Modified Tone Reservation Approach for the Reduction of PAPR in OFDM Systems

Manik Virdi, Dr. Neeraj Sharma

***Abstract*— OFDM is a technique in which data stream at high rates are divided into many low data streams for simultaneous transmission of data in a channel. It is one of the effective techniques used for high speed transmission of data over a communication channel. It is a modulation technique. The main limitation of OFDM system is high Peak to Average Power Ratio (PAPR). So in order to achieve low PAPR, there is a need to apply an effective technique on these systems. In this paper, a modified approach is applied for the reduction of PAPR in OFDM systems. The techniques applied are Tone Reservation, Partial Transmit Sequence and Companding.**

***Index Terms*— Companding, OFDM System, PAPR, Partial Transmit Sequence, Tone Reservation.**

I. INTRODUCTION

A. OFDM

Orthogonal Frequency-Division Multiplexing (OFDM) is a technique that is being used widely and is an attractive technique for transmission of high data rate over a communication channel. Inverse Fast Fourier Transform (IFFT) and FFT are being employed so that modulators and demodulators present in OFDM systems can be implemented to make the system more efficient and effective. OFDM systems are being used in next generation mobile communications. In a communication channel, data is being modulated into a single carrier frequency. The possible bandwidth is being covered by each symbol. This type of system will lead to ISI (inter-symbol-interference). In OFDM, the available spectrum is divided into a number of orthogonal sub-channels and these channels will experience a flat fading. Data rates are large in OFDM systems and are having sufficient robustness. There are specialized teams working for the optimization of OFDM systems.

In a particular OFDM system, much number of orthogonal signals and narrow sub carriers are being transmitted parallel. The available bandwidth to be transmitted is divided by the carriers. The sub carriers are separated in such a way that spectral utilization is very compact. Sub channels can overlap in a frequency domain which will increase the transmission rate in an OFDM system. Hence it improves bandwidth efficiency. Capacity of the system is also increased so that reliable transmission is provided. The idea behind OFDM system is to divide data stream of high rate into a number of data streams of low rate so as to transmit these data streams simultaneously over numerous sub carriers. Overlapping of sub carriers to each other is there. By introducing a guard time ISI is completely removed. One of the major problems in OFDM systems is high Peak to Average Power ratio (PAPR).

B. PAPR in OFDM

High PAPR is a problem in OFDM systems, which is a result of sum of sine waves and a non constant envelope. Large PAPR will lower the efficiency of radio frequency (RF) power amplifier and will increase the complexity of Digital to Analog convertor (DAC). In a huge linear region, RF power amplifiers are operated. Signal distortion is there when signals enter a non-linear region. This distortion results in inter modulation of sub carriers and out of band radiation. If the PAPR is low then power amplifier will work efficiently. If the PAPR is high then the signal peak will move into a non–linear region which will result in low efficiency of RF power amplifier. If the value of the PAPR is high then the value of DAC resolution and ADC resolution will be high at the transmitting end and the receiving end simultaneously. Any non-linearity will lead to distortion like inter-symbol interference (ISI) and inter –carrier interference (ICI). Efficiency of PAPR can be measured using Cumulative Distribution Function (CDF). Complementary (CCDF) is used normally to measure efficiency of PAPR when it exceeds the limit of threshold.

The Peak to Average Power Ratio (PAPR) may be defined as the square of peak value divided by the square of rms value.

$$PAPR=|X|_{peak}^2 / X_{rms}^2 = C^2 \quad (1)$$

Where, C is Crest Factor.

$$C=|X|_{peak} / X_{rms} \quad (2)$$

PAPR and Crest Factor are equal when they are expressed in decibels (db). Hence, these are dimensionless quantities.

C. PAPR Reduction Techniques Used

The combination of Partial Transmit Sequence, Tone Reservation and Companding is used so as to reduce the value of PAPR.

