A

DISSERTATION REPORT

ON

PERFORMANCE ANALYSIS OF OFDM SYSTEM IN TERMS OF BER AND PAPR

for partial fulfillment of Master of Technology in Electronics and Communication Engineering

BY

MANDVI

(2015PWC5308)

UNDER THE GUIDANCE OF

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DECLARATION

I, **Mandvi**, hereby declare that the dissertation report entitled "**PERFORMANCE ANALYSIS OF OFDM SYSTEM IN TERMS OF BER AND PAPR**", being submitted by me towards the partial fulfillment of the requirement of **Masters of Technology in the field of Wireless and Optical Communication from Malaviya National Institute of technology, Jaipur**. It is record of the work carried out by me under the supervision of **Mr. Ashish Kumar Ghunawat** and has not been submitted anywhere else.

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CERTIFICATE

This is to certify that the dissertation work entitled "**PERFORMANCE ANALYSIS OF OFDM SYSTEM IN TERMS OF BER AND PAPR**", submitted by **Mandvi (2015Pwc5308)** in partial fulfillment for the award of the **degree of Master of Technology in Wireless and Optical Communication**, **Malaviya National Institute of Technology**, Jaipur is a bonafide work done by her under my guidance and supervision. The work submitted, in my opinion, has reached to a level required for being accepted for dissertation. The matters embodied in this project work, have not been submitted to any other University or Institute for the award of any degree or diploma to the best of my knowledge.

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ABSTRACT

Mobile Communication is the most widely used segment in the communication industry. But, there are various technical difficulties that must be overcome. Signals that are transmitted through a wireless channel face the problem of fading, shadowing, interference, propagation path loss etc. Wireless Communication is always needs a greater demand of high capacity with a good quality of service. In that situation, orthogonal frequency division multiplexing (OFDM) is a good technique, which is a solution for high bandwidth data transmission, by converting a high data rate streams into many lower data rate streams. The transmission of these lower data rate streams onto the orthogonal carriers that eliminate the effect of inter-symbol interference. In this thesis, the performance of OFDM system is analyzed in terms of SNR V/S BER under the Rayleigh fading channel. Here we are assuming that Rayleigh fading channel is a noisy channel. BPSK, QPSK and M-QAM modulation techniques are used for mapping of input stream of data bits .OFDM transmitter and receiver are implemented using IFFT and FFT of size 64 with 52 sub carriers to convert the spectra into time domain and vice a versa. The signal frequency is 20MHz; subcarrier spacing is 312.5 KHz, total symbol duration 4μs, data symbol duration 3.2μs, and cyclic prefix duration is 0.8μs.

Energy efficiency plays a vital role in mobile communication system. The main important factor is the growing energy cost of network operation which results in 50% of the total operation cost. The main drawback of OFDM system is its high peak to average power ratio (PAPR). The efficiency of high power amplifier gets reduced due to high PAPR that degrades the system performance. A high PAPR reduces the battery lifetime in mobile applications. As mobiles have finite life time of battery, so it is necessary to find the technique that would reduce high PAPR value. A low value of PAPR allows for a smaller and more efficient high power amplifier, which results in longer battery life. In this thesis, we have proposed Hybrid RCF+ Companding (tanhR) and a hybrid RFC with COS Companding technique for PAPR reduction.

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ACRONYMS

The following abbreviation and acronyms are used in this standard:

OFDM	Orthogonal Frequency Division Multiplexing
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
3GPP	Third Generation Partnership Project
WiMax	Wireless Interoperability for Microwave Access
PAPR	Peak to Average Power Ratio
BER	Bit Error Rate
SNR	Signal to Noise Ratio
CCDF	Complementary Cumulative Distribution Function
SQNR	Signal to Quantization Noise Ratio
RCF	Repetitive Clipping and Filtering
RFC	Repetitive Filtering and Companding
LOS	Line of Sight
NLOS	Non Line of Sight
TDD	Time Division Duplex
FDD	Frequency Division Duplex
WCDMA	Wideband Code Division Multiple Access
LTE	Long Term Evolution
AMPS	Advanced Mobile Phone System
GSM	Global System for Mobile Communication
VOIP	Voice over Internet Protocol
RNC	Radio Network Controller
ARQ	Automatic Repeat Request
HSDPA	High Speed Downlink Packet Access
MAC	Medium Access Control
BPSK	Binary Phase Shift Keying
QPSK	Quadrature Phase Shift Keying

QAM	Quadrature Amplitude Modulation
CP	Cyclic Prefix
DAC	Digital to Analog Converter
ADC	Analog to Digital Converter
FFT	Fast Fourier Transform
IFFT	Inverse Fast Fourier Transform
UE	User Equipment
ITU	International Telecommunication Union
IEEE	Institute of Electrical and Electronics Engineering
AWGN	Additive White Gaussian Noise

Chapter 1 Introduction

Amid the most recent two decades, the demand has been developed tremendously for multimedia wireless communication services and this demand increasing continuously in the near future. Multimedia communication is the most demanding area of study with rapidly developing antenna's, and an increasing number of users. Hence it becomes essential to consider the widespread use of technologies to design a system which provide more bandwidth with low BER for VOIP (voice over internet protocol) purpose. OFDM has been accepted in various wireless communication standards such as European digital audio broadcasting, terrestrial digital video broadcasting. OFDM has been approved by many IEEE standard working groups, such as IEEE 802.11a/g/n and IEEE 802.16d/e. OFDM is investigated as the most promising radio transmission techniques for LTE of the 3rd generation partnership project (3GPP), International mobile Telecommunication- Advanced systems.

In OFDM system a single high stream of data is divided into lower data rate streams with closely spaced subcarriers. Subcarriers are used to transmit data on several parallel channels. The Orthogonality between subcarriers is achieved if the OFDM symbol duration is equal to the reciprocal of the frequency separation between sub- carriers. OFDM is computationally an efficient technique by utilizing the IFFT and FFT techniques to implement modulation and demodulation. To eliminate the effect of inter-symbol interference from the previously transmitted symbol, cyclic prefix has to be used.

OFDM is a multicarrier modulation technique and broadly utilized as a part of both wired and wireless communication system. Energy efficiency matters a lot in mobile communication system. The primary critical variable is the growing energy cost of network operation which brings about 50% of the aggregate operation cost. The principle disadvantage of OFDM system is its high peak to average power ratio (PAPR). The efficiency of high power amplifier gets decreased because of high PAPR brings about degrade the system performance. A high PAPR lessens the battery lifetime in mobile applications. As the mobile have a limited life of battery, so it is important to discover the technique for lessening the high PAPR esteem. A low estimation of PAPR takes into account a littler and more effective HPA, which brings about longer battery life.

1.1 Evolution of Mobile Communication Technology

AT&T acquired the license to operate the first mobile telephone service in 1946 from the US Federal communication commission (FCC). Ever since then, the evolution of mobile technology can broadly be classified into generations of advancements such as 1G to 5G, currently 5G is under development and is able to accomplish user demands.

1.1.1 First Generation

The first Generation (1G) cellular network was introduced in around 1980¬s. First Generation phone were analog, used for voice calls and Line of sight (LOS) system. In case of Advance Mobile System (AMPS), the First Generation system started in USA.

1.1.2 Second Generation

The Second Generation (2G) cellular network started in 1990s. The first system was introduced in Europe to provide facilities of roaming between different countries. One system in the second generation is the global system for mobile communication (GSM). The GSM standard uses Time division Multiple Access (TDMA) combined with slow frequency hopping. The Personal communication services (PCS) use IS-95 and IS-136standards. The IS-136 standard uses TDMA, while IS-95 uses CDMA. The GSM and PCS IS-136 uses data rat 9.6Kbps. The 2G system are Non Line of Sight (NLOS).

1.1.3 Third Generation

In Third Generation (3G) the Universal Mobile Telecommunication system (UMTS) was introduced. The 3G has higher bandwidth. The 3G network have the transfer speed of up to 3Mbps and enable more services of broadband application, video conferencing, receiving video from the web, downloading e-mail message.

1.1.4 Fourth Generation

The Fourth Generation (4G) cellular system upgrades existing communication networks and it will be providing, the secure Internet protocol (IP) based solution to facilities voice, Data and streamed multimedia to the users at anywhere and anytime

1.1.5 Fifth Generation

5G arrangements to accomplish higher limit then current 4G, permitting higher density of mobile broadband users, supporting device to device, ultra reliable, and massive machine communication.5G innovative work likewise goes for bring down inactivity than 4G latency and lower battery utilization for better execution of the internet of things. There is currently no standard for 5G deployments.

1.2 Evolution of LTE Advanced

In LTE-Advanced concentrate is on higher capacity: The main thrust to additionally create LTE towards LTE–Advanced .LTE Release10 was to give higher bitrates in a cost efficient manner and, in the meantime, totally satisfy the prerequisites set by ITU for IMT Advanced, likewise alluded to as 4G. LTE Advanced includes WCDMA, WiMAX, and CDMA 2000.

1.2.1 Wideband Code Division Multiple Access (W-CDMA)

W-CDMA is a spread-spectrum modulation technique; one which utilizes channels whose bandwidth is substantially more prominent than that of the data to be exchanged. Rather than every association being conceded a committed frequency band sufficiently wide to oblige its visualized most extreme data rate, W-CDMA channels share a significantly larger band. The modulation technique encodes each channel such that a decoder, knowing the code, can choose the needed signal from different signals utilizing a similar band, which just show up as so much noise

The network Architecture of W-CDMA consists of several nodes and interfaces. Node B in Figure1.1 is the logical node that deals with error- correcting mechanism, spreading, modulation and conversion from baseband to radio-frequency. Node B is responsible for transmission and reception for various different cells, Node B is known as base station for the transmitting cells because the mobile device communicates with this node. As shown in Figure1.1 Several Node Bs are connected to each other and controlled by the Radio Network Controller (RNC). According to the usability of the cells each RNC (Radio network controller) consist of number of Node Bs. The Node B'S vary between a few no to hundreds. Thus, the RNC having the responsibility for managing a call setup and maintain the quality of service. RNC uses the ARQ protocol for error correcting and handling re-transmission process. The high-speed downlink packet access (HSDPA) can be termed as advancement over W-CDMA technology. It added a new MAC (Medium access control) sub-layer in Node B; this layer is known as the MAC-hs. This sub-layer schedules, rate controls and operate a hybrid ARQ (Automatic repeat request) protocol thus affecting the overall operation of Node B. The overall architecture remains the same as that of W-CDMA. High speed downlink packet access (HSDPA) is the advancement of CDMA technology. It supports both TDD (time division duplex) and FDD (frequency division duplex) variants.

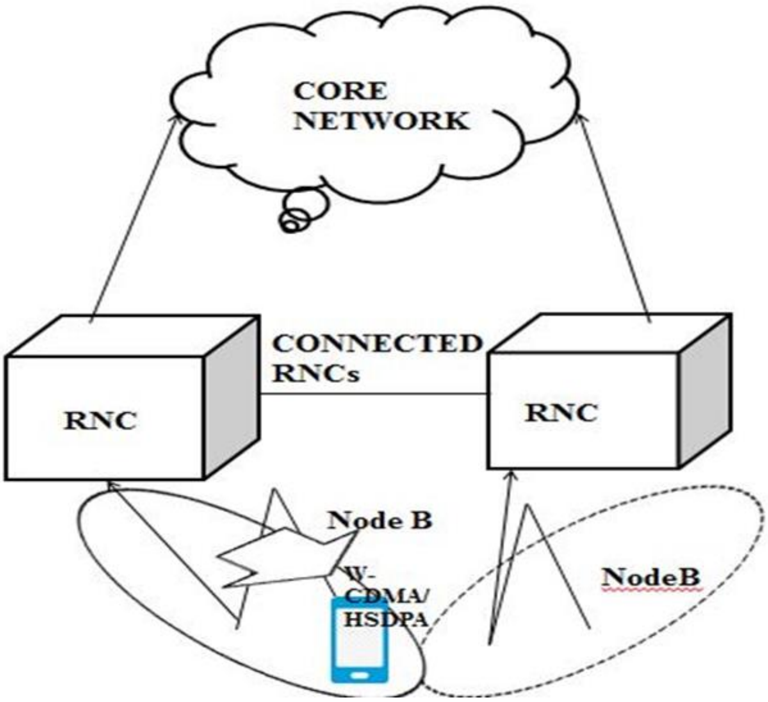

Figure1.1W- CDMA NETWORK ARCHITECTURE

1.2.2 Worldwide Interoprobability for Microwave Access (WiMax)

Mobile WiMax is same as OFDM but WiMax system uses single carrier and different Bandwidth for Uplink and downlink. WiMax is based on the IEEE 802.16 standards. Figure 1.2 shows the block diagram for WiMax system. WiMax forum created the name WiMax, that's aim is to promote and identify compatibility of device based on the IEEE802.16 standard. WiMax provide the upload/download speed up to 10Mbps and coverage distance is 10K.M from a base station. It is same as LTE (Long term evolution) technology having small narrower channels.

The WiMax (802.16) backhaul is relying upon the public wireless network in general wireless networks using microwave interface, optical fiber or any rapid availability. At times, for example, mesh networks; point to multi point (pmp) is utilized for a backhaul. For the most part WiMax utilized point to point antennas as a backhaul (backhaul implies give availability between core network and sub-network). WiMax family standards (802.16) comprise of two sorts of utilization models, for example, fixed WiMax and a mobile WiMax. The essential distinction between two is the ground speed at which the system is to be designed.

