PAPR Reduction in OFDM Systems using RCF and SLM Techniques

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ABSTRACT
Orthogonal Frequency Division Multiplexing is considered as one of the prominent technology for 4G communication to achieve high data rate, spectral efficiency over multipath fading channel. However one of the major drawbacks of OFDM system is high PAPR. Repetitive clipping and filtering(RCF) and selective mapping (SLM) techniques being considered as simple and less complex compare to other techniques, both techniques are analysed and simulated result will give significant reduction in PAP ratio.

Keywords
Orthgonal Frequency Division Multiplexing(OFDM), Peak-to-Average Power Ratio(PAPR), Complimentary Cumulative Distribution Function(CCDF), Selective mapping(SLM),Repetitive clipping and filtering(RCF)

1. INTRODUCTION
OFDM is special type of the multicarrier modulation technique divides the entire frequency selective fading channel into many orthogonal narrow band flat fading channel in which high bit rate data stream is transmitted in parallel over number of low bit rate subcarriers there by substantially reducing the inter symbol interference [1] and improved spectral efficiency. Advancement in digital signal processing and VLSI technology, OFDM can be easily implemented using FFT/IFFT.

OFDMA/OFDM is used in IEEE 802.11a/g/n WLAN, HIPERLAN/2, WiMAX, DVBT,Asymmetric Digital Subscriber Line (ADSL), very high rate DSL (VDSL), and others. It has also been chosen as the physical layer architecture for 3GPP long-term evolution (LTE)[2].

However OFDM systems suffers from high PAPR, requires tight synchronization between transmitter and receiver other wise leads to carrier frequency offset errors. High peak values in OFDM system results from superposition of large number of statistically independent sub channels that can constructively sum up high peaks[2] .It is shown that as number of carriers increases ,PAPR also increases. The PAP ratio is approximately equal to N, where N is the number of sub carriers. High PAP ratio results in amplifier to work in large dynamic range which decreases the efficiency of power amplifier, DAC and ADC.

PAP ratios analyzed using CCDF(Complimentary cumulative distributive function)plots. Various PAPR reduction techniques are Clipping & filtering[4-8], , selective mapping [8-13],Partial transmit sequence[12-15] , nonlinear companding,Tone Injection, Tone Reservation[16], Active Constellation[17] and coding techniques[25-26]. Although many techniques found in the literature to reduce PAPR ratio in OFDM systems . RCF and SLM is most widely used and less complex. Here RCF and SLM techniques are studied and simulated results gives significant decrease in PAP ratio.

2. BASICS OF OFDM, PAPR AND CCDF
2.1 OFDM
Consider an OFDM system consisting of N subcarriers. Let a block of N symbols X= {Xk, k=0,1,---N-1}is a data block, each symbol modulating on one set of subcarriers. The complex base band representation of multicarrier signal consisting of N subcarriers is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k\, e^{j2\pi f_k} t \;, \quad 0 \le t \le NT \qquad (1)\ (1)$$

Where X_k is transmitted symbol on k^{th} subcarrier and $j=\sqrt{-1}$, Δf is the sub carrier spacing and NT denotes useful data block period.

2.2. PAPR
In general the PAPR of OFDM signal is defined as the ratio of the maximum instantaneous power to its average power.

$$PAPR[x(t)] = \frac{\max\limits_{0\le t\le NT}\left[|x[t]|^2\right]}{P_{av}} \qquad (2)$$

To better approximate the PAPR of continuous signals, the OFDM signals are L times oversampled. From the literature

It is studied that L is approximately equal to 4 is sufficient to get accurate PAPR results. Therefore the L-times oversampled time domain OFDM signal samples can be defined as

$$x[n] \triangleq \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k\, e^{\frac{j2\pi nk}{LN}} \quad ,0 \le n \le LN-1 \qquad (3)$$

Where E{.} denotes the expectation operator

2.3.Complimentary Cumulative Distribution Function(CCDF)
It is a statistical technique as shown in Fig.1 that provides the amount of time ,a signal spends above given power level. In modern communication CCDF measurement is considered as one of the precious tool offers comprehensive analysis of signal power peaks. For sufficient large number of sub carriers ,the amplitude of multicarrier signal, CCDF expression for OFDM signal can be written as

$$\begin{aligned} P(PAPR > z) &= 1 - P(PAPR \le z) \\ &= 1 - F(z)^N \\ &= 1 - (1 - exp(-z))^N \qquad (4) \end{aligned}$$

Where N signal samples are statistically independent uncorrelated.

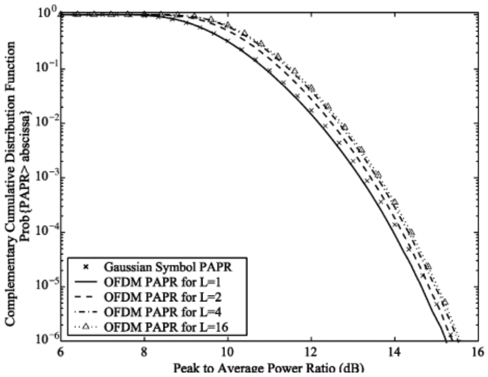

Fig 1. Distribution of PAPR of OFDM signal samples oversampled by different L.