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1. Partial Transmit Sequence (PTS)

In an OFDM system, PAPR is reduced using Partial Transmit Sequence (PTS). In this, the data block is provided with an input in X which is broken down into a number of dissimilar sub-blocks M and is represented as [28]

$$\{X^{(m)}, m=0, 1\ldots M-1\} \quad (3)$$

Hence [22],

$$X=\sum_{m=0}^{M-1} X^{(m)} \quad (4)$$

Where $X^{(m)} =[X_0^{(m)} X_1^{(m)}\ldots\ldots\ldots X_{N-1}^{(m)}$ with $X_k^{(m)}= X_k$ or 0 ($0\leq m\leq M-1$). PTS can be classified into three categories: adjacent portioning, interleaved partitioning and pseudo random partitioning. The sub blocks are converted into M time domain PTS. These are represented as [23]

$$X^{(m)} = [x_0^{(m)} x_1^{(m)} x_2^{(m)}\ldots\ldots\ldots x_{LN-1}^{(m)}] =IFFT_{LN*N}[X^{(m)}] \quad (5)$$

Independently rotate these sequences by phase factors (b).

$$b= \{b_m= e^{j\emptyset}{}_m, m=0,1,\ldots.,M-1\} \quad (6)$$

The main aim is to combine the M sub blocks optimally so as to obtain low PAPR. [24]

$$X= \sum_{m=0}^{M-1} bm X^{(m)} \quad (7)$$

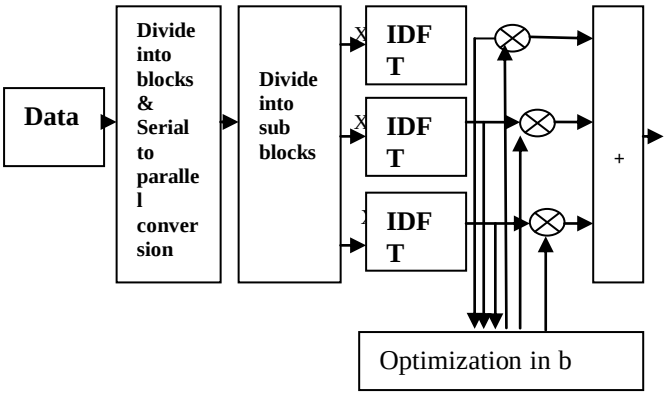

Figure 1: Block Diagram of PTS [17]

2. Tone Reservation(TR)

In Tone Reservation, transmitter and receiver will reserve a subset of tones so that PAPR reduction signals c can be generated. For transmission of data these tones are not used. In this, time domain signal c is found so that it can be added to the original time domain signal x as it will reduce PAPR. Complex symbols for TR are represented as {c= c_n|n = 0, 1… N-1 }.

Processing of TR will change data vector to x+c and a new modulated OFDM signal will be generated. [27]

$$X_v= IFFT (x+c) = X+C \quad (8)$$

Where C=IFFT (c). Hence, the main purpose of TR is getting the accurate value of c so as to get the value of vector X_v with low PAPR.

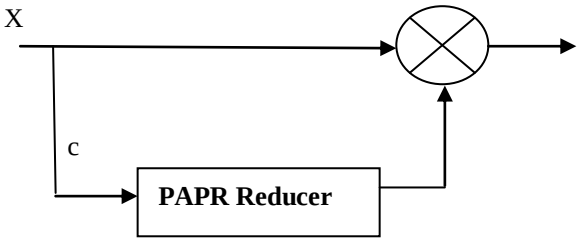

Figure 2: Block Diagram of TR [29]

3. Companding

Two types of companding techniques are there: linear companding and non linear companding. For expanding small signals linear companding is being used. Small signals are enlarged and large signals are compressed using non linear companding. Hence, distribution of signals is uniform. Thereby, increasing the average power and reducing the PAPR value.

D. Comparison of Different PAPR Reduction Techniques

Comparison between three PAPR Reduction techniques is shown in the table.

Technique	Complexity	Distortion	Data	Power
PTS	Yes	No	Yes	Yes
Companding	No	No	Yes	Yes
TR	No	No	No	Yes

Table1. Comparison between different Techniques

Table 1 shows the comparison between three PAPR Reduction techniques i.e. PTS, Companding, TR. There is some degradation in BER Performance as a result of PAPR reduction techniques if we compare it with the original PAPR. Only that reduction technique will be efficient which will reduce the PAPR of the system without any affect to the performance and its implementation cost will be low.

II. LITERATURE SURVEY

Suverna Sengar, Partha Pratim Bhattacharya published a paper on "Performance Improvement in OFDM System by PAPR Reduction". Here, few techniques like coding, phase rotation and clipping have been proposed to reduce the PAPR Reduction in OFDM systems. Two different techniques like Partial Transmit Sequence and Selective Mapping have been used and there is a significant reduction in PAPR. In the end performance of these two techniques has been compared.