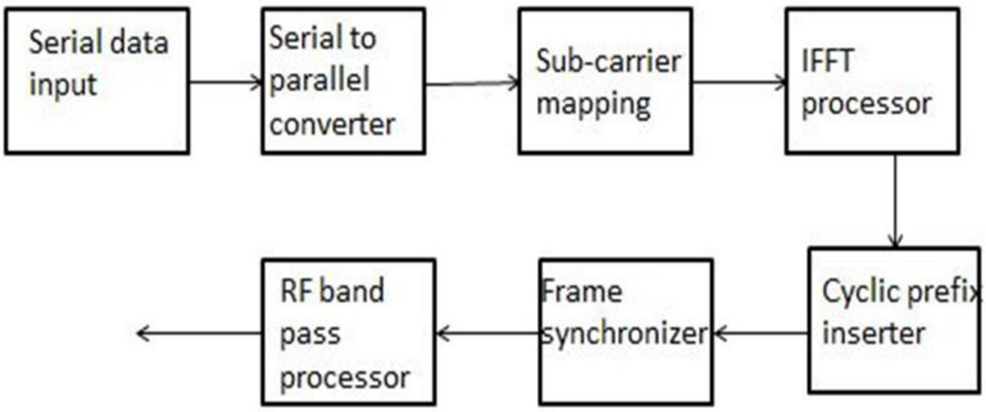

Figure 1.2 BLOCK DIAGRAM OF WIMAX SYSTEM

As shown in above Figure 1.2 it consist of serial data input serial To parallel Converter, IFFT processor, Sub-carriers mapping block, cyclic prefix (CP), frame Synchronizer, inserter, and an RF band pass processor at the transmitter side. WiMax (worldwide interoperability for microwave access) uses a Time division duplex (TDD) frame for OFDM transmission and reception. The Serial to parallel converter is used to convert the user data input to a parallel output and then the parallel output data is mapped according to the corresponding sub-carriers. Block interleaving is done at the sub-carrier mapping level where a block size having the same size as the encoded block size in bits interleaved with the parallel stream of data interleaving is done into two steps, in the first step the adjacent coded bits are mapped onto non adjacent sub-carriers. Mapping of these adjacent coded bits onto the Constellations map takes place in the second step. Different types of modulation schemes BPSK, QPSK, 16-QAM, 64-QAM and 128-QAM cans be used for this purpose.

1.3 Literature Review

In recent years the development of digital communication has been expanding quickly, and it also require fast data transmission scheme. The mobile communication industry confronts the issue of giving such a technique, to the point that can give such a rapid data transmission. Numerous techniques have been proposed and OFDM based technique has increased much consideration for various reasons.

In the time of 1960s, it was perceived as a decent technique for rapid information transmission. The OFDM technique begun in the mid 60's Chang [23] proposed a technique for synthesizing a band limited signals for multi-channel transmission. Multi-channel transmission technique is capable for transmit signals at the same time with no ICI using a straight band limited channel.

From that point onward, Saltzberg [24] proposed an examination that depends on chang's work and he reason that rather to concentrate on outline a multi-channel technique must discover a technique that can decrease crosstalk between adjacent channels instead of consummating the individual signals.

In 1971, Weinstein and Ebert [25] proposed an OFDM technique utilizing discrete Fourier Transform (DFT) to perform the modulation and demodulation. DFT replaces the bank of oscillators. For evacuating the impact of ICI and ISI they utilized guard interval between symbols. This system did not able to accomplish the ideal Orthogonality between sub carriers over a dispersive channel.

Peled and Ruiz [26] in 1980 uses cyclic prefix instead of guard band that solved Orthogonality issue. They assume that for removing the ISI and ICI CP is longer than channel impulse response.

ICI problem that arises due to the carrier frequency offset is removed by using two different approaches. One approach is CFO estimation and compensation. There are various CFO estimation technique and can be categorized as training based methods [1994 (Moose), 1997 (Schmidl and Cox, 1999 (Moreilli and Mengali), 2000(Lei and Tung-Sang), 2004 (Hlaing Minn et.al), 2006 (Hlaing Minn and Xing S)]. Training methods offer fast synchronization, low complexity and reliable performance at the cost of training overhead but the blind or semi blind technique save trainning overhead at the cost of longer latency, high complexity and low reliable performance. The Second approach is used for ICI cancellation (Zhao and Haggaman, 1996; Armstrong, 1999) at the cost of sacrifice data rate. In all current OFDM systems, the first approach is used.

In 2012, N.shirisha, K.balamunaiah, S.munirathnam, "**A simulation and analysis of ofdm system for 4g communications**", the paper indicate that Inter-symbol interference is the Main problem in OFDM system. These problems are solved with the insertion of cyclic prefix. A cyclic prefix at least as long as the maximum multipath delay spread is required for eliminating the effect of ISI.

In 2012, Vineet Sharma, Anuraj Shrivastav, Anjana Jain, Alok Panday, " **BER performance of OFDM-BPSK,-QPSK,- QAM over AWGN channel using forward Error correcting code**", study reported that With the help of error correcting codes using AWGN channel the BER gets improved.

In2012, Abhijyoti Ghosh, Bhaswati. Majumder, Parijat Paul, Pinky Mullick, Ishita Guha Thakurta, Sudip Kumar Ghosh "**Comparative BER Performance of M-ary QAM-OFDM System in AWGN &Multipath Fading Channel**", To reduce the BER with the help of error correcting codes the complexity gets increased(because it is difficult to choose such a code word) and spectral efficiency gets reduced results in reduced data rate. To accomplish high data rate M-array modulation technique is favored on the grounds that it gives preferable data transfer capacity use over the lower order modulation technique. In M-ary modulation technique as we are utilizing the higher value of M the data rate and transfer speed get increased. As we will increase signal power the error rate will be diminished for both AWGN and multipath fading channel however error rate gets increase as the value of M increased. The error rate is higher in multipath fading channel than AWGN channel for same signal.

In 2013, Usha S. M., Dr. K. R. Nataraj2, "' **BER Performance of Digital Modulation Schemes With and Without OFDM Model for AWGN, Rayleigh and Rician Channels**'', In OFDM system a single high stream of data is divided into lower data rate streams with closely spaced subcarriers. Subcarriers are used to transmit data on several parallel channels. OFDM has been used for various broadcast standards such as Digital Video Broadcasting (DVB) and Digital Audio Broadcasting (DAB) standards.

In 2013, Sahasha Namdeo1, Reena Rani2, "**Designing and Performance Evaluation of 64 QAM OFDM System**", for maximizing the average throughput of the OFDM system it is necessary to choose a BER below a target value.

In2015, Mohd. Abuzer Khan1, Sonu Pal2, Ankita Jose, "**BER Performance of BPSK, QPSK & 16 QAM with and without using OFDM over AWGN, Rayleigh and Rician Fading Channel**", it showed that if we are not considering the effect of spectral efficiency than lower order modulation technique is good for use in communication system.

In 2015, Mranali Joshi, Amar Nath Dubey, Debendra Kumar Panda, "**Analyzing various Fading channels using different Modulation Techniques under IEEE 802.16 Standard**", the Nakagami channel is performing better at SNR at 6 dB and 9Db by using 4-QAM and QPSK.

In 2016, Kalaivani.P, Puviyarasi.T2, Raju S.S3, Suresh.S4, " **Performance Evaluation of OFDM System for Different Modulation Techniques on the basis of Bit Error Rate and Peak to Average Power Ratio**", The orthogonally between subcarriers minimizes interference. OFDM is computationally an efficient technique by utilizing the IFFT and FFT techniques to implement modulation and demodulation. To eliminate the effect of inter-symbol interference from the previously transmitted symbol, cyclic prefix has to be used.

In 2016, Pavan Kumar, Amita Kumari, "**BER Analysis Of BPSK, QPSK, 16-QAM & 64-QAM Based OFDM System Over Rayleigh Fading Channel**", if spectral efficiency is considered then we must use higher order modulation techniques. It is also shown that the lower order modulation techniques result in less BER at receiver and hence it results in the improved system performance.

The first nonlinear companding transform for PAPR reduction was given in 1999 by Chang et.al. It has found better performance (based on μ law companding) than that of clipping technique. The μ law companding transform for the most part concentrates on enlarging small amplitude signal while peak signals unaltered, brings about increment the average power of the signals and may prompt defeat the saturation region of HPA to make the performance of the OFDM system more awful.

In 2007, Gang Yang, Yunfeng Zhou and Shixiang Qian, "**Using hyperbolic tangent sigmoid transfer function for companding transform in OFDM system**,'' By selecting the proper companding parameters the BER performance gets improved.

In 2014, E. Singh and M. Arif, "**Novel companding technique for PAPR reduction in OFDM system**," Companding based PAPR reduction technique having very low complexity, higher efficiency, no restriction on number of subcarriers and modulation type used in the system. Companding technique adjusts the amplitudes of large as well as small signals, and maintains the constant average power level by choosing the proper companding parameters.

In 2014, G. S. Toor, H. Singh and A. S. Bhandari, "**PAPR reduction and BER improvement by using logarithmic companding hybrid with SLM technique in bit interleaved COFDM system**," In logarithmic companding hybrid with SLM PAPR reduction technique as we are increasing the compression parameters in companding to additionally decrease PAPR, the BER performance gets degrade. So still, there remains a kind of tradeoff between PAPR reduction and BER performance.

In 2014, E. Singh, M. Arif, V. Shrivastava and R. Bhatia, "**Nonlinear companding technique for PAPR reduction in OFDM**," By selecting the proper companding parameters the BER performance gets improved.

In 2014, M. Hu, Y. Li, W. Wang, and H. Zhang, "**A Piecewise Linear Companding Transform for PAPR Reduction of OFDM Signals with Companding Distortion Mitigation**," By selecting the proper companding parameters the BER performance gets improved.

In 2015,R. Yoshizawa; H. Ochiai, "**Energy Efficiency Improvement of Coded OFDM Systems Based PAPR Reduction**, "It is shown that power amplifier efficiency plays a very important role in the design of communication system.

In 2015, R. K. Singh and M. Fidele, "**An efficient PAPR reduction scheme for OFDM system using peak windowing and clipping**," Clipping technique provides the good results when the value of clipping ratio (CR= 2, 1.8, 1.6, 1.4, 1.2,).

In 2016, A. Kangappaden, A. R. Daniel, V. P. Peeyusha, M. P. Raja, P. Sneha and A. M. V. Das, "**Comparison between SLM-companding and Precoding-Companding techniques in OFDM systems**," Hadamard modified selective mapping technique reduce the PAPR value up to 2 dB and Riemann modified reduced the PAPR value up to the original OFDM signal's PAPR value.

In 2016, E. H. Krishna, K. Shivani and K. A. Reddy, "**Performance evaluation of different PAPR reduction methods in OFDM systems**," In [13] Companding technique increases the value of SNR when the value of the input signal is low therefore the system's noise effect gets reduced

In 2016, Zhuo Wang, Enchang Sun, Yanhua Zhang, '**an overview of peak-to-average power ratio reduction techniques for ofdm signals**', Clipping and filtering technique exceed the Clipping level at some instants, so to resolve this problem, RCF is used to clip the time domain oversampled signals by using the filtering technique at the cost of increased complexity.

In 2016, K. Sultan, H. Ali, and Z. Zhang, "**Joint SLM and modified clipping scheme for PAPR reduction**," The combined (SLM +clipping) technique provides better results compare to the traditional techniques.

In 2017, Manjula A. V., K. N. Muralidhara, ' **PAPR Reduction in OFDM Systems using RCF and SLM Techniques**,' it shows that as the clipping ratio decreases the BER decreases.

1.4 Thesis Objective

This thesis objectives is to Study and analyze performance analysis of OFDM with respect to its Bit Error Rate (BER) and Peak to Average Power Ratio (PAPR) using BPSK, QPSK, M-QAM digital modulation with and without OFDM technique using Rayleigh fading channel.

Energy efficiency matters a lot in mobile communication system. The primary critical variable is the growing energy cost of network operation which brings about 50% of the aggregate operation cost. The principle disadvantage of OFDM system is its high peak to average power ratio (PAPR). The efficiency of high power amplifier gets decreased because of high PAPR brings about degrade the system performance. A high PAPR lessens the battery lifetime in mobile applications. As the mobile have a limited life of battery, so it is important to discover the technique for lessening the high PAPR esteem. A low estimation of PAPR takes into account a littler and more effective HPA, which brings about longer battery life.

In this thesis for PAPR reduction two techniques are proposed such as Hybrid RCF+ Companding (tanhR) and a hybrid RFC with COS Companding technique.

1.5 **Thesis Outline**

The present work is divided into following 7 chapters.

Chapter1 starts with the introduction of wireless communication and the reason to opt this topic as a thesis. It also states the problem definition in current scenario of wireless communication and possible solution.

Chapter 2 defines BER performance analysis of OFDM system. Further it includes different modulation technique to enhance the spectral efficiency and also define the role of Orthogonality to remove ISI.

Chapter3 describes the PAPR problem in OFDM and also explain the various parameters that are directly related to the PAPR.

Chapter4 Presents the PAPR reduction technique.

Chapter5 describes research methodology used for proposed work.

Chapter6 describes the BER performance analysis of OFDM System with the mapping of different modulation technique over conventional modulation technique and performance improvement through PAPR reduction technique.

Finally, Chapter 7 summarizes the work done by giving the conclusion

Chapter 2 BER PERFORMANCE ANALYSIS OF OFDM SYSTEM

In recent years a lot of research has been done in this area. BER performance was analyzed using OFDM and it showed that if we are not considering the effect of spectral efficiency than lower order modulation technique is good for use in communication system. But if spectral efficiency is considered then we must use higher order modulation techniques. It is also shown that the lower order modulation techniques result in less BER at receiver and hence it results in the improved system performance

2.1 Orthogonal Frequency Division Multiplexing

OFDM is the most popular technique for parallel data transmission in wireless communication system. OFDM is widely used in all 4G wireless communication systems. Multicarrier modulation technique forms the basis of OFDM system [1]. In OFDM system a solitary high stream of data is separated into bring lower data rate streams with closely spaced subcarriers. Subcarriers are utilized to transmit data on several parallel channels. OFDM has been used for various broadcast standards such as Digital Video Broadcasting (DVB) and Digital Audio Broadcasting (DAB), standards [2]. OFDM is also used in Wireless local area standards such as IEEE802.11a, IEEE802.11g and 802.11n. The orthogonally between subcarriers minimizes interference. The orthogonally between subcarriers is achieved if the OFDM symbol duration is equal to the reciprocal of the frequency separation between sub- carriers.

OFDM is computationally an efficient technique by utilizing the IFFT and FFT techniques to implement modulation and demodulation. FFT and IFFT eliminate the bank of oscillators used for modulation and demodulation, and make the process is fast. The IFFT and FFT is fast algorithm to calculate the discrete Fourier transform. To dispense with the impact of Inter symbol interference s(ISI) between symbols from the beforehand transmitted symbol, cyclic prefix must be utilized [3]. For evacuating the impact of inter symbol interference the length of cyclic prefix ought to be more prominent than the delay spread.

