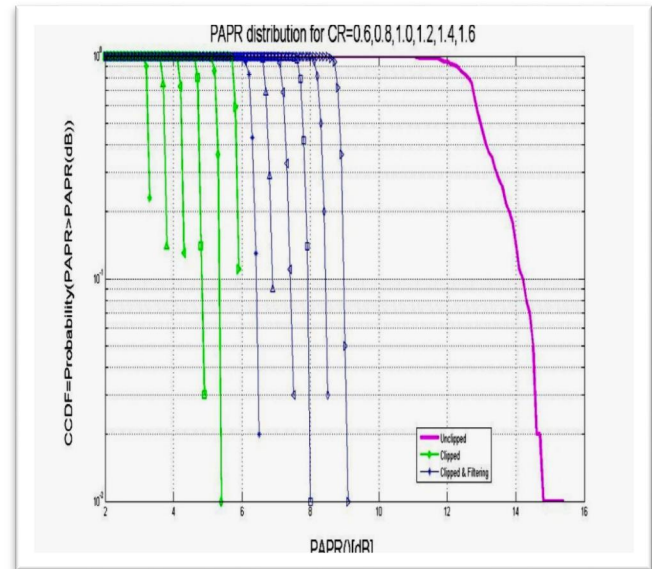


Fig. 15. Proposed Method for PAPR Reduction for clipping and Filtering

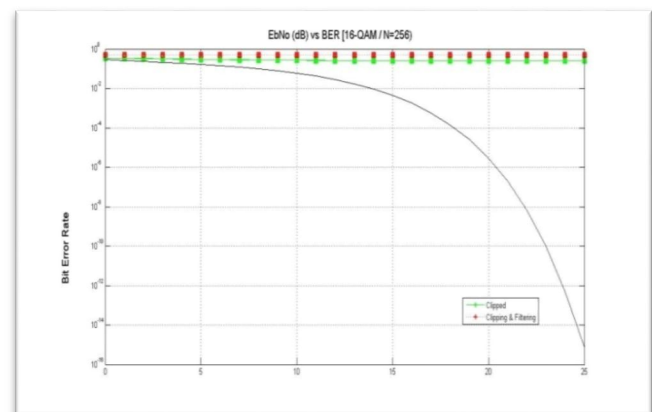


Fig. 16. BER performance by Proposed Method

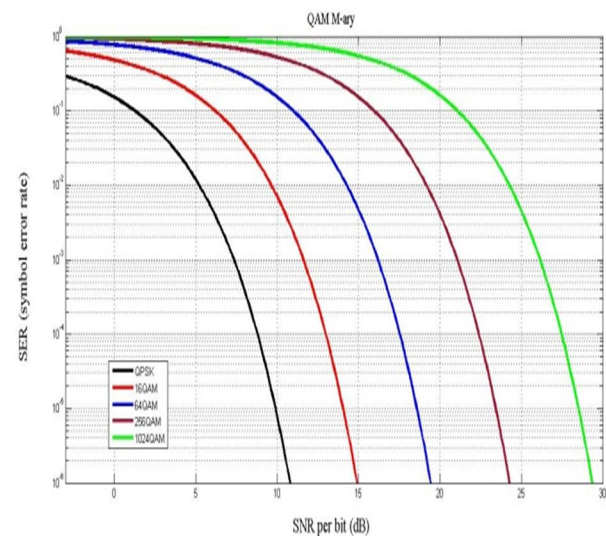


Fig. 17. Symbol Error Rate for different M-ary QAM modulation

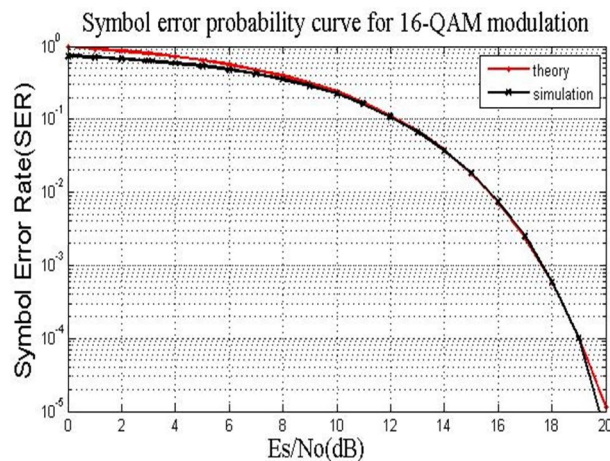


Fig. 18 Symbol Error Probability Curve for 16-QAM modulation

PAPR reduction (power gain in dB) by proposed method is shown in Table 2

Table 2: PAPR reduction (power gain in dB) by proposed method

CR	Previous Method	Proposed Method
0.6	9.2	6.45
0.8	9.35	6.9
1.0	9.5	7.65
1.2	9.6	8.0
1.4	9.9	8.5
1.6	10.2	9.0

6. CONCLUSION

Clipping and Filtering provides significant gains at moderate additional complexity than SLM&PTS and other techniques. It is observed from the simulation that PAPR of OFDMA is increasing while increase of subcarrier or FFT size. However a tolerable BER is increased by the proposed technique but reduced the PAPR for the OFDM signal in a relatively higher rate. No power is increased here and no data loss occurs. But it has a slight distortion problem. It is believed that this filter can minimize the PAPR and BER problem with clipping and filtering method and can be used as alternative of the existing one [7] for higher modulation& FFT size.

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