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COMPARATIVE ANALYSIS OF CLIPPING, SLM AND TWO PIECEWISE COMPANDING TECHNIQUES FOR PAPR REDUCTION IN OFDM SYSTEM

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ABSTRACT

Orthogonal Frequency Division Multiplexing(OFDM) is hottest topic for wireless communication. Now a days OFDM is used in variety of communication standards. Major drawbacks of OFDM are carrier off set and high Peak to Average Power Ratio (PAPR).High PAPR increases the cost of Radio Frequency Power amplifier (RFPA). We are comparing few techniques like Clipping technique, Selective Mapping Technique(SLM) and Two Piecewise Companding (TPWC).Clipping is the most basic technique where signal is chopped as it increase beyond certain level and the level remains same if it is below the level. SLM is perfect linear operation in which the transmitted signal is picked from the set of probable signals after performing few operations on the original signal. TPWC is companding technique where smaller amplitude signals are expanded and larger amplitudes signals are compressed at transmitter end and reverse is being done at the receiver end. Bit Error Rate (BER) Analysis is done for above mentioned methods with PAPR calculations. It will be shown that TPWC gives best result for PAPR reduction compare to clipping and SLM methods.

Key Words :Bit Error Rate(BER), Orthogonal Frequency Division Multiplexing (OFDM), Peak To Average Power Ratio (PAPR), Radio Frequency Power amplifier (RFPA),Selective Mapping Technique(SLM), Two Piecewise Companding(TPWC),

I. INTRODUCTION

The increasing demand of fast internet access leads to increase in demand of very high data rates for systems with reliable wireless communication. Such demand led to many new emerging methods to reach different goals of communications .Orthogonal Frequency Division Multiplexing (OFDM) is the latest technique which offers reliable high bit rate for wireless system with some complexity. OFDM has captures both wireless and wired domain in the communication field. OFDM is the one of the promising contender for the physical layer technique in 4^{th} generation of wireless system [1].It is the main research area of the researcher in both form of communication. One of the most drawback of OFDM systems is high Peak to Average Power Ratio (PAPR) at the transmitter end which is due to fact that the instantaneous output of an OFDM system often has very large fluctuation compare to traditional single carrier system [1].

An OFDM system is the heart of many wireless communication standards like Digital Video Broadcasting (DVB), Digital Audio Broadcasting (DAB), Worldwide Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE) and Asymmetric Digital Subscriber Loop (ADSL).[2] A lots of techniques were proposed to reduce PAPR at the transmitter part of the OFDM system which includes clipping method [3] ,interleaving method[4],SLM method[5]PTS method[6] and Two Piecewise Companding (TPWC)[7].As we apply any method of the PAPR reduction, the BER performance degrades. In other words the more error in received bits occurs at the receiver end, when we apply PAPR reduction techniques. The high PAPR means costly RFPA and less backup time of battery of system. Thus PAPR should be reduced to as small as possible and we will see that TPWC is one of the good techniques for it.

II. BASICS OF OFDM

A patent was applied for in mid 1960 regarding the concept of OFDM whose importance was not realized at that time [8].The concept is too old but due to fast emergence of VLSI technology, its practical implementation is possible in the new era of wireless and wired digital communication. The realizability of FFT and IFFT made this possible due to digital signal processing concept embedded with fast moving low power VLSI technology. The OFDM converts the information into N parallel streams by serial to parallel converter on which IFFT processing is being done then again parallel to serial is being done. Cyclic prefix is added and then Digital to Analog (D/A) conversion is being done before making it ready for transmission. These things are already shown in “Fig 1”.The receiver part is just invert of the transmitter part. Analog to Digital (A/D)conversion is being done after receiving the signal and then cyclic prefix is completely removed then serial to parallel is being done followed by FFT which is reverse of IFFT at transmitter end. Lastly the Parallel to serial conversion is being done followed by Demapping. OFDM is very popular now a days and currently *Wireless Local Area Networks (IEEE 802.11a, IEEE802.11g)*uses the technology [9].