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Md. Ibrahim Abdullah, Md. Zulfiker Mahmud, Md. Shamim Hossain, Md. Nurul Islam proposed a paper on "Comparative Study of PAPR Reduction Techniques in OFDM". Here, OFDM is considered as an efficient technique to reduce PAPR. Different PAPR Reduction Techniques have been used and then their results have been compared. SLM is being used when sub carriers are large in number.SLM is the most appropriate technique for reducing PAPR.

Zhongpeng Wang published a paper on **"**Reduction PAPR of OFDM Signals by Combining SLM with DCT Transform". Here, DCT and SLM techniques are combined to reduce PAPR.

K Srinivasarao, Dr B Prabhakararao, and Dr M V S Sairam, represents a paper on "Peak to Average Power Reduction in MIMO OFDM Systems using Sub-Optimal Algorithm". Here, Multiple Input Multiple Output (MIMO) OFDM is considered as one of the important techniques for fourth Generation mobile radio communications. Its drawback is PAPR and to reduce it techniques like coding, clipping and phase rotation have been proposed. Selective Mapping and Partial Transmit Sequence are used. Sub-Optimal Algorithm is used and results have been verified using MATLAB software.

Seung Hee Han, published a paper on "Modified Selected Mapping Technique for PAPR Reduction of Coded OFDM Signal". Here, a modified selective mapping technique has been proposed so that PAPR can be reduced in coded OFDM systems. In this phase sequence is embedded to reduce PAPR of the data block. In this, PAPR Reduction and error performance is achieved as there is no loss in data transmission rate.

Peyali Choudhury, Achala Deshmukh, represents a paper on "Comparison and analysis of PAPR reduction techniques in OFDM". Here, different PAPR Reduction techniques are discussed. If the PAPR value is large then it will degrade the performance of the system. Dynamic range of an OFDM system is two to four times bigger than the single carrier system. If the value of dynamic range is increased, it will increase the cost and power consumption. Hence, value of PAPR is also increased. In this, it is proposed that SLM can be used to reduce PAPR.

R. Divya Kanti and R.V. Ch. Sekhar Rao, proposed a paper on "Systematic Comparison of Different PAPR Reduction Methods in OFDM Systems". Here, SLM is used for reduction of PAPR in OFDM systems. In this, original frame of OFDM system is rotated by various phase sequences and a number of representations of OFDM symbols are generated. The signal which is having minimum PAPR is selected and is transmitted over a channel. The index of selected phase sequence is transmitted over a channel so that phase rotation effect can be compensated at the receiving end.

Tao Jiang, and Yiyan Wu, published a paper on "An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals". Here, different methods to overcome the problem of high PAPR are discussed. Some of the techniques are based on computational complexity, expansion of bandwidth and performance of the OFDM system.

III. PROBLEMS WITH EXISTING SYSTEM

The Orthogonal Frequency Division Multiplexing is one of the widely used modulation techniques in the wireless communication .In OFDM the subcarriers are used to transmit information signal OFDM signal is having low noise, has high spectral efficiency and low non- linear distortion ,due to all these it provide high data rates and sufficient robustness. It also provides low implementation complexity.

OFDM is quite advantageous technique but it has some limitation also, that is the high peak-to-average power ratio (PAPR) of transmitted signal due to the superposition of many subcarriers. This problem can be quantified as the PAPR. Due to rise in PAPR in the signal the output that is received at the receive side is in non uniform, though the input is uniform, so it degrade the quality of the signal, also these large peaks cause saturation in the power amplifiers, so it is desirable to reduce the PAPR . It can also causes many problems in the OFDM system at the transmitting end. Complexity is increased in the analog to digital and digital to analog converter. Also there is decrease in the gain of the signal.

Many techniques have been proposed earlier for the reduction of PAPR, like Clipping, filtration, SLM etc, but were not that much efficient. Most of these methods are unable to achieve simultaneously a large reduction in PAPR as its complexity and coding overhead is low and there is no degradation in the performance. These technique achieved PAPR reduction at the expense of the transmit signal power increase, increase in bit error rate (BER), loss of data rate; increase in computational complexity .A method has to be found that could reduce the effect of PAPR. As this is one of the major problems of the OFDM modulation technique, new methods need to be proposed to reduce its effect.

IV. METHODOLOGY

In OFDM modulation, the high peak-to-average power ratio (PAPR) of transmitted signal due to the superposition of many subcarriers is one of the major problems. Due to the rise of PAPR in the signal the quality of the signal is degraded, also the complexity is increased in the analog to digital and digital to analog converter. So there is a need to reduce the effect of PAPR, Many techniques have been suggested for reducing PAPR, at numerous levels of complexity and success. Techniques like clipping ,filtration ,PTS etc were proposed but these techniques achieve PAPR reduction at the expense of transmit signal power increase, increase in bit error rate (BER), loss of data rate, increase in computational complexity, and so on. So there is need to proposed some other techniques that can reduce PAPR to a great extent, by studying previous PAPR reduction techniques, a new technique is proposed in this thesis .