2.1.1 Orthogonal Multicarrier Technique

In OFDM technique a high input data rate stream is divided into a number of parallel lower data streams. These parallel lower data streams are transmitted using various orthogonal sub-carriers [6].The division of a serial data stream into a number of parallel lower data streams results in increased symbol duration, thus the problem of inter symbol interference (ISI) is going to be reduced. OFDM makes the task for managing the inter symbol interference much easier because of insertion of cyclic prefix. Insertion of cyclic prefix makes the OFDM symbol duration much longer than the single carrier frequency division multiplexing, so the coherence bandwidth is greater than the signal bandwidth. OFDM makes the frequency selective fading channel into flat fading channel. So in OFDM system frequency selective fading channel gets changed over into flat fading channel.

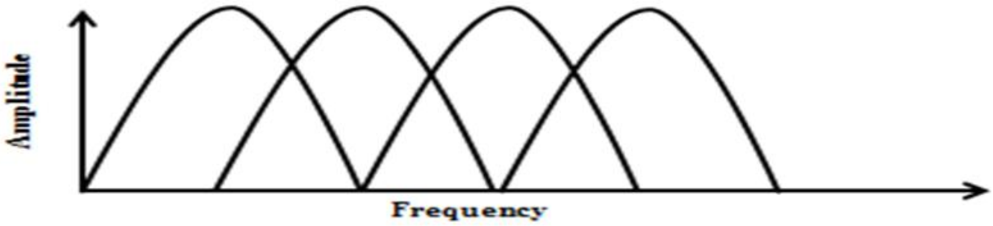

Figure 2.1 ORTHOGONAL MULTICARRIER TECHNIQUE (OFDM)

OFDM system makes the signal orthogonal in the frequency domain which eliminates the effect of Inter symbol interferences as indicates in Figure 2.1 these sub-carriers experiences ‘flat fading’ because the subcarrier bandwidth is less than the coherence bandwidth of the mobile channel.

2.2 OFDM System Model

Fig-2.2 shows an OFDM system model using the Inverse Fast Fourier transform and Fast Fourier transform for modulation-demodulation. Fast Fourier transform is a fast algorithm to perform Fourier transform. In OFDM model the input serial stream of data is mapped into complex data symbols (with the help of different modulation techniques) with symbol rate 1/TS (where TS is the OFDM symbol period). Serial to parallel converter used in this model gives an output X_0 to X_{n-1}, i.e. consist of N complex symbols. The output then passes through an IFFT having N points. IFFT have a rectangular window whose length is N*Ts. IFFT gives different complex samples X_0 to X_{n-1}.The output of IFFT is in the form of samples .These samples are added to the front of the serial data stream and then converted into a serial data stream to produce the OFDM transmit symbol of length T=N*Ts . To eliminate the effect of inter-symbol interference from the previously transmitted symbol, cyclic prefix has to be used. CP store the copies of the last part of frequency selective fading which introduce inter-symbol interference, prefix it with cyclic prefix to eliminate the effect of inter symbol interference. After that OFDM symbols transmitted through Rayleigh fading channel. In 4G mobile communication system the signals are received maximum time through various Reflection, diffraction and scattering, if there is no dominant line of sight path between transmitter and receiver we used Rayleigh fading channel if there exist at least one line of sight path, Ricians fading channel is used .

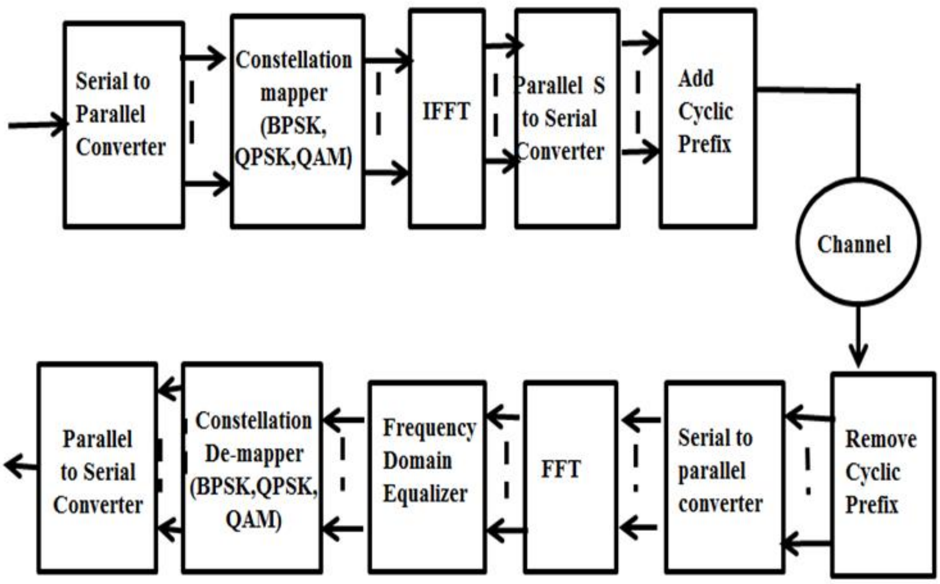

Figure 2.2 OFDM SYSTEM MODEL

In Rayleigh fading channel we assume that the signals that are passes through the channel will vary in a random manner, and follow the Rayleigh distribution. At the receiver side the inverse transmitter phenomenon is done for obtaining the transmitted data, the cyclic prefix (CP) is removed prior to the FFT processing. OFDM is computationally an efficient technique by utilizing the IFFT and FFT techniques to implement modulation and demodulation.

2.3 BER Performance of OFDM System

For an OFDM signal with bit duration Td, the total time period of an OFDM signal is given as Td + TCP, where TCP is the time period of the cyclic prefix adder. So the relation between energy of OFDM signal and bit energy Eb is given as

$$E_b \times T_d = E_S(T_d + T_{Cp}) \tag{1}$$

Now, consider additive white Gaussian noise (AWGN) n, with a two sided noise spectral density is No, the variance is given as

$$Variance = \frac{N_O}{2} \tag{2}$$

And the OFDM symbol energy can be expressed as,

$$E_S = \log_2(M) \times R_C \times R_b \tag{3}$$

Where for QPSK M = 4 and for 16- QAM M=16, for BPSK M=2. RC is the code rate of the system and Eb is the bit energy.

Simplifying the equation (3) and dividing it by No, the expression is given as

$$\frac{E_b}{N_0} = \frac{E_S}{\log_2(M) \times R_C \times No} \tag{4}$$

The relation between the symbol energy and bit energy in terms of number of used subcarriers (n DSC) and FFT size (n FFT) is as follows [9]

$$\frac{E_S}{N_0} = \frac{E_b}{N_O} \times (n\,DSC \div N\,FFT) \times \left(\frac{T_d}{(T_{CP} + T_{CP})}\right) \tag{5}$$

The above equations are used to obtain the relation between symbol energy and bit energy during the MATLAB coding

Chapter 3 PAPR PROBLEM IN OFDM SYSTEM

A high PAPR lessens the battery lifetime in mobile applications. As the mobile have a limited life of battery, so it is important to discover the strategy for diminishing the high PAPR esteem. A low estimation of PAPR takes into consideration a littler and more efficient HPA, which brings about longer battery life.

3.1 Basics of PAPR

To achieve high data rate we are mapping higher order modulation technique with OFDM in wireless mobile communication. Higher Order modulation means more number of bits is mapped in each symbol. To achieve high data rate we are transmitting more number of symbols .These symbols are modulated onto the subcarriers using IFFT process. At the output of IFFT these symbols are added up resulting high PAPR. A high PAPR causes undesirable distortion in the system (because we have limited linear range power amplifier and A/D, D/A Converter).

3.1.1 Definition of PAPR

For a continuous time OFDM signal the PAPR is defined as the ratio of maximum power to the average power.

$$PAPR[X(t)] = 0 \le T \le T_S \frac{[|\mathrm{X(t)}|^2]}{\mathrm{P_{AVG}}} \tag{6}$$

X (T)-Transmitted OFDM signal, P_AVG- is the average power of x (t), T_(S)is the useful duration of an OFDM symbol.

For a discrete time OFDM signal, the PAPR is defined as

$$PAPR[X(n)] = \ 0 \le n \le N \frac{[|\mathrm{X(n)}|^2]}{E[|X(n)|^2]} \tag{7}$$

Where E [.] denotes the expectation operator and N denotes the total number of subcarriers. The PAPR of an OFDM signal is defined in terms of CCDF (Complementary cumulative distribution function) can be written as-

$$P(PAPR>PAPR_0) = 1-(1- e^{PAPR_0})^2 \quad (8)$$

Where $PAPR_0$ represents the clipping level. CCDF is nothing but the probability of getting high PAPR.

3.1.2 PAPR Distribution

To build up a powerful PAPR reduction strategy the PAPR distribution assumes an imperative part. The distribution of PAPR can be utilized direct to compute the BER performance and to make estimation for the achievable data rates. We ought to expect for the OFDM system that the input stream of data is statistically independent and distributed identically, so that the real and imaginary parts of x[n]are orthogonal and uncorrelated,, According to the central limit theorem for large value of N, the imaginary and real parts of x[n] are independent and distributed identically i.e. Gaussian random variables, having with zero mean and variance.

$$\sigma^2 = \frac{E[|x(n)|^2]}{2} \quad (9)$$

The probability distribution of complex OFDM signals with a large value of N is a complex Gaussian distribution given by the following relation

$$\Pr\{x[n]\} = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(\frac{-x^2(n)}{2\sigma^2}\right) \quad (10)$$

Where P_r {.} represents the probability distribution function. σ^2Is the variance of x[n].The OFDM signal amplitude has a Rayleigh distribution and its probability density function (PDF) is given by

$$P_r\{x(n)\} = \frac{|x(n)|}{\sigma^2} \exp(-|x(n)|^2/\sigma^2) \quad (11)$$

3.2 Identification of the PAPR Problem

Multi-carrier technique is thought to be the real improvement in wireless Communication system and among them OFDM technique is being the essential one. The

Major drawback of OFDM is the high PAPR esteem brings about power efficiency going to be lessened. To beat the low power efficiency it is important to utilize large Dynamic range DAC as well as profoundly effective HPA and expansive linear range converters, Results in the addition in the hardware cost and furthermore the complexity will be increased. To diminish the complexity of the system and furthermore to reduce the hardware cost it has turned out to be basic to utilize effective PAPR reduction technique.

The drawback of utilizing extensive dynamic range is that it forces on the design of components for example, the word length of the FFT/IFFT pair, mixer stage and the HPA, which is composed? To handle the irregularity happening during large peaks diminishes the signal to quantization Noise ratio (SQNR) of analog to digital converter and digital to analog converter. The PAPR Problem is more noteworthy in the uplink on the grounds that in the uplink the mobile terminal has the Limited battery power, so the effectiveness of power amplifier is basic in the uplink Transmission. It is hard to design components having a satisfactorily extensive linear range brings about the saturation of the HPA. The saturation introduces both in-band distortion and out of band distortion, increased BER or spectral splatter, brings about Adjacent channel Interference. To take care of the issue it is important to design such components that work within large linear range, however this is unrealistic as the components will be working improperly and the cost turns out to be too high. This is particularly evident in the HPA where a high cost and ~50% of the size of a transmitter lies.

3.2.1 Nonlinear HPA and DAC

To obtain maximum output power efficiency the HPAs have to be operated at or near the saturation region. A high PAPR happen when the data on the subcarriers are add up in a constructive manner at the Transmitter. Because of high PAPR the composite transmit signal could be clipped through the DAC and power amplifier because of their bounded dynamic range. Due to clipping a Significant amount of distortion occur in the output. So to remove the distortion in the Output signal it is necessary to reduce the PAPR of an OFDM signal via modifying the Characteristics of the signal in both time and frequency domain clipping of the composite OFDM signal. Clipping of OFDM signal presents different undesirable results, for example, Signal distortion and spectral regrowth. Clipping causes in-band noise that outcome in BER Performance degradation. Moreover, higher order harmonics that spill over into OOB Spectrum also occurs due to signal clipping. To remove the spectral leakage from the System filtering is used after HPA. It's an extremely power wasteful, so it is an undesirable Solution. It's an extremely power wasteful, so it is an undesirable Solution. It's a to a great degree power wasteful, so it is an undesirable Solution. Thusly, the dynamic range of DAC should be adequately broad to suit the largest peak of signals. Thusly, the dynamic range of DAC should be adequately broad to suit the largest peak of signals. A high precise DAC support high PAPR having a commendable measure of quantization noise, But it is costly to a particular sampling rate of the system, yet a low precise DAC would be more affordable, yet the quantization noise will be more, which diminish the signal to noise ratio. The linear range of DAC is expanded to oblige high PAPR, for the most part the DAC going to be saturated and clipping will happen. To oblige large PAPR esteems the dynamic range of the power amplifiers ought to be sufficiently large, sotherwise the power amplifier may saturate results in clipping. As the dynamic range of the DAC and power amplifier increases the cost is going to be increased.

3.3 Power Saving

HPA with high dynamic range has low power efficiency. By reducing the PAPR value the Power could save. The power efficiency is-

$$\eta = 0.5/PAPR \tag{12}$$

Where η =Pout,ave/pdc , η - HPA efficiency, Pout,ave- the average of the output power, Pdc- A fixed amount of power regardless of their input power. The PAPR of OFDM system has to reduce for neglecting this level of power inefficiency.

3.3.1 Factors influencing the PAPR

There are various factors that influence the PAPR some of them are given below. Each factor has its own advantage and disadvantage on PAPR reduction. It is important to choose such a technique so that the performance of the system cannot degrade.

3.3.1.1 The number of sub-carriers

3.3.1.2 The order of modulation

3.3.1.3 Constellation shape

3.3.1.4 Pulse shape

3.4 The Gauge for Judgment of the PAPR Reduction in OFDM System

There are different strategies for PAPR diminishment. Every strategy has a few merits and demerits. Thus, there is always a trade-off between the PAPR lessening and different factors like bandwidth Average power, computational complexity and some more. There are some characteristics given below for an ideal PAPR reduction technique. These factors play a very important role for analyzing the performance of PAPR reduction technique in terms of CCDF and BER.