2.1 Basics of Papr with Methods

Larger peaks in OFDM system is usually expressed as Peak to Average Power Ratio (PAPR) is also called Peak Average Ratio (PAR).

It is usually defined as

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

$$PAPR=10\log_{10}\frac{max[|x_n|^2]}{E[|x_n|^2]} \qquad (2)$$

here

$max[|x_n|^2]$=maximum value of signalx_n

$E[|x_n|^2]$ =expected value of signal x_n

x_n=OFDM signal which are obtain after taking IFFT operation on input symbols X_k

Mathematically x_n can be given as (for N sub carriers)

$$x_n = \frac{1}{(N)^{1/2}} \sum_{k=0}^{N-1} X_k \, W_N^{nk} \qquad [10] \qquad (3)$$

2.2 Clipping Technique

In this technique, the clipping threshold is decided. The amplitudes which are below the clipping threshold are passed as it is but amplitudes which are above the clipping threshold are chopped at the threshold. This method is simplest of all but with more BER degradation particularly when the clipping threshold is reduced drastically.

2.3 Slm Technique

In the SLM technique, same information is multiplied by different phase rotation vectors then IFFT or IDFT operation is performed. As shown below, the line of minimum PAPR is chosen out of U parallel lines. The side information is the information regarding which line had given minimum PAPR. This information is required at the receiver end to decode the information.

Mathematically SLM technique can be explained in coming lines here and also with the help of “Fig 2”. The fundamental of discrete time OFDM transmission method says that we ought to develop a data block looking for N number of symbols. Here N means the number of mathematical orthogonal subcarriers which are used in the given system. Then using that same data block in U different numbers of independent candidate vectors are to be generated with the multiplication with independent phase vectors like 1,-1,j,-j.. Mathematically, let us consider X is the given data block in the given condition with X(ku) is as the mapped sub symbol.Here ku = {0, 1, 2 ...N−1}.Let us consider that the u^{th} phase vector is denoted as PV(u). Where u= {1, 2 ...U}.The u^{th} vector

that is obtain by the multiplication of data block with the phase vector is denoted as X(u)[(ku)].So we can write the equation to get the k^{th} element of u^{th} candidate vector as

$$X(u)[(ku)] = X[(ku)] * PV(u)[(ku)] \qquad (4)$$

After doing IFFT operation to each candidate vector as shown in the figure of last page, we can obtain U different alternative OFDM signals. The signal having minimum PAPR is to be selected for transmission from the given set , reaches to antenna after A/D conversion,out of the U different numbers of alternative OFDM signals arising from U different paths .The block diagram of SLM technique is shown below.

The advantage of SLM technique is that no distortion is introduced but it has few drawbacks. One of the major drawbacks is that it requires transmitting bits of side information which is very crucial as the side information has to be received without errors. In other words the side information has to be heavily protected. SLM has a complexity of *U* numbers of IFFT operations and *U* numbers of complex vector multiplications as a complexity.

The amount of PAPR reduction will depend on number of *U* selected and the design of the phase sequences used for the multiplications. If we increase the number of U, the PAPR for SLM technique decreases.

2.4 Two Piecewise Companding (Tpwc)

As shown in "Fig 3"that in two piecewise companding, the input signals up to amplitude v are expanded by u1while other input amplitudes are compressed by u2 at the transmitter end. The main highlight of the method is that the average value of signals at the transmitter end before and after the companding remains same. However the BER performance degrades after the companding in comparison with non companding case. Mathematically we can write that to have same average power in both cases discussed above

$$[\int_0^v (u1\ x)^2\ f(x)\ dx + \int_v^\infty (u2\ x\ + S\ )^2 f(x)\ dx\ ] \ = \ \int x^2 f(x)\, dx \ = \sigma^2 \qquad (5)$$

$$for \quad f(x) = \frac{2x}{\sigma^2} e^{-x^2/\sigma^2} = \text{PDF of the function}$$