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In this thesis, work is done on the basis of hybridization of reduction techniques. As clipping can only clip the portion of the signal and Tone reservation has limited average power. So in this thesis along with PTS and tone reservation, companding is combined. As companding allows signals with a large dynamic range to be transmitted over facilities that have a smaller dynamic range capability, so by combing these three techniques the ratio of PAPR in the received signal is low .So this approach can result in the output signal with lessen PAPR. Also there is low implement complexity and there is rise in gain of the signal.

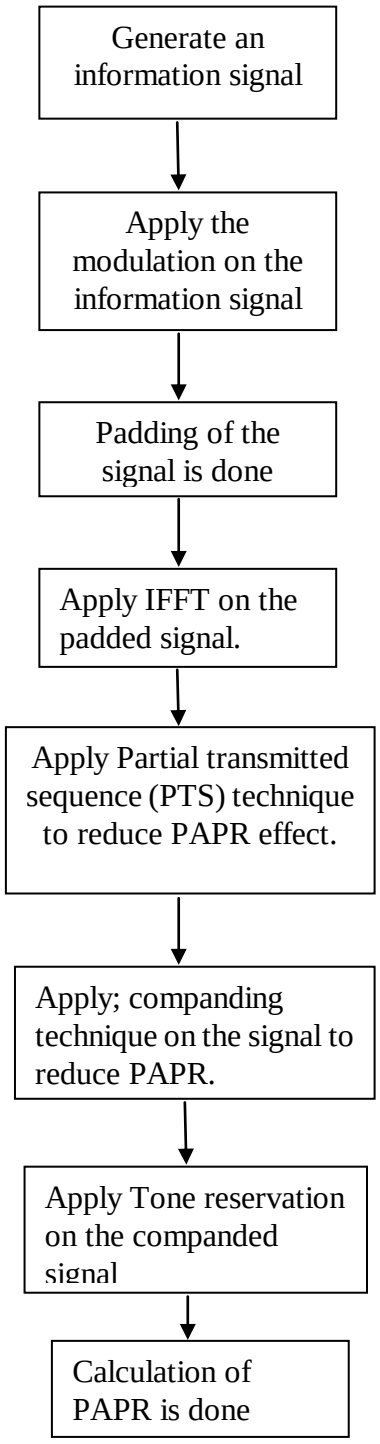

Figure 3: Implementation Flow Chart

V. IMPLEMENTATION AND RESULTS

MATLAB has been used during the implementation process. The figures described below will show the implementation results. The main aim is to achieve low PAPR using some of the reduction techniques available in OFDM.

A. Original Signal

Figure 4 shows the original signal that will be transmitted over a channel from the transmitting end to the receiving end. In this, a random signal is generated. This generated signal carries information which will be sent to the receiver at the receiving end without any distortion.

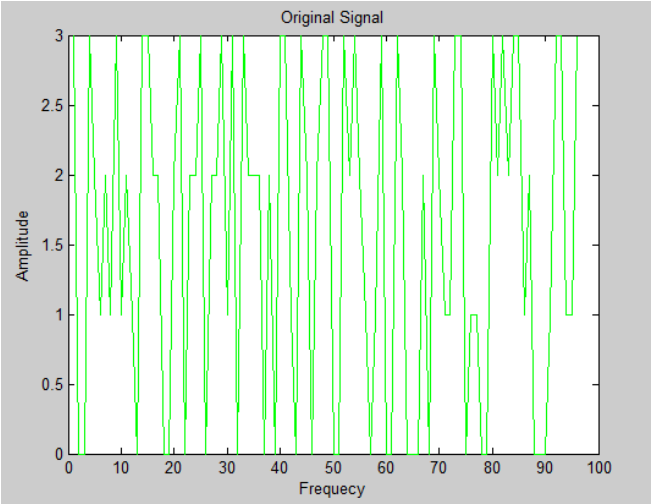

Figure4. Original Signal

B. Transmitted Signal

Figure 5 show that random signal is being transmitted. The random signal is being divided into a number of sub signals/carriers and these sub carriers are being transmitted simultaneously over a communication channel. Sub carriers overlap each other which results in high PAPR value.