3.4.1 No Spectral Spillage

Any PAPR decrease strategies can't conquer OFDM captivating specialized features, for example, immunity to the multipath fading, so in PAPR lessening strategy the spectral spillage must be overlook.

3.4.2 No Additional Power Requirement

The power efficiency is very important in wireless communication system. So for PAPR Reduction technique chooses such a technique which doesn’t require extra power. Our aim is to choose such a technique that requires the same power as before applying PAPR reduction technique.

3.4.3 No Degradation in the BER Performance

The fundamental aim of the PAPR reduction technique is for the good system performance in terms of BER which is better than that of the original OFDM system.

3.4.4 No Bandwidth Expansion

Bandwidth is the main resource in the system. The extension in bandwidth has straightforwardly related in the information code rate loss because of side information, so the loss in bandwidth Because of side information must be kept away from.

3.4.5 Low Implementation Complexity

For PAPR reduction chooses such a method having both time and hardware imperatives for the PAPR reduction must be minimal. Complexity ought to continue as before as before applying the PAPR reduction system.

Chapter 4 PAPR REDUCTION TECHNIQUE

To achieve high data rate we are mapping higher order modulation technique with OFDM in wireless mobile communication. Higher Order modulation means more number of bits is mapped in each symbol. To achieve high data rate we are transmitting more number of symbols .These symbols are modulated onto the subcarriers using IFFT process. At the output of IFFT these symbols are added up resulting high PAPR. A high PAPR Causes undesirable distortion in the system (because we have limited linear range power amplifier and A/D, D/A Converter).There are various techniques for reducing PAPR each having its own advantage and disadvantage.

4.1 Hybrid Repetitive Clipping Filtering+Companding

OFDM is in reality exceptionally vigorous as far as delays spread and inter symbol interference; this is a noteworthy Advantage of OFDM. In any case, the OFDM has additionally a critical impediment and this is the generally high PAPR. The clipping is the simplest method for PAPR reduction in time domain. In this technique we have to reduce the PAPR by setting a maximum level for the OFDM signal. This technique cut the peak of the signal above the desired threshold level. Clipping technique introduced the high out of band radiation, so to reduce the out of band radiation the use of frequency domain filtering, the filtering improves the BER. But filtering cause's problem of peak regrowth, the problem of peak regrowth is reduced by using repetitive clipping with filtering technique. On the other hand, Companding has also a good technique for PAPR reduction having no bandwidth expansion.

In [11] Hadamard modified selective mapping technique reduce the PAPR value up to 2 dB and Riemann modified reduced the PAPR value up to 3dB in comparison to the original OFDM signal's PAPR value. Pre coding with Companding provides more than 80% efficiency for reducing PAPR value.

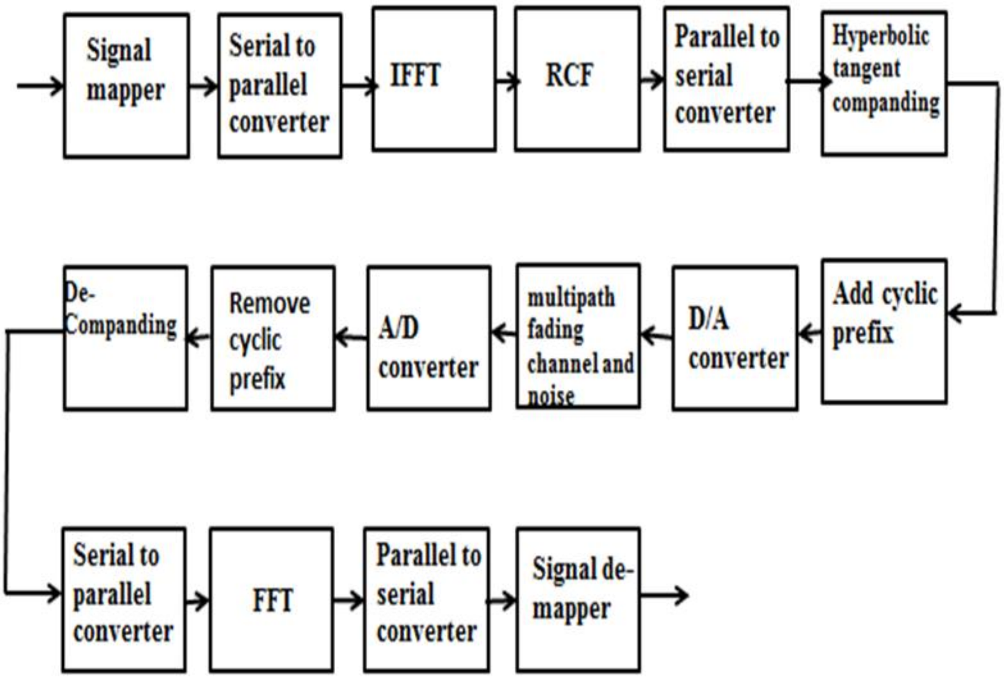

Figure 4.1Block diagram of hybrid RCF + COMPANDING

In [12] Companding technique increases the value of SNR when the value of the input signal is low therefore the system's noise effect gets reduced. In [13] Clipping technique provides the good results when the value of clipping ratio (CR= 2, 1.8, 1.6, 1.4, 1.2, 1).While in[14] As the clipping ratio decreases the BER decreases. Clipping and filtering [15] technique exceeds the Clipping level at some instants, so to resolve this problem, RCF is used to clip the time domain oversampled signals by using filtering technique at the cost of increased complexity.

4.2 Hybrid RCF with Companding Model

A hybrid RCF + Companding technique is proposed in fig4.2. The generated random binary data sequence is first mapped with QPSK symbols. IFFT and oversampled module is used for obtaining OFDM signal. The RCF +Companding are used to reduce the high PAPR value after the IFFT processing. At the receiver the inverse transmitter process is done to obtain the original information.

4.2.1 Mathematical Expression used in MATLAB Coding for Addition of TanhR Companding with RCF

After the fourth time of RCF technique add the tanhR companding technique for observing the effect of PAPR reduction on RCF. These are the equations used in MATLAB coding for tanhR companding technique. The proposed tanhR Companding equations are-

$$f(x) = \tanh((|x| * k)\hat{}y) * sgn(x) \qquad (13)$$

Where k is a positive number used for controlling the companding level applied to the envelope x, |x| and Sgn |x| is used for maintaining the phases of the OFDM signal.

De-Companding equation is as follows

$$f^{-1}(x) = \left|(a \tanh({|x|}/{k}))\hat{}\ {1}/{y}\right| * sgn(x) \qquad (14)$$

4.3 RFC +COS Companding

A hybrid RFC with COS Companding method has been proposed to diminish the PAPR impact of the OFDM system, which helps for expanding the power amplifiers efficiency and additionally lessens the complexity of the analog to digital converter (ADC) and digital to analog converter (DAC). RFC decreases the effect of filter on PAPR and enhances the BER Performance. RFC system Improve the PAPR and BER performance and then COS Companding more decreases the PAPR value.

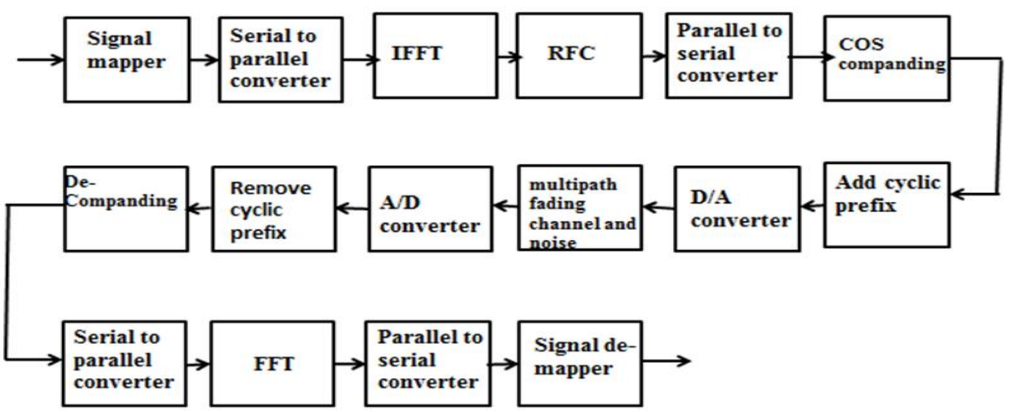

Figure 4.2 SYSTEM MODEL FOR RFC + COS COMPANDING

4.3.1 Distribution of PAPR

The PAPR of a continuous time baseband signal is defined as the ratio of most extreme instantaneous power to its average power of the signal. For choosing a viable PAPR reduction method, it is critical to appropriately recognize the PAPR distribution in OFDM system design. The PAPR distribution assumes an imperative part. The PAPR distribution can be utilized to find out the proper output back-off of the HPA to decrease the aggregate degradation. It can be useful to compute the BER and to appraise the achievable information rate. The PAPR distribution is expressed in terms of complementary cumulative distribution function (CCDF). The CCDF is defined as the probability that a real- valued Random variable X with a given probability distribution will be found at an esteem more noteworthy than or equivalent to X. The CCDF is given by

$$F(Z) = 1\text{-}\exp(Z) \qquad (15)$$

$$P_r(PAPR>Z) = 1\text{-}P_r(PAPR\leq Z) \qquad (16)$$

$$P_r(PAPR>Z) = 1\text{-}F(Z)\ \hat{}\ N \qquad (17)$$

$$P_r(PAPR>Z) = 1\text{-}(1\text{-}\exp(-Z)\ \hat{}N) \qquad (18)$$

4.3.2 Repeated Frequency Domain Filtering and Clipping with COS Companding

In the proposed method the filter is placed before the clipping as in fig (3.2.2). The filtering in frequency domain depends on the interpolation that improved the performance of BER but the PAPR gets increased. The concept behind this method is that the BER performance of OFDM system is improves because of employing filter before the clipping technique. Clipping technique will improve PAPR. The filtering signal is being clipped in the time domain. The clipping technique is described with the following equations-

$$\boldsymbol{C} = \begin{cases} x\sqrt{C_{R*E[|x^2|]*\frac{x}{|x|}}}\ , & |x^2| > C_m \\ x, & |x^2| \leq C_m \end{cases} \qquad (19)$$

Where C is the time domain output signal and Cm is give as-

$$C_{m= C_R*E[|x^2|]} \qquad (20)$$

Where Cm represents the threshold clipping level, |x^2 | is the signal power, E [|x^2 |] is the mean power, CR is the clipping ratio, Clipping ratio is the ratio of the clipping level to the mean power of unclipped baseband signal. As shown in the equation (5), the time domain discrete signal is clipped in amplitude. At each point where the time domain complex signal exceeded the level of clipping, the amplitude was minimized to the clipping level and the complex signal's phase was unchanged.

The frequency domain filtering is followed by clipping to enhance the BER performance of the system. Then again, the companding technique has additionally been a decent method, since it has the great PAPR reduction ability with no expansion in bandwidth having low computational complexity. The companding system has additionally another favorable position is that at the receiver the signal is effectively recovered through inverse companding transform. This proposed hybrid technique gives great outcomes because the first RCF lessen the PAPR with the BER improvement and then COS companding again minimize PAPR esteem. The OFDM model with the proposed technique is shown in fig (4.3.2).

For the addition of COS companding the following equation are utilized as a part of MATLAB coding. The COS companding equation is-

$$\text{h(x)} = \text{sgn(x)}\sqrt[y]{\alpha\left[1-\cos\left(\frac{-|x|}{\sigma}\right)\right]} \tag{21}$$

The COS de-companding equation is-

$$h^{-1}\text{(x)} = \text{sgn(x)}\left|-\sigma\cos^{-1}\left(1-\frac{|x|^{\frac{2}{y}}}{\alpha}\right)\right| \tag{22}$$

The constant α is given as-

$$\alpha = \left(\frac{E(|x|^2)}{E\left[\sqrt[d]{1-\exp\left(\frac{-|x|}{\sigma}\right)}\right]^2}\right) \tag{23}$$

Chapter 5 RESEARCH METHODOLOGY

Since the objective of this is to evaluate the performance of OFDM system in terms of SNR V/S BER and PAPR V/S CCDF. For this purpose we have used Matrix laboratory (MATLAB) as the research tool.

5.1 Methodology used for the Performance Evolution of OFDM System

5.1.1 MATLAB as a tool

MATLAB provides an effective numerical computing environment with multiple paradigms. It allows one to manipulate matrices, plot various functions and data, implement algorithm etc. It offers an optimized platform for solving scientific and engineering structured problems. MATLAB is basically a Matrix based language which comes handy in solving computational mathematics.

5.1.2 Tool selection grounds for MATLAB

MATLAB is much better in handling up of large data as compared to other similar tools. It is used standardly by large number of scientist and engineers across the globe. On comparing with the similar tool such as Excel, MATLAB is much more language and algorithm oriented whereas excel as a tool is much more analytically oriented.

MATLAB by default provides the output values at every sample point taken within the iteration in tabular format while similar thing cannot be readily find into other tool.

Chapter 6 SIMULATION RESULTS AND ANALYSIS

6.1 MATLAB Coding for BER Comparison of OFDM System with the Mapping of Different Modulation Techniques over Conventional Modulation Technique

The performance of BER using BPSK, QPSK, M-QAM (here we have taken M=16, 64, 128) digital modulation with OFDM technique using Rayleigh fading channel and comparison of it with the BER performance of conventional modulation techniques (BPSK, QPSK, M-QAM) over the same fading channel. The performance of BER has been investigated by using MATLAB coding.

We have taken following OFDM system parameters (based on IEEE 802.11a specifications) --Number of subcarriers used (N DSC) is 52, FFT sampling frequency is 20MHz, Spacing between subcarriers is 312.5 KHz, Duration of Cyclic prefix, TCP is 0.8us, Duration of data symbol, Td is3.2 us, Total symbol duration, TS is 4us, Method used for Modulation are BPSK, QPSK, M-QAM.