The companding function is given as below

$$y_n = \begin{cases} u1|x_n|.sgn(x_n) & for\ |x_n| \le v \\ (u2|x_n| + s).sgn(x_n) & for\ |x_n| > v \end{cases} \qquad (6)$$

Where u1 > 1 and 1 > u2 > 0 and s > 0 [7]

The signal is passed through AWGN channel and decompanding is done in the receiver. In the paper [7], it was assumed that when m ≥ 1.2 where $v = m\sigma$ the complementary function is approximately equal to one leads to

final equation which is relation between u1 and u2 as below

$$[(1 - e^{-m^2})(u1)^2] + [\,e^{-m^2}\,(u2)^2] \ = 1 \qquad (7)$$

The companding is performed after parallel to serial conversion which is just after IFFT in transmitter before converting it to analog signal for transmission

III RESULTS

For clippings technique graphs obtain are as shown in "Fig 4" and "Table 1". These completely gives the idea that the PAPR reduces by 1dB when clipping is done from 80% to 70 % of peak value also clipping at 80% of peak value reduced PAPR by 2.05 dB.For SLM technique graphs obtain are as shown in "Fig 5" and "Table 2" here the PAPR reduces by 1.4 dB when we increase the number of paths from 2 to 4, the PAPR reduces by 0.95 dB when SLM technique is applied on OFDM system. When we apply companding technique, PAPR reduces drastically from original 12.35 dB to 7.2 dB for m=2 and 4.7 dB for m=1.2 as shown in "Fig 6" and "Table 3".In "Fig 7" and "Table 4" the Overview is given showing that TPWC is better technique to reduce the PAPR as it is reducing maximum PAPR from 12.35dB to 4.7dB.For techniques mention in "Fig 7", the BER Vs SNR plot is obtain in "Fig 8".The "Fig 8" clearly shows that for clipping BER is worse in all of techniques in general. The BER of TPWC is also more but the PAPR reduction is very high. SLM has low BER but it is not reducing the PAPR very much.