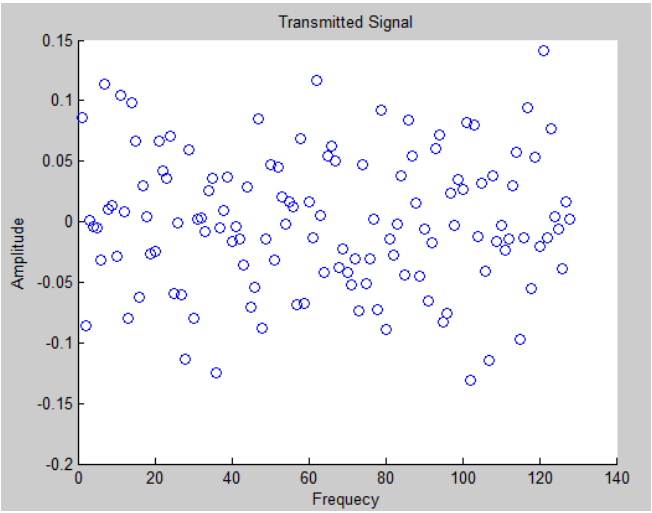

Figure5. Transmitted Signal

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C. PAPR

When signal is received at the receiving end, it is corrupted with the noise which is there in the channel. Due to which there is a high value of the PAPR. Figure6 show that the value of PAPR is 12 db.

D. Result

Figure 7 show the result that we get after implementation. Original PAPR was 12db. After implementation i.e. by using three techniques PTS (Partial Transmit Sequence), Companding and TR (Tone Reservation) is 4.5db approximately. PAPR has been reduced to a much extent using the described reduction methods.

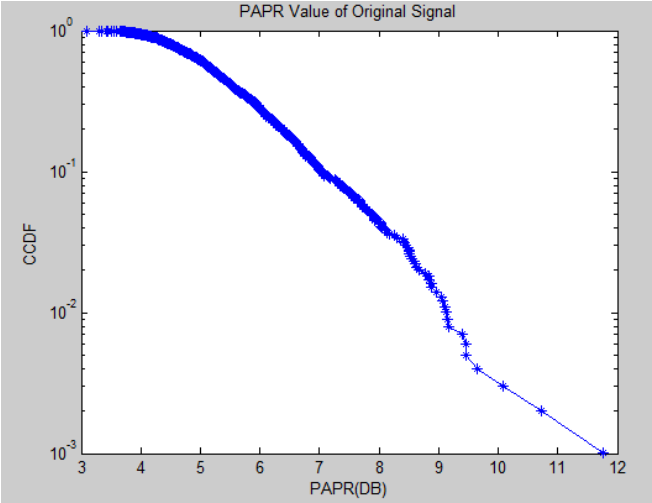

Figure6. PAPR

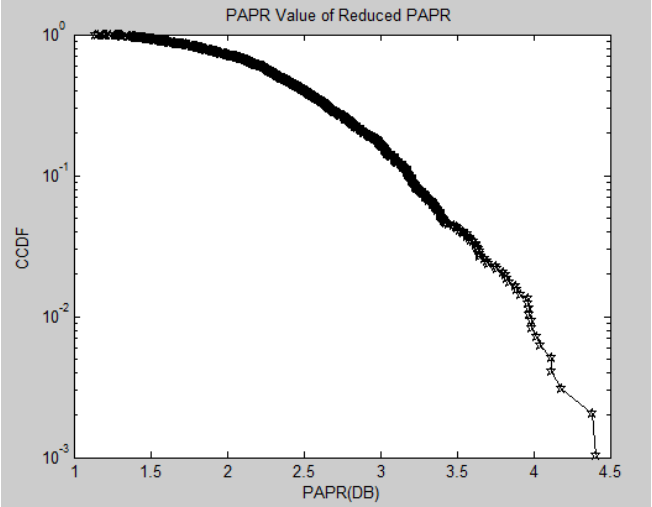

Figure7. Implementation Result

E. Comparison of Original and Proposed PAPR

Figure 8 show the comparison between the original and proposed PAPR. Blue line depicts the original PAPR when no reduction technique is applied on it. Black line depicts the value of PAPR that we get after applying reduction techniques.