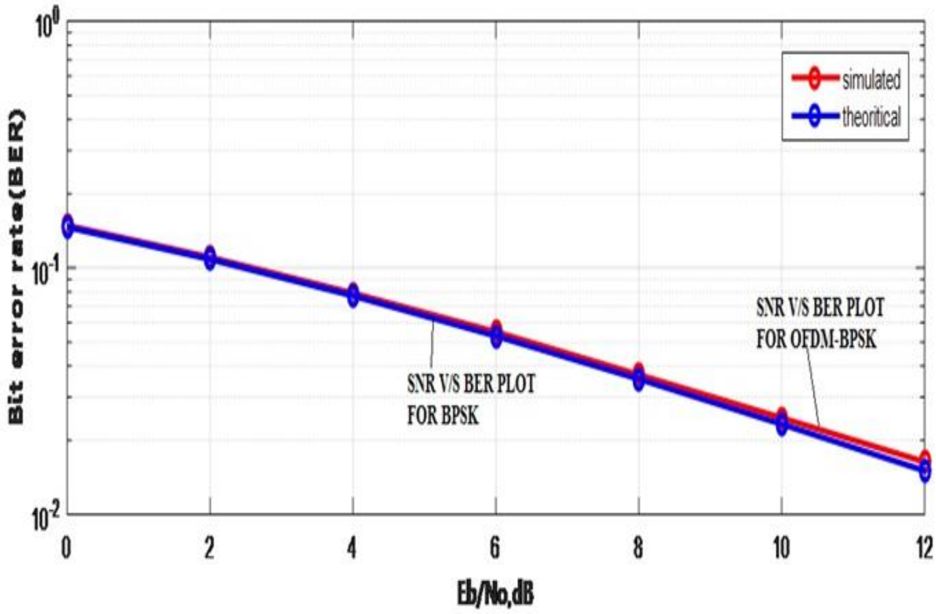

Figure 6.1 PERFORMANCE OF OFDM-BPSK OVER BPSK MODULATION USING RAYLEIGH FADING CHANNEL

An exceptionally prevalent digital modulation scheme, binary phase shift keying (BPSK), shifts the carrier sine wave 180° for each change in binary state. BPSK is coherent as the phase changes happen at the zero crossing points. The proper demodulation of BPSK requires the signal to be contrasted with a sine carrier of a similar phase. In a prevalent variety of BPSK, quadrature PSK (QPSK), the modulator produces two sine carriers 90° apart. The binary information modulates each phase, creating four unique sine signals shifted by 45° from each other. The two phases are added together to create the final signal. Every unique pair of bits produces a carrier with a different phase. The formation of symbols that are some combination of amplitude and phase can convey the idea of transmitting more bits per symbol further. This technique is called quadrature amplitude modulation (QAM).

The BER performance of an OFDM-BPSK over conventional BPSK using Rayleigh fading channel is shown in fig-6.1. From the MATLAB results we can observe that the OFDM-BPSK modulation has no advantage over a conventional BPSK modulation scheme. Because of the BER performance of OFDM-BPSK and conventional BPSK are same. So there is no advantage of using OFDM-BPSK over conventional BPSK scheme.

The BER performance of an OFDM-QPSK over conventional QPSK using Rayleigh fading channel is shown in fig-6.2. From the results it is clear that OFDM-QPSK performs well over QPSK after the SNR equal to 7 dB from the result it is conclude that OFDM-QPSK is used where SNR value is greater than 7dB.

The BER performance of an OFDM – 16QAM over 16-QAM using Rayleigh fading channel is shown in fig-6.3. From the results it is clear that OFDM-16QAM performs well over conventional 16-QAM as after SNR equals to 15.5dB; the BER is less in comparison with that of 16- QAM.

The BER performance of an OFDM-64QAM over 64-QAM using Rayleigh fading channel is shown in fig-6.4. From the result it is clear that OFDM-64QAMperforms well over conventional 64-QAM as after SNR equals 17dB, the BER is less in comparison with that of 64-QAM.

The BER performance of an OFDM-128QAM over 128-QAM using Rayleigh fading channel is shown in fig-6.5.From the result it is clear that OFDM-128QAM performs well over 128- QAM as after SNR equals 17.5dB, the BER is less in comparison with that of 128-QAM.

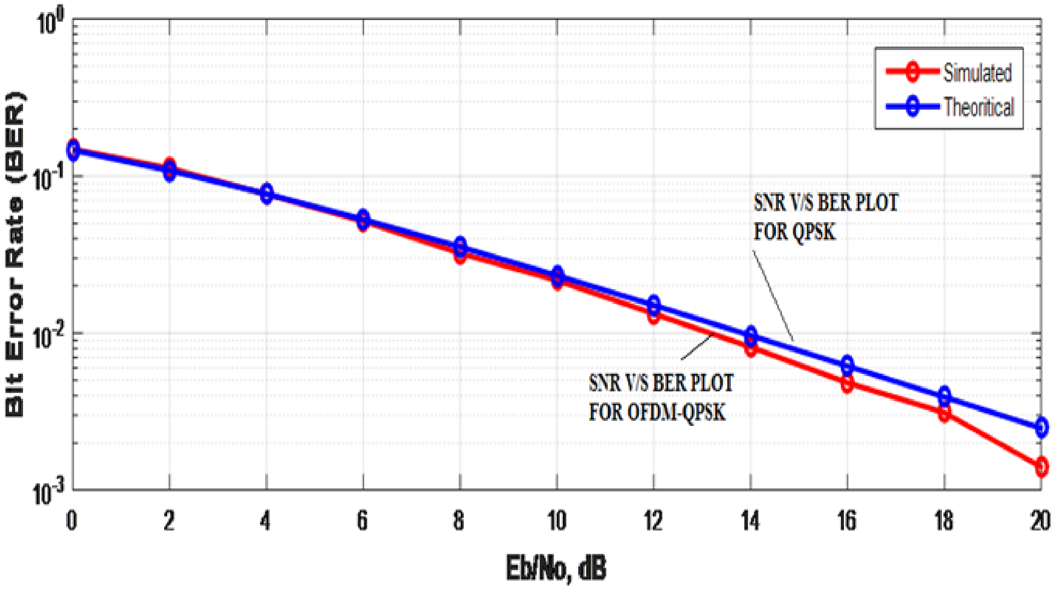

Figure 6.2 PERFORMANCE OF OFDM-QPSK OVER QPSK MODULATION USING RAYLEIGH FADING CHANNEL

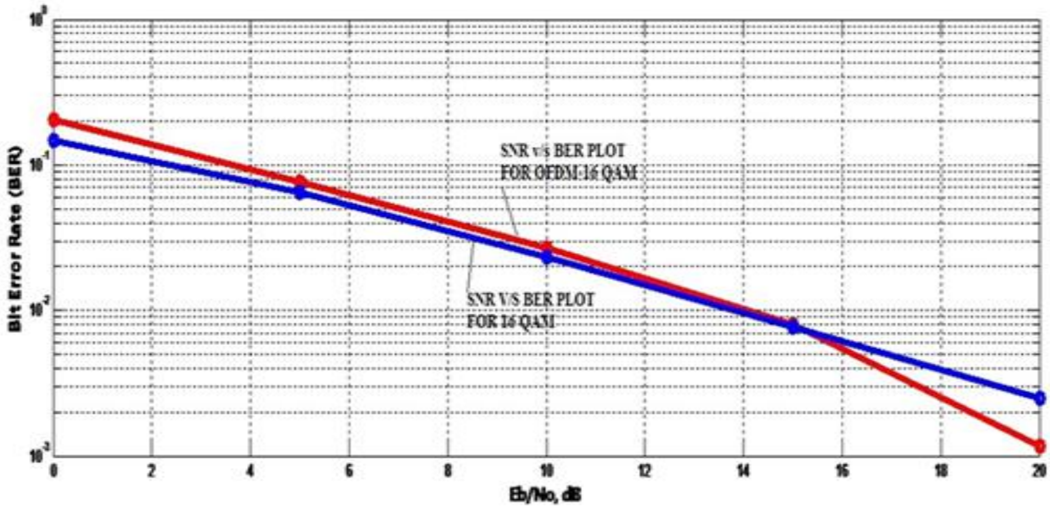

Figure 6.3 PERFORMANCE OF OFDM-16 QAM OVER 16 QAM USING RAYLEIGH FADING CHANNEL

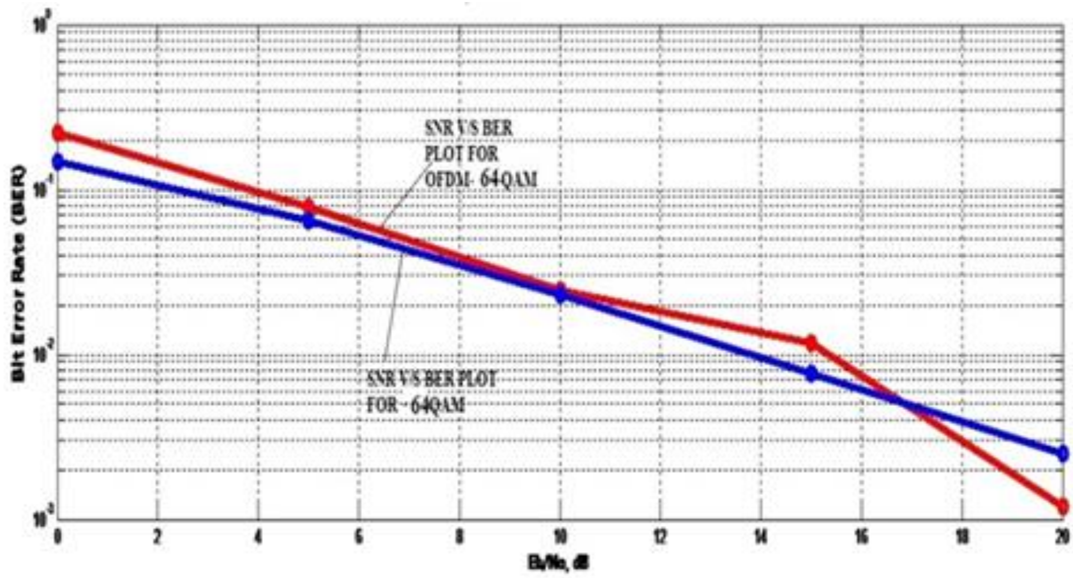

Figure 6.4 PERFORMANCE OF OFDM-64 QAM OVER 64-QAM USING RAYLEIGH FADING CHANNEL

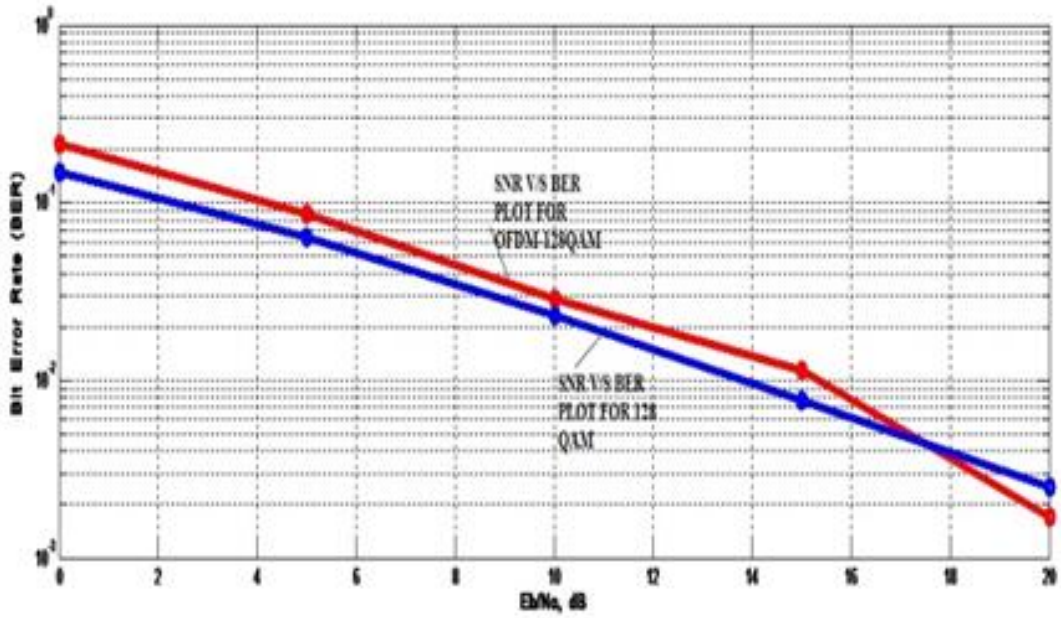

Figure 6.5 PERFORMANCE OF OFDM-128 QAM OVER 128-QAM USING RAYLEIGH FADING CHANNEL

From the Figure 6.1, Figure 6.2, Figure 6.3, Figure 6.4, it is clear that there is no advantage of OFDM-BPSK over conventional BPSK; But OFDM-QPSK performs well over a QPSK after SNR value of 7 dB. OFDM with M-QAM performs well over a conventional QAM at high SNR (greater than 15 dB) values. So, nowadays in 4G mobile communication we are using OFDM with the mapping of higher order QAM system to achieve high date rate at slightly high SNR value. OFDM with higher order QAM is used where proper SNR values is available (to take the advantage of high signal to noise ratio and high data rate).

6.2 MATLAB Coding Results for Hybrid Repetitive Clipping and Filtering + Companding (TanhR) Technique for PAPR Reduction in OFDM System

We have taken the following specifications for obtaining the results using MATLAB@2013a for PAPR reduction in OFDM system.