IV. FIGURES AND TABLES

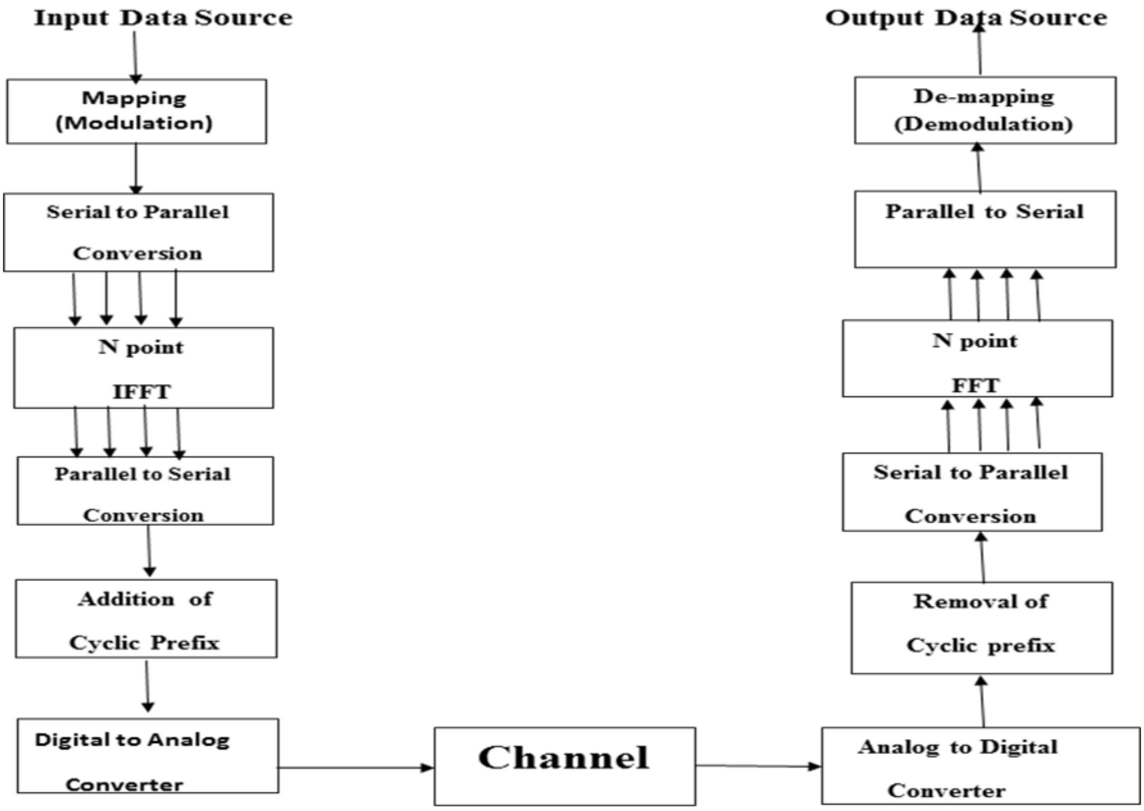

Figure1 Block diagram of OFDM Transmitter & Receiver

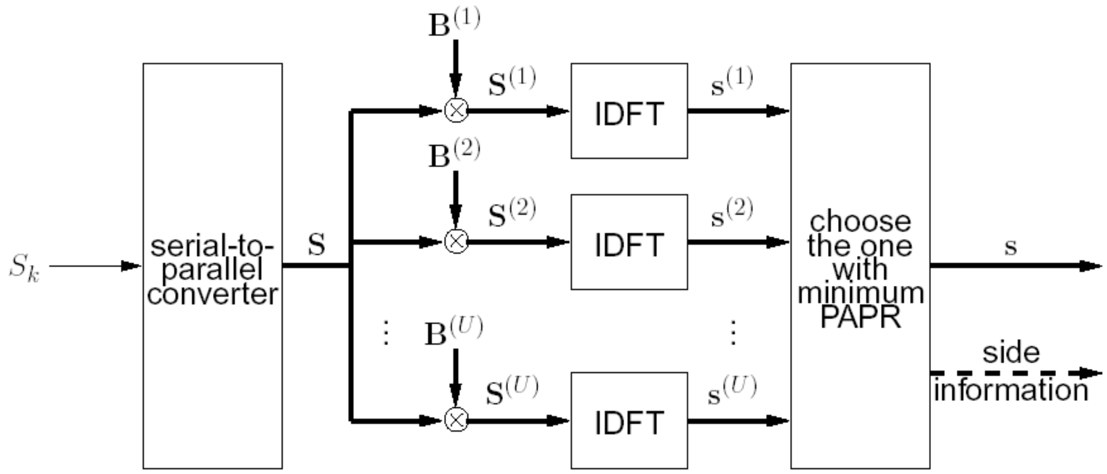

Fig 2 Block diagram of SLM technique