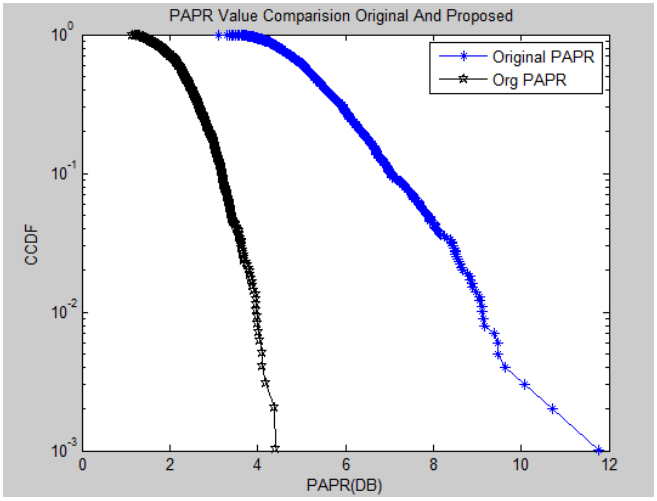

Figure8 Comparison of Original and Proposed PAPR

F. PAPR Value Using Clipping and Filtering

The following figure9 show the value of PAPR is 6db. Filtering and clipping are the two methods used so that PAPR can be reduced.

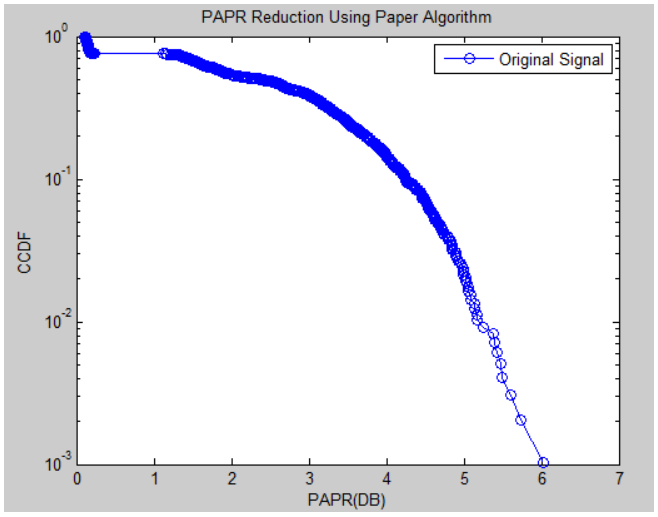

Figure9. PAPR value using Clipping and Filtering

G. Comparison of Original and Proposed PAPR

Figure 10 shows different comparisons. Blue line shows the PAPR value without any reduction technique. Red line depicts the value of PAPR by using techniques like clipping and filtering. Original value of PAPR is 12db.Black line depicts the value of PAPR that we get after applying PTS, companding and TR. The value of PAPR in the proposed system is reduced to 4.5 db. The comparison clearly shows that PAPR value has been reduced using a modified approach.

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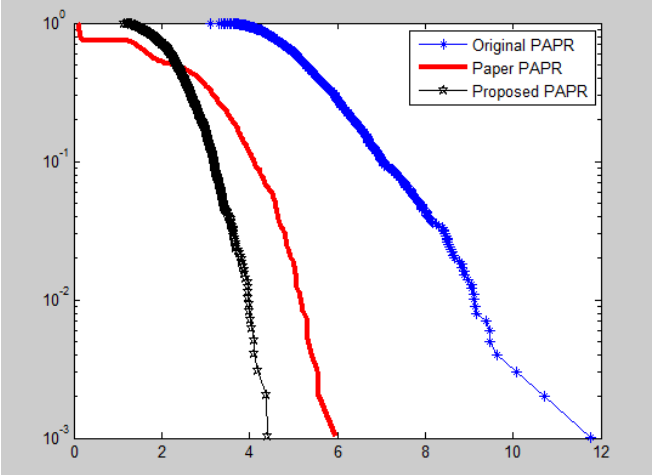

Figure10. Different Comparisons

VI. CONCLUSION AND FUTURE SCOPE

OFDM systems are very efficient for wireless communications as their channel is robust. But PAPR is considered as a main drawback of the OFDM system. In this paper, techniques namely Partial Transmit Sequence, Companding and Tone Reservation are proposed so that noise can be reduced. Its performance is measured in terms of PAPR reduction. This will attain a PAPR reduction of 4.5 db. The complexity of the system is reduced which will enhance the performance of the system. There will be an efficient use of the communication channel and loss of data rate will be low.

In the future, SCOFDM and Turbo STBCMIMO can be used which will reduce the PAPR. In this, codes are attached to the signal at the transmitting end which will encode the signal. The signal will be decoded at the receiver's end which will help to reduce the PAPR.

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