- M = 4 (QPSK Signal Constellation)
- FFT size is = Interpolation factor *Size of OFDM Symbol
- 128 FFT/IFFT blocks
- F spacing = 15KHz
- Max Doppler frequency Shift (assume 0)
- Size of OFDM Symbol = 128
- Interpolation factor = 2
- Hyperbolic tangent Companding is used with RCF technique
- Clipping Ratio-1, 2, 3, 4
- 1000 number of symbols
- Iteration number=4
- Cyclic prefix length = .25*Size of OFDM Symbol
- Channel used = Rayleigh fading channel
- QPSK modulation is used for mapping of the input bits
- SNR = 0 to 30dB
- Sampling frequency = f spacing*FFT size
- Bandwidth = 1.5 MH_Z

MATLAB coding results for proposed technique is shown in the following figures. The curve is obtained to evaluate the performance of the OFDM system in terms of SNR V/S BER and PAPR V/S CCDF for different values of companding parameter k and y and clipping ratio CR. The value of companding parameter y is varies from .1 to .5 (given in literature) and clipping ratio varies from 1 to 4for evaluating the performance of the proposed technique

6.2.1.1.1 K =40, y=.5, CR=4

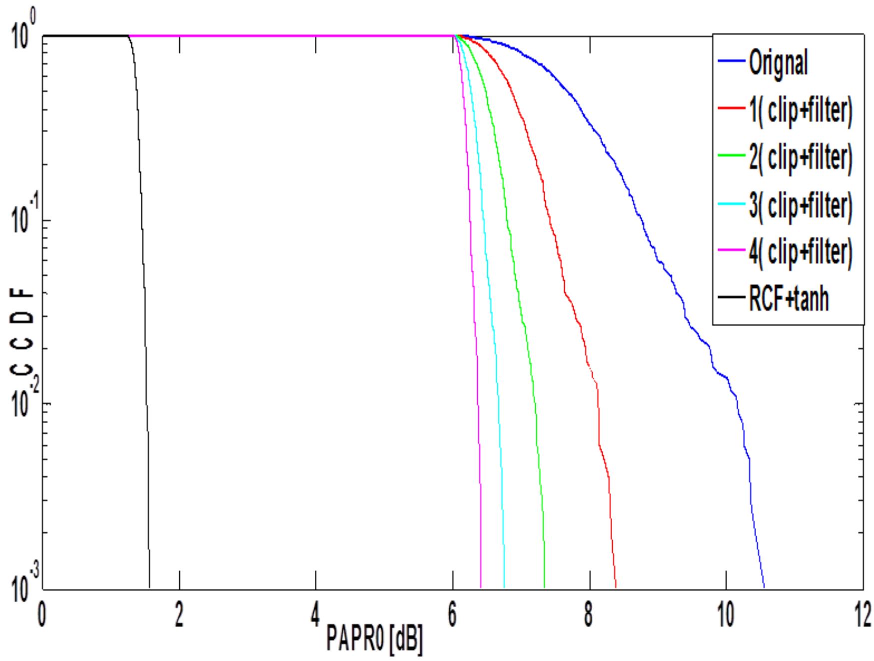

Figure 6.6 PAPR V/S CCDF CURVE K =40, Y=.5, CR=4

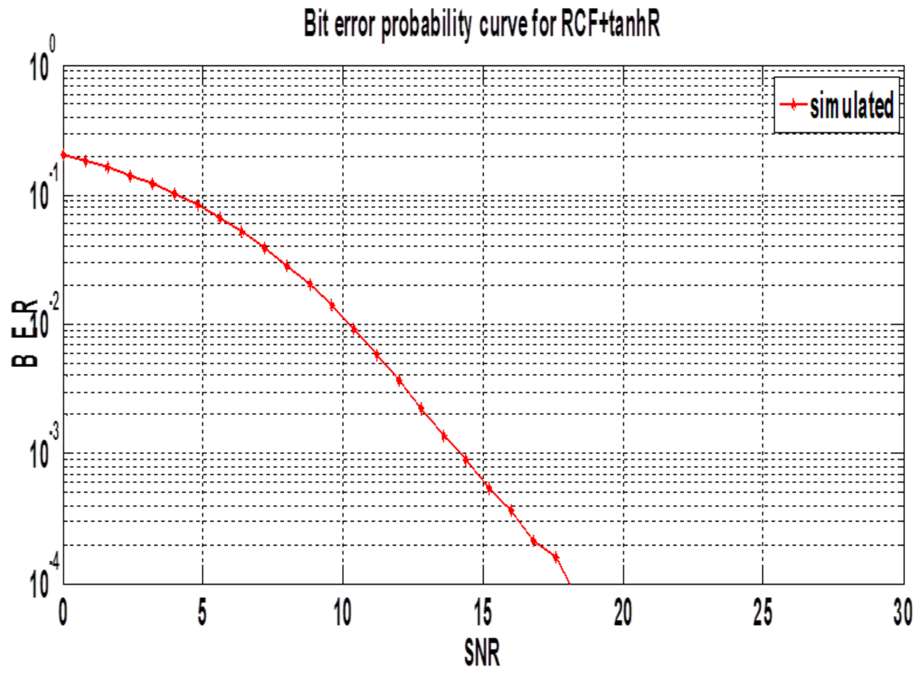

Figure 6.7 SNR V/S BER CURVE FOR RCF + TANHR COMPANDING

K =40, Y=.5, CR=4

6.2.1.1.2 K =20, y=.5, CR=2

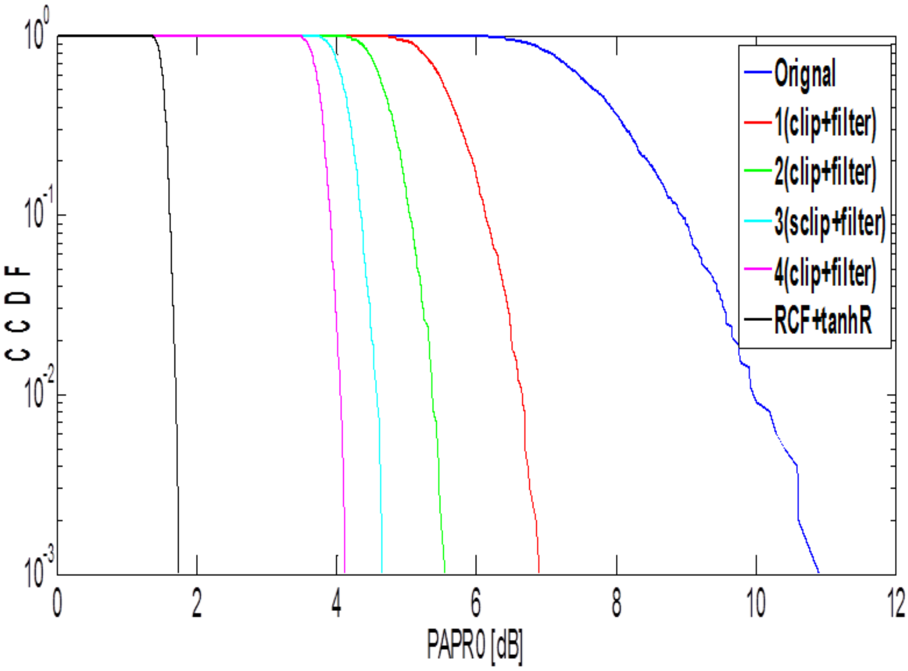

Figure 6.8 PAPR V/S CCDF CURVE FOR K =20, Y=.5, CR=2

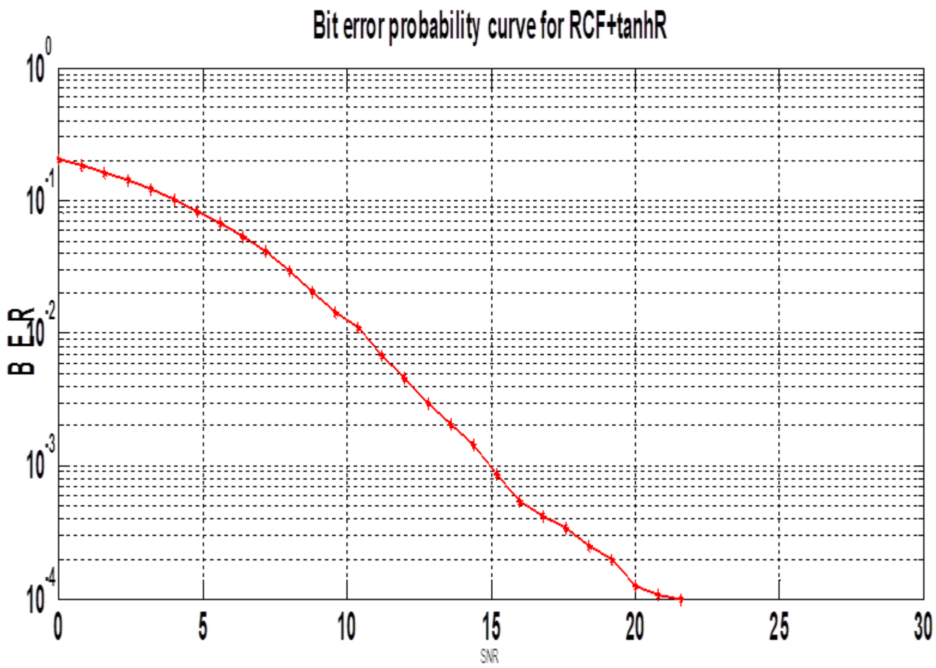

Figure 6.9 SNR V/S BER CURVE FOR RCF + TANHR COMPANDING K =20, Y=.5, CR=2

6.2.1.1.3 K =30, y=.5, CR=2

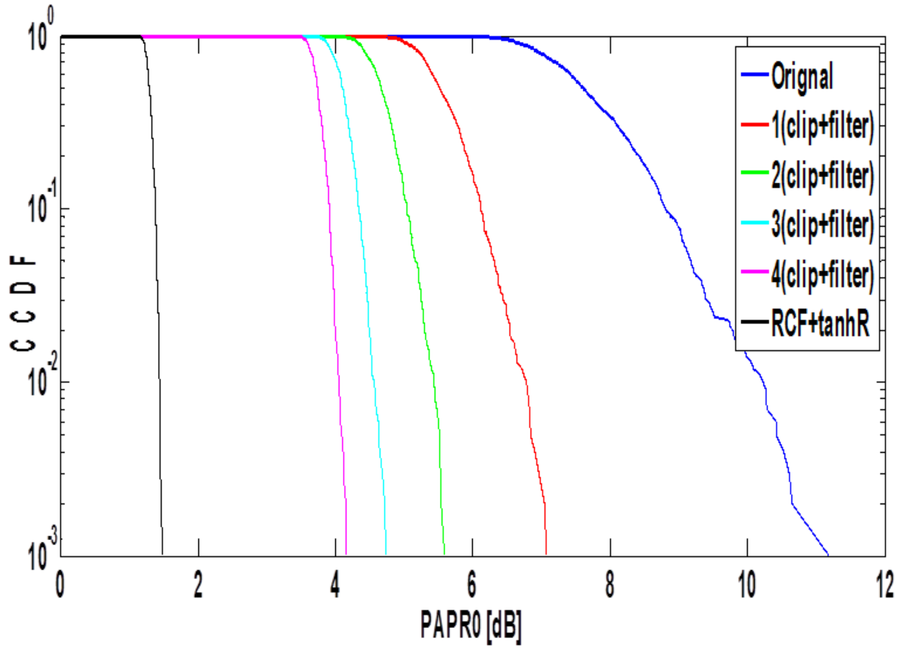

Figure 6.10 PAPR V/S CCDF CURVE K =30, Y=.5, CR=2

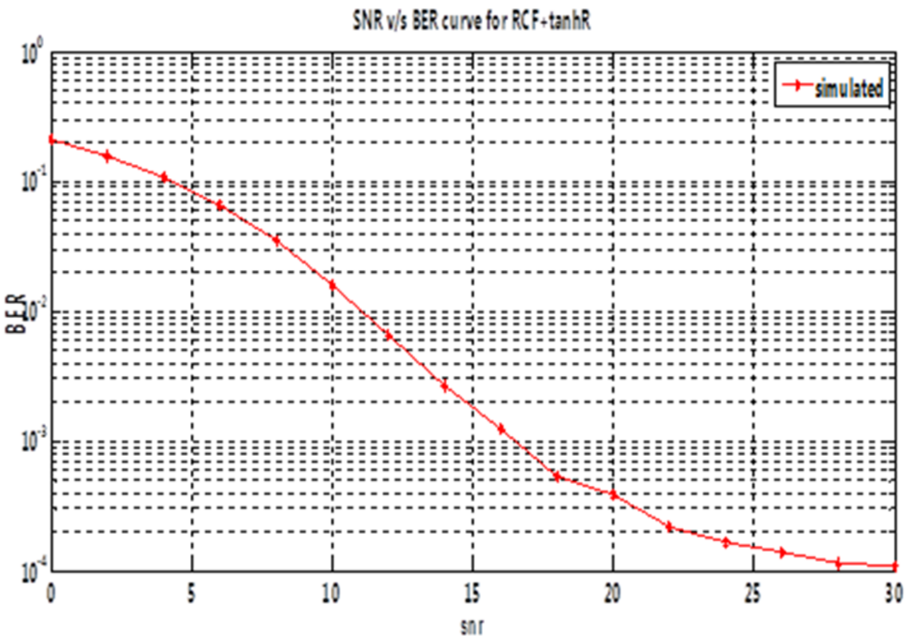

Figure 6.11 SNR V/S BER FOR RCF +TANHR COMPANDING

K =30, Y=.5, CR=2

6.2.1.1.4 K =40, y=.5, CR=2

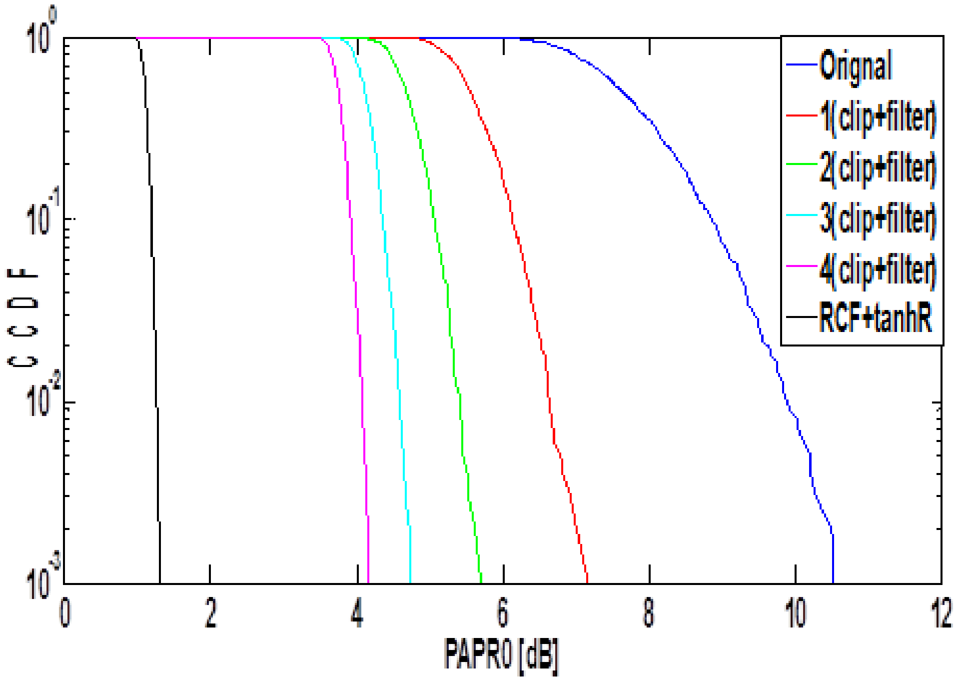

Figure 6.12 PAPR V/S CCDF CURVE K =40, Y=.5, CR=2

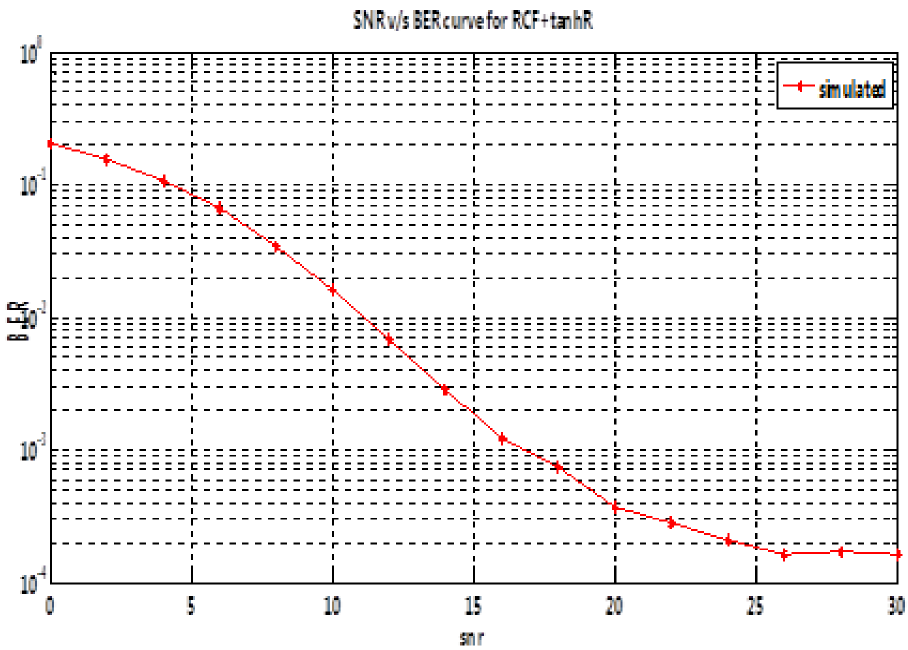

Figure 6.13 SNR V/S BER CURVE FOR RCF+ TANHR COMPANDING

K =40, Y=.5, CR=2

6.2.1.1.5 K=40, y=.2, CR=3

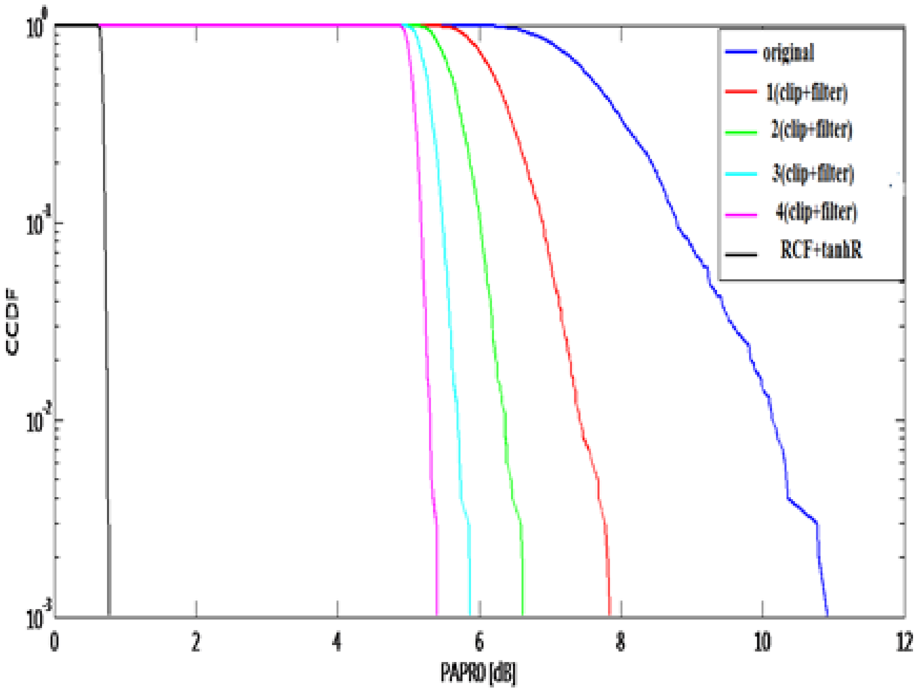

Figure 6.14 PAPR V/S CCDF CURVE K=40, Y=.2, CR=3

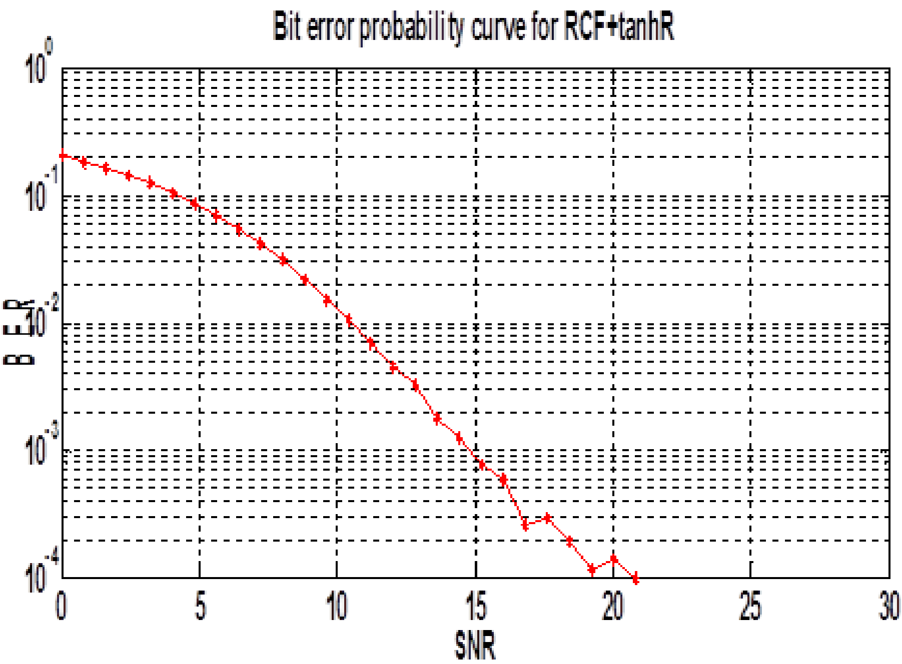