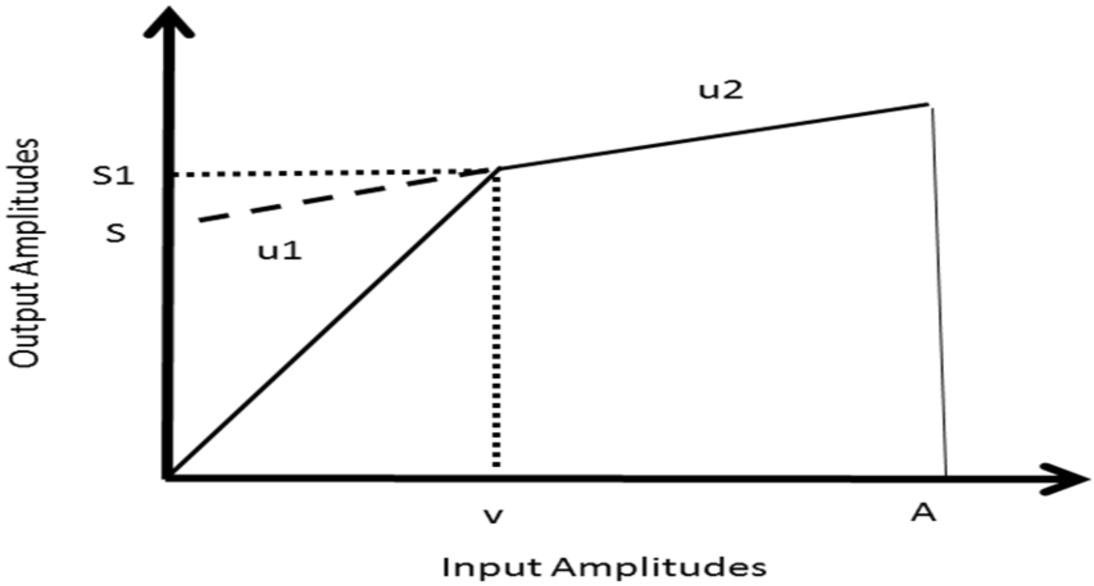

Figure 3 Input and output relation for TPWC

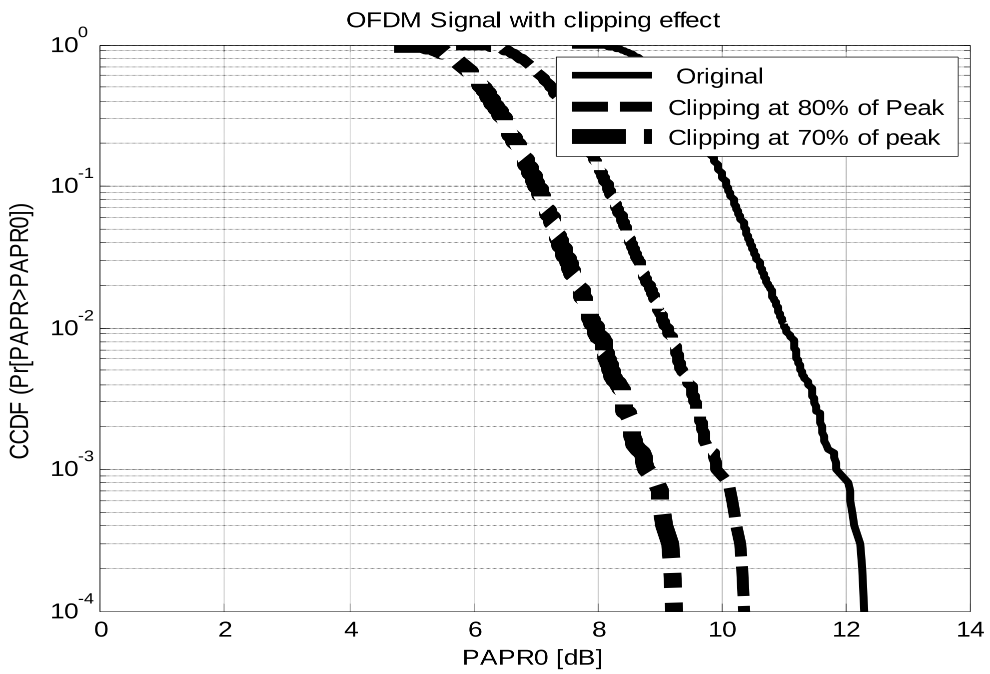

Figure 4 OFDM signal with and without clipping effects for PAPR reduction