3. REPETITIVE CLIPPING AND FILTERING

This is signal distortion based technique as shown in Fig.2.In this method the L times oversampled discrete time signal $x^I[m]$ is generated from the IFFT equation 3i.e.

$X^I[K]$ with N(L-1) zero padding in frequency domain) is then modulated its carrier frequency f_c to get passband signal and clipped version of the signal is given by

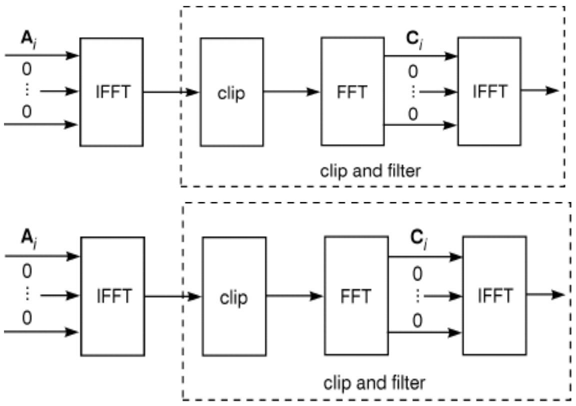

Fig.2 Block diagram of Clipping and Filtering

$$x_c^p[m] = \begin{cases} -A & x^p[m] \le -A \\ |x^p[m]| & |x^p[m]| < A \\ A & x^p[m] \ge A \end{cases} \quad (5)$$

clipping ratio is defined as CR= A/σ. Where A is specified clipping level and σ is RMS value of OFDM signal

Filtering can reduce out of band radiation and clipping of the signal amplitude causes peak re growth . Jean Armstrng et.al[4] proposed repetitive clipping and filtering for further reduction in PAP ratio. But number of iterations are more than clip and filter methods. clip and filter and repetitive clip and filtering methods are used to reduce PAP ratio. simulated for different clipping ratios.

4. SELECTIVE MAPPING

In SLM technique as shown in Fig. 3 the data block $X = [X[0], X[1], \dots\dots\dots, X[N-1]]$ is multiplied with different phase sequences generate alternate input data sequences $B^v = [B_0^v, \ B_1^v \ \dots\dots B_{[N-1]}^v]^T$ to $X^{(0)}, X^{(1)}, \dots\dots\dots\dots. X^{(V-1)}$, the time domain sequences for these data sequences obtained by applying IFFT. Among these time domain sequences $x^{(0)}, x^{(1)}, \dots\dots\dots\dots. x^{(V-1)}$ the one with lowest PAPR is selected for transmission . In this method the phase sequences must be known to both transmitter and receiver. In the literature different methods which does not require side information are proposed[14]

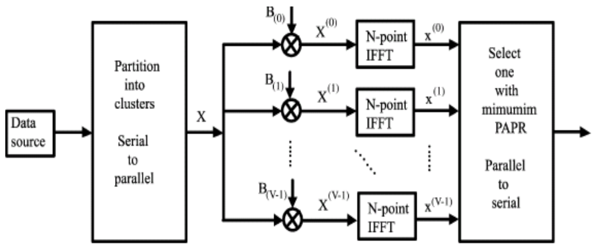

Fig.3 Block diagram of SLM technique

5. SIMULATION RESULTS OF RCFAND SLM

Clipping and filtering applied to OFDM system and simulated using MATLAB. Results Obtained for single clip and filtering with different clipping ratios CR=0.4,1,2 and 4 with reference to obtained result as clipping ratio decreases BER decreases. Futher results obtained for iterative clipping and filtering method ,with this method PAPR reduces for more iterations(with increased computational complexity).