Figure 6.15 SNR V/S BER CURVE FOR RCF + TANHR COMPANDING

K=40, Y=.2, CR=3

6.2.1.1.6 K=40, Y=.6, CR=4

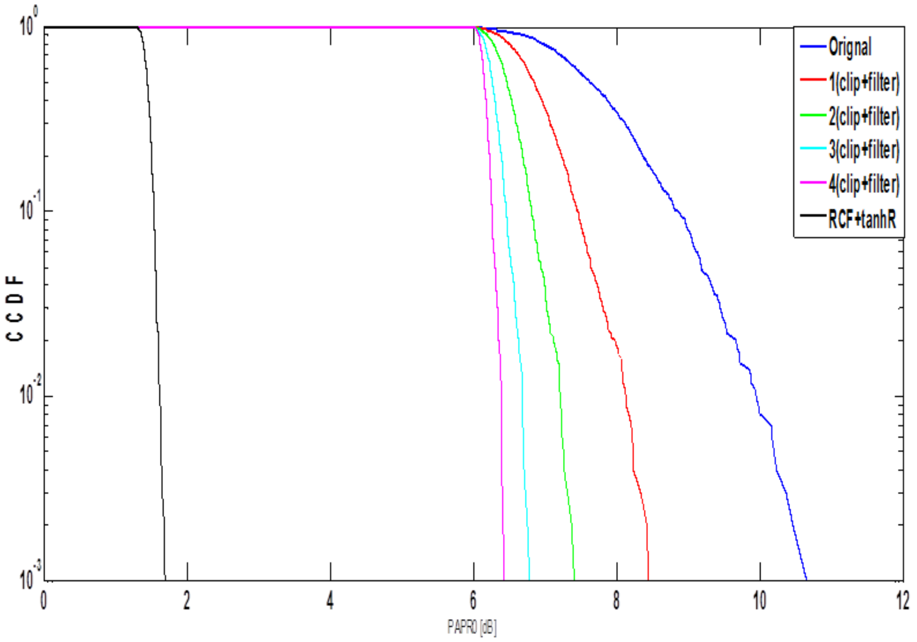

Figure 6.16 PAPR V/S CCDF CURVE K=40, Y=.6, CR=4

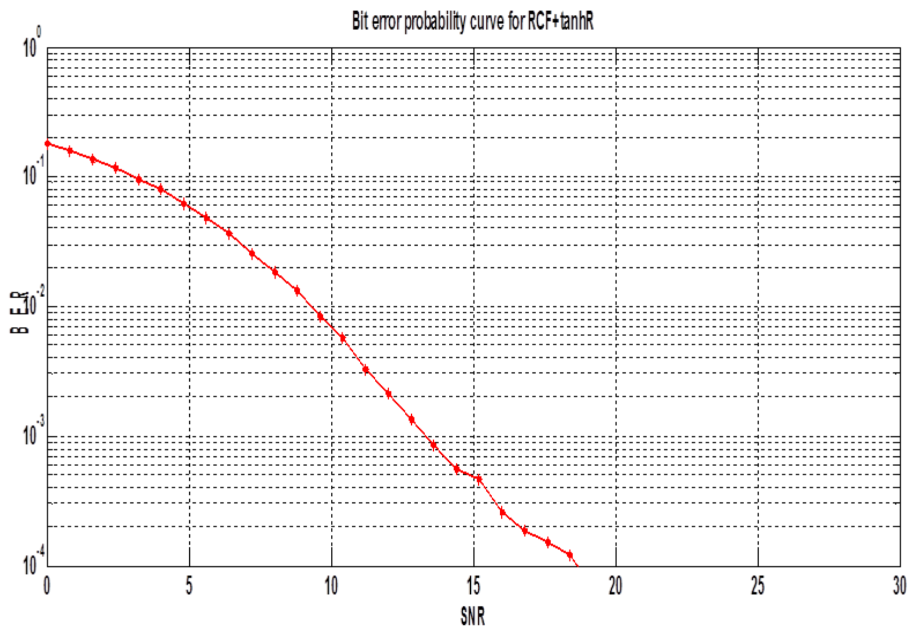

Figure 6.17 SNR V/S BER CURVE FOR RCF + TANHR COMPANDING

K=40, Y=.6, CR=4

Table 6-1 Simulation parameters for RCF + Companding (tanhR)

K	**Y**	**CR**	**PAPR(dB)at CCDF(10^{-3})**	**SNR(dB) at BER(10^{-4})**
40	.5	4	1.5	17.5
40	.5	3	1.4	19.75
40	.5	2	1.35	>>30
40	.5	1	1.33	Extremely high
40	.4	4	1.30	19
40	.4	3	1.30	21.25
40	.4	2	1.20	>>30
40	.4	1	1.10	Extremely high
40	.3	4	1.25	20.5
40	.3	3	1.15	21.75
40	.3	2	.90	>>30
40	.3	1	.85	Extremely high
40	.2	4	.80	23.5
40	.2	3	.80	24.75
40	.2	2	.65	>>30
40	.2	1	.65	Extremely high
40	.1	4	.45	28.5
40	.1	3	.45	29.75
40	.1	2	.40	>>30
40	.1	1	.30	Extremely high
30	.5	4	1.90	17
30	.5	3	1.70	17.25
30	.5	2	1.50	26.50
30	.5	1	1.35	very high
30	.4	4	1.60	17.15
30	.4	3	1.50	18.75
30	.4	2	1.25	29.62
30	.4	1	1.00	very high
30	.3	4	1.25	19
30	.3	3	1.15	22.5
30	.3	2	1.00	>>30
30	.3	1	.80	very high
30	.2	4	.90	22.75
30	.2	3	.90	29
30	.2	2	.65	>>30
30	.2	1	.50	very high
30	.1	4	.50	28.15
30	.1	3	.45	>30
30	.1	2	.35	very high
30	.1	1	.30	Extremely high
20	.5	4	1.90	16
20	.5	3	1.70	17

20	.5	2	1.40	22.75
20	.5	1	1.20	Very high
20	.4	4	1.90	16
20	.4	3	1.70	17
20	.4	2	1.40	22.75
20	.4	1	1.20	Very high
20	.3	4	1.40	18
20	.3	3	1.25	19.62
20	.3	2	1.05	27.50
20	.3	1	.90	Very high
20	.2	4	1.00	23
20	.2	3	.90	23.25
20	.2	2	.70	>>30
20	.2	1	.55	Very high
20	.1	4	.50	28.125
20	.1	3	.45	29
20	.1	2	.40	>>30
20	.1	1	.30	Very high
10	.5	4	2.90	12.75
10	.5	3	2.55	13.62
10	.5	2	2.10	17.50
10	.5	1	1.65	Very high
10	.4	4	2.40	14.5
10	.4	3	2.05	15.5
10	.4	2	1.65	20.25
10	.4	1	1.35	Very high
10	.3	4	1.70	16.875
10	.3	3	1.60	18.0
10	.3	2	1.25	25
10	.3	1	.95	Very high
10	.2	4	1.15	20.75
10	.2	3	.95	22.125
10	.2	2	.75	28
10	.2	1	.50	Very high
10	.1	4	.50	27.75
10	.1	3	.50	28.625
10	.1	2	.40	Very high
10	.1	1	.30	Extremely high

Table 2 Simulation parameters for RCF + Companding (tanhR)

FFT Size=no. of frames	128
Frequency Spacing	$15KH_Z$
Bandwidth	$1.25MH_Z$
Cyclic prefix	32
No. of symbols	1000