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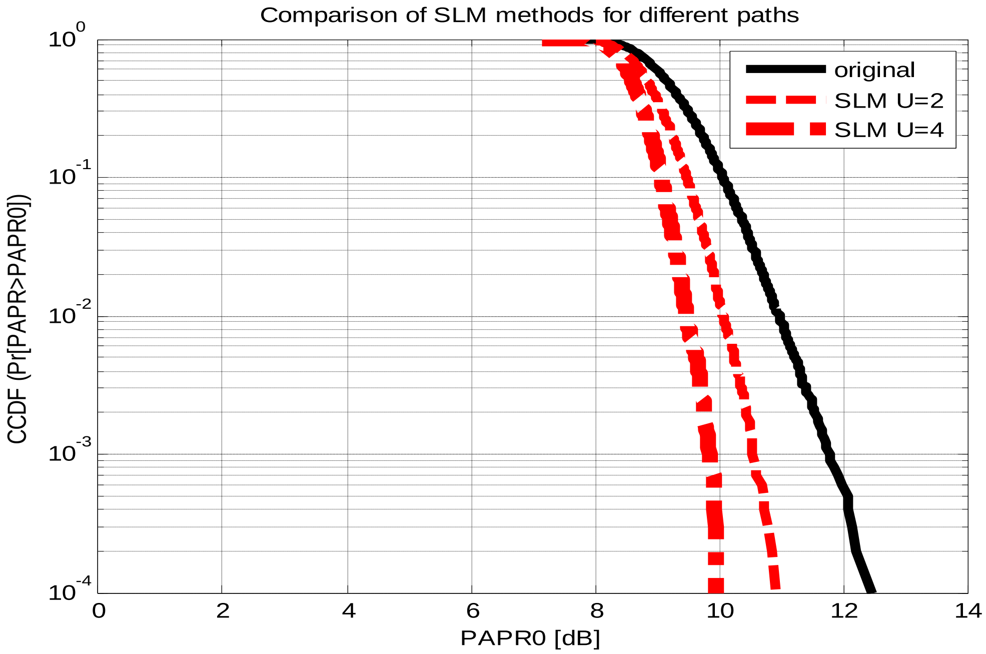

Figure 5 OFDM signal with and without SLM technique incorporated for PAPR reduction