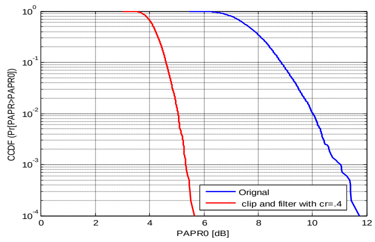

Fig.4 PAPR performance of clipping and filtering withCR=.4

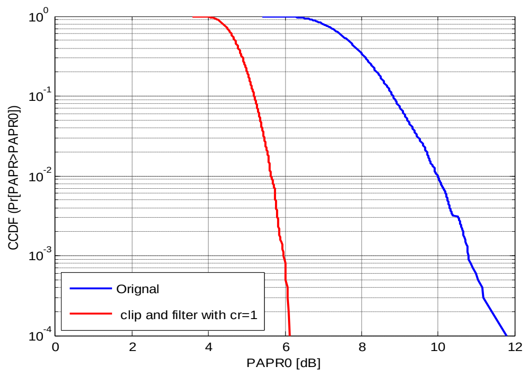

Fig.5 PAPR performance of clipping and filtering with CR=1

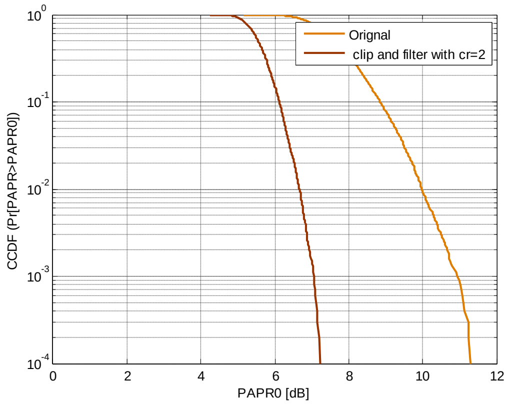

Fig.6 PAPR performance of clipping and filtering with CR=2

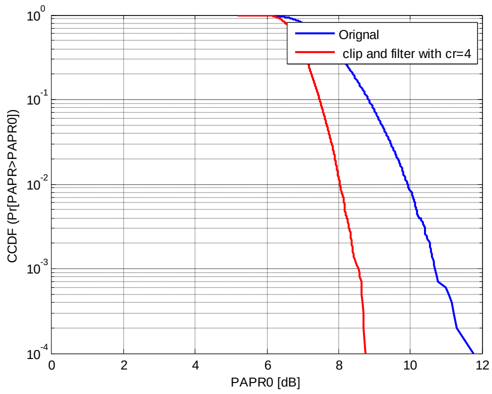

Fig.7 PAPR performance of clipping and filtering with CR=4

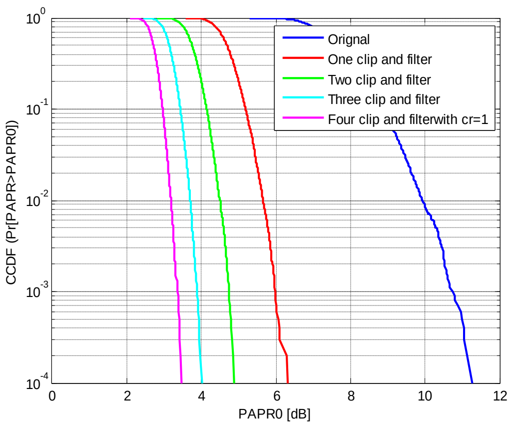

Fig.8 PAPR performance of repetitive clipping and filtering with CR=1

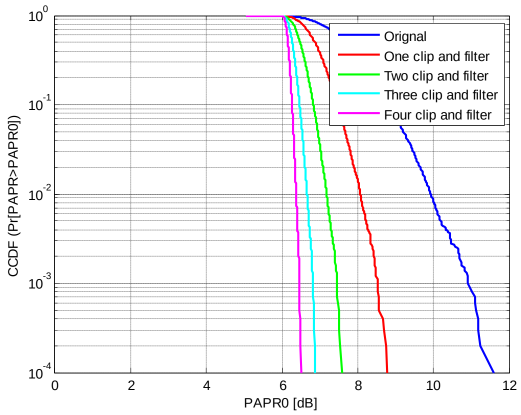

Fig.9 PAPR performance of repetitive clipping and filtering with CR=4

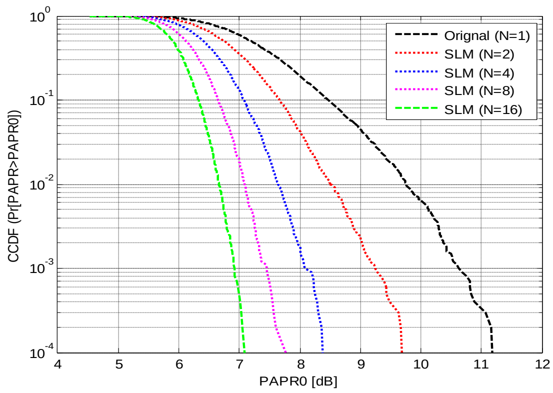

Fig.10 PAPR performance of selective mapping technique with different phase sequences

6. CONCLUSION

OFDM is a Multicarrier transmission technique is a very attractive technique for high-speed transmission over a faded communication channel. The PAPR problem is one of the important issues to be addressed in developing multicarrier transmission systems, two simple PAPR reduction techniques are used to reduce the peak t average power ratio to significant level. Simulated results are summarized in the Table 1 as shown.Further combining both the methods as hybrid technique to reduce PAPR ratio.

Table 1. PAPR Performance of RCF and SLM Techniques

No.of OFDM symbols	100000	PAPR (original)	11.253db
Mdulation technique	QPSK Modulation	PAPR(clf with cr=1)	7.27dB
Clipping Ratio	0.4,1,2,4	PAPR (RCLF with cr=1) 4 iteration	2.06db
No . of ffts	128	SLM technique K=128(no. of ffts)	N=2, PAPR=9.76 dB N=16 PAPR=7.09 dB
Oversampling factor	2		
No of iterations	1,4		

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