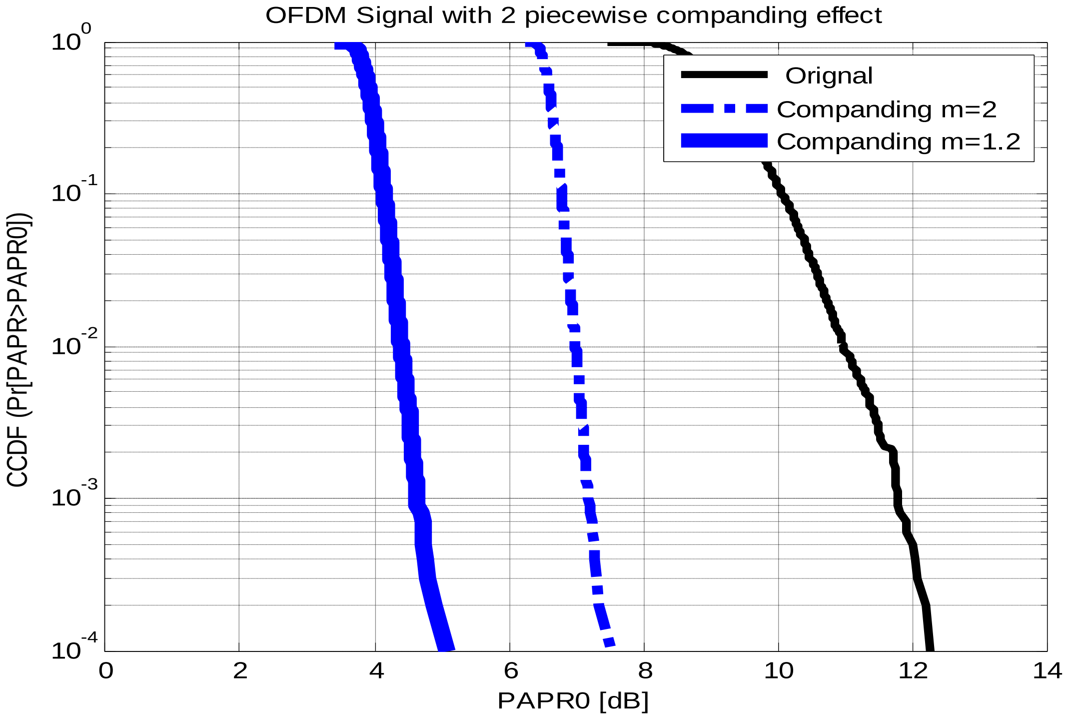

Figure 6 OFDM signal with and without companding technique incorporated for PAPR reduction

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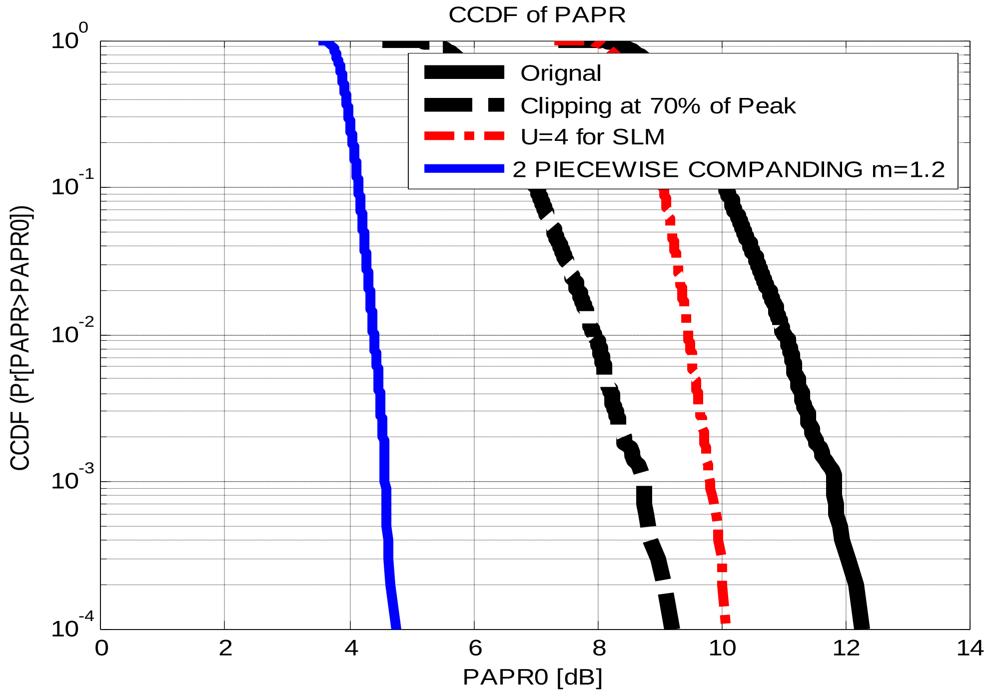

Figure 7 OFDM signal with and without different techniques incorporated for PAPR reduction

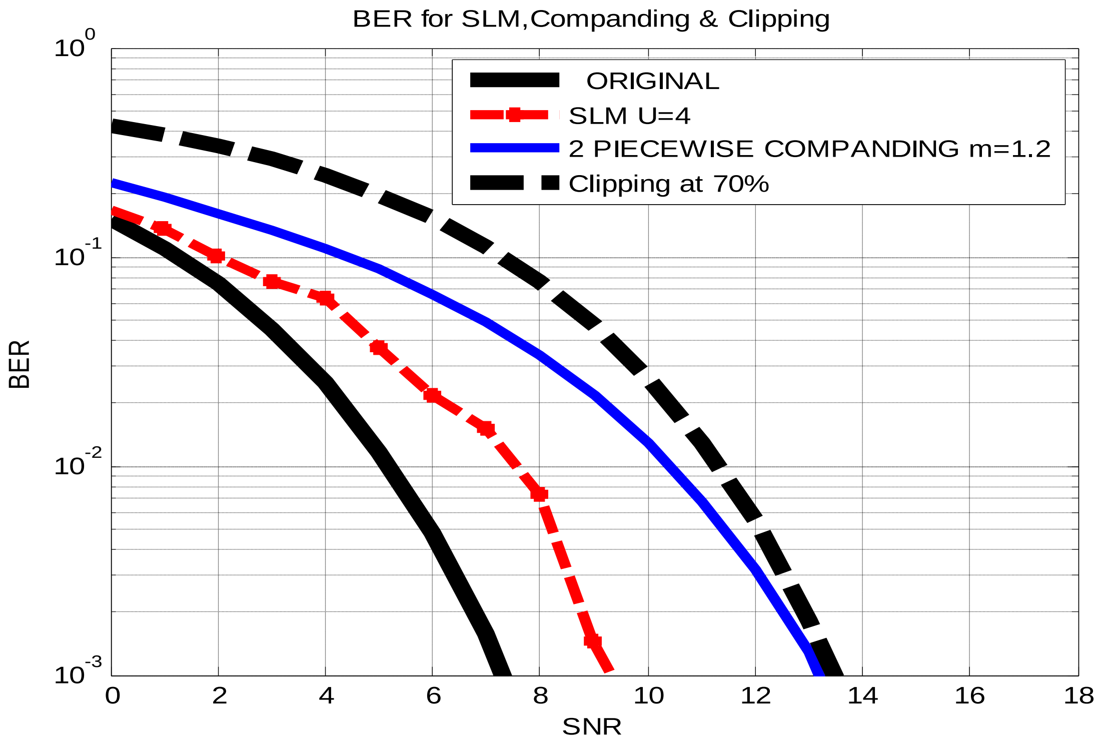

Figure 8 BER Vs SNR of all four cases mentioned earlier in just previous figure

Tables

Table 1

S.N.	State of Signal	PAPR (in dB) at 10^{-4} CCDF
1	Original OFDM Signal	12.35
2	OFDM Signal clipped at 80% of Peak value	10.40
3	OFDM Signal clipped at 70% of Peak value	9.40

Table 2

S.N.	State of Signal	PAPR (in dB) at 10^{-4} CCDF
1	Original OFDM Signal	12.35
2	OFDM Signal processed with two SLM paths	11.40
3	OFDM Signal processed with four SLM paths	10.00

Table 3

S.N.	State of Signal	PAPR (in dB) at 10^{-4} CCDF
1	Original OFDM Signal	12.35
2	OFDM Signal processed with m=2	7.2
3	OFDM Signal processed with m=1.2	4.7

Table 4

S.N.	State of Signal	PAPR (in dB) at 10^{-4} CCDF
1	Original OFDM Signal	12.35
2	OFDM Signal processed with four SLM paths	10.00
3	OFDM Signal clipped at 70% of Peak value	9.40
4	OFDM Signal processed with m=1.2	4.7

V CONCLUSION

In this paper we have performed the experiments and analyzed the concept using simulations in MATLAB. PAPR is reduced at the cost of degradation in BER. Clipping is very simple method but the amount of clipping should be based on the requirements of BER of given system .SLM is a technique which is relatively better than clipping but complexity is higher compared to simple clipping. TPWC is best as the reduction in PAPR is very large. The degradation in BER is there but it can be overcome by other methods like MIMO etc. The optimization of TPWC should be done for further reduction of PAPR. The TPWC can be implemented in

OFDM system which will reduce PAPR drastically and hence reduce the cost of transmitter system with giving advantage of long batter backup for the system.

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