6.3 MATLAB Coding Results for Hybrid Repetitive Filtering and Clipping + Companding (cos) Technique for PAPR Reduction in OFDM system

We have taken the following specifications for obtaining the results using MATLAB@2013a for PAPR reduction in OFDM system.-

- M = 4 (QPSK Signal Constellation)
- FFT size is = Interpolation factor *Size of OFDM Symbol
- 128 FFT/IFFT blocks
- F spacing = 15KHz
- Max Doppler frequency Shift (assume 0)
- Size of OFDM Symbol = 128
- Interpolation factor = 2
- COS Companding is used with RFC technique
- Clipping Ratio-1, 2, 3, 4
- 1000 number of symbols
- Iteration number=4
- Companding parameter y varies from .1 to 1
- Cyclic prefix length = .25*Size of OFDM Symbol
- Channel used = Rayleigh fading channel
- QPSK modulation is used for mapping of the input bits
- SNR = 0 to 30dB
- Sampling frequency = f spacing*FFT size
- Sampling period = 1/ sampling frequency
- COS companding is used

6.3.1.1.1 Y=0.9, CR=2

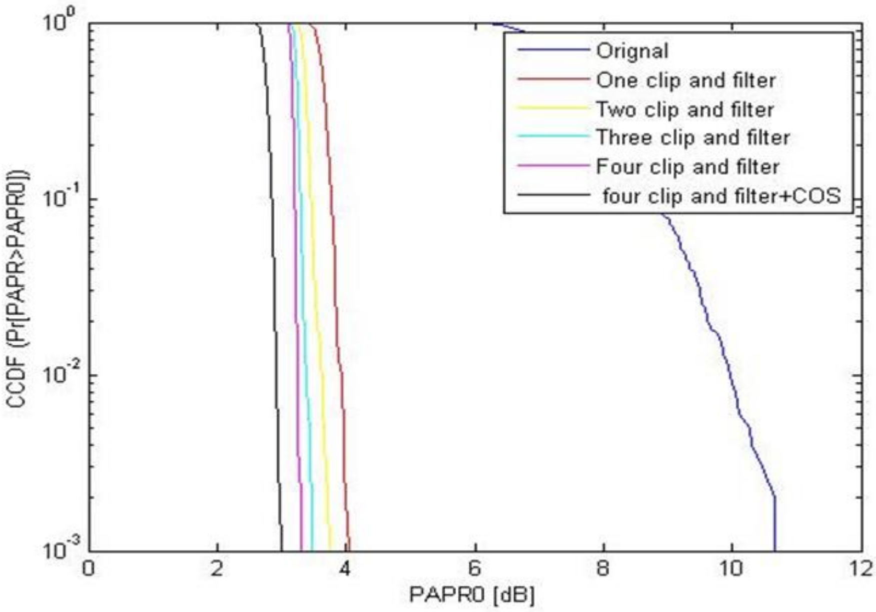

Figure 6.18 PAPR V/S. CCDF curve Y=0.9, CR=2

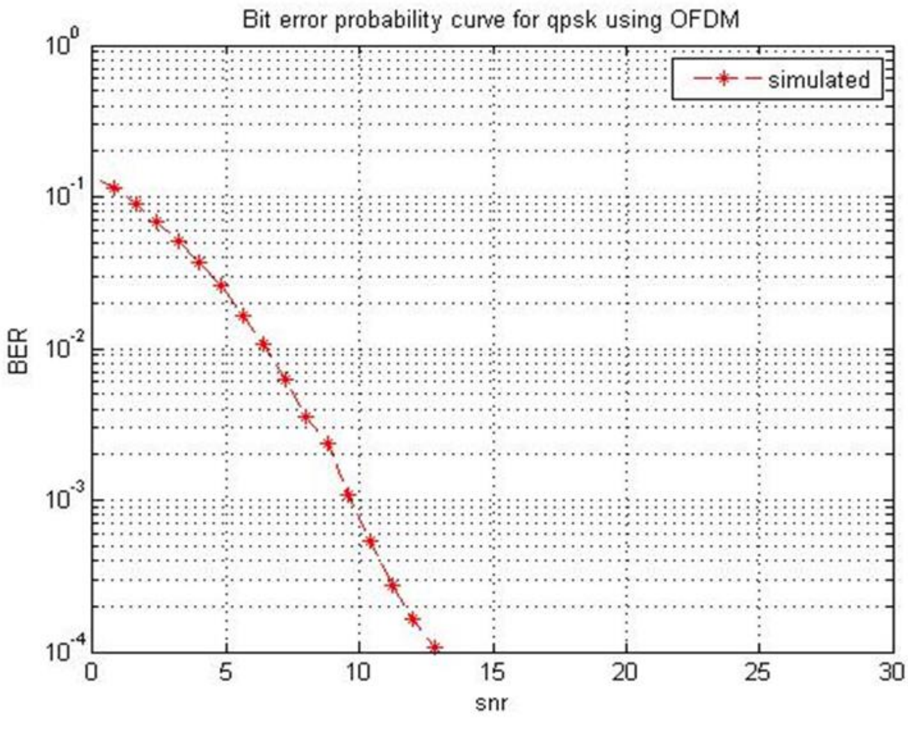

Figure 6.19 SNR V/S BER CURVE Y=0.9, CR=2

6.3.1.1.2 Y=.9, CR=3

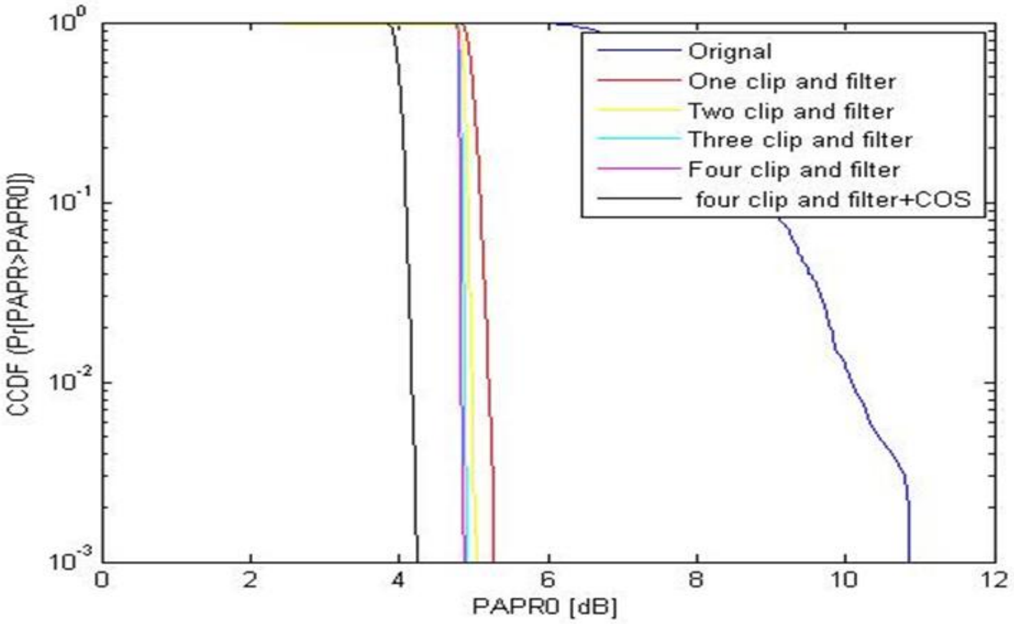

Figure 6.20 PAPR V/S CCDF CURVE Y=.9, CR=3

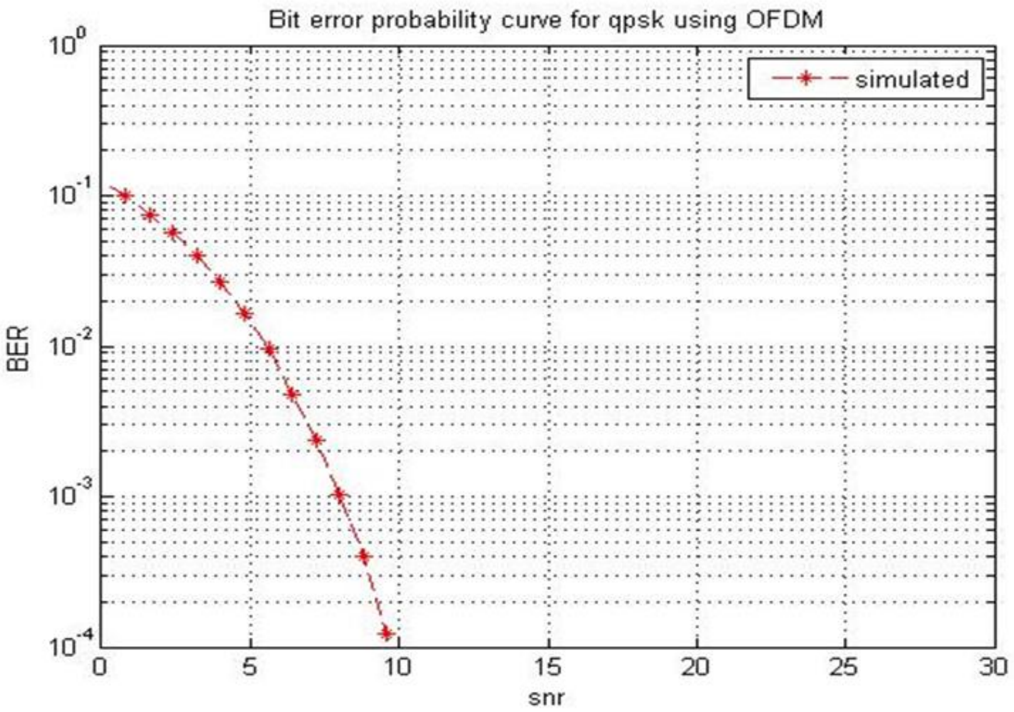

Figure 6.21 SNR V/S BER CURVE Y=.9, CR=3

6.3.1.1.3 Y=.8, CR=2

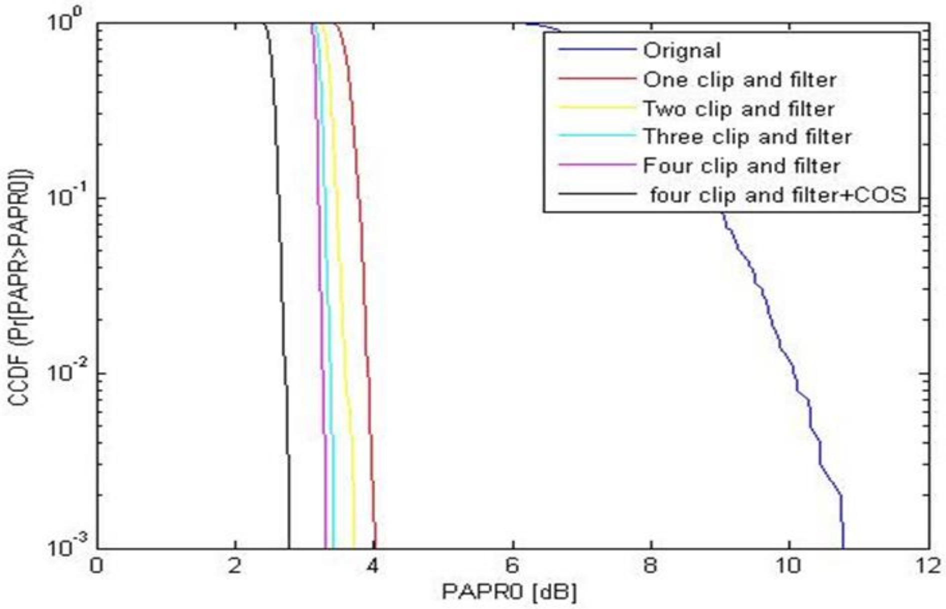

Figure 6.22 PAPR V/S CCDF CURVE Y=.8, CR=2

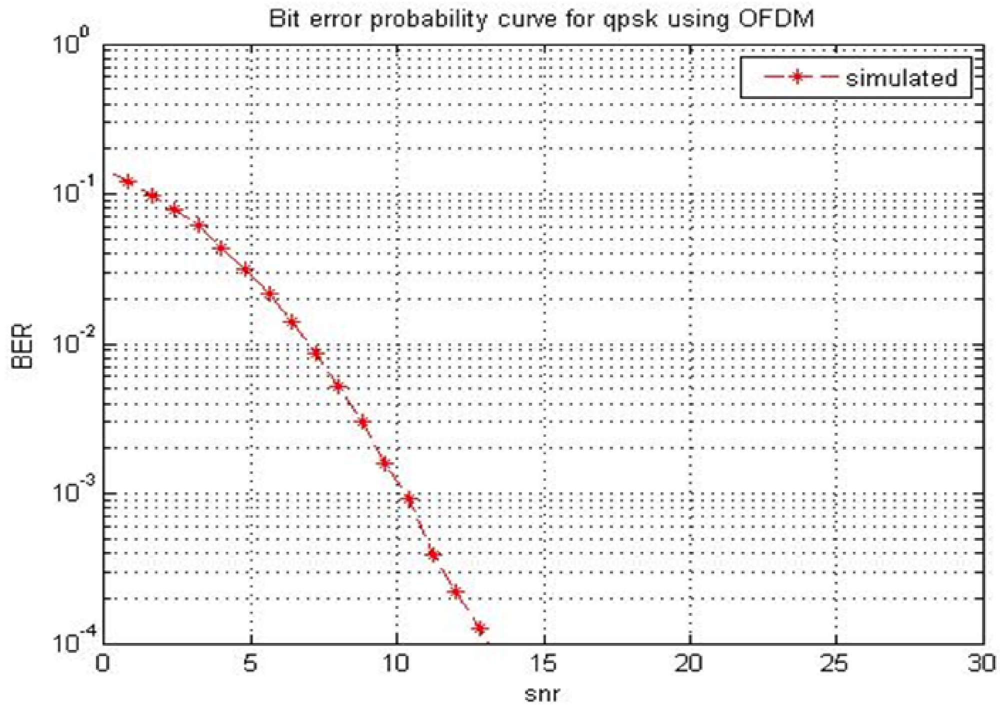

Figure 6.23 SNR V/S BER CURVE Y=.8, CR=2

6.3.1.1.4 Y=.6, CR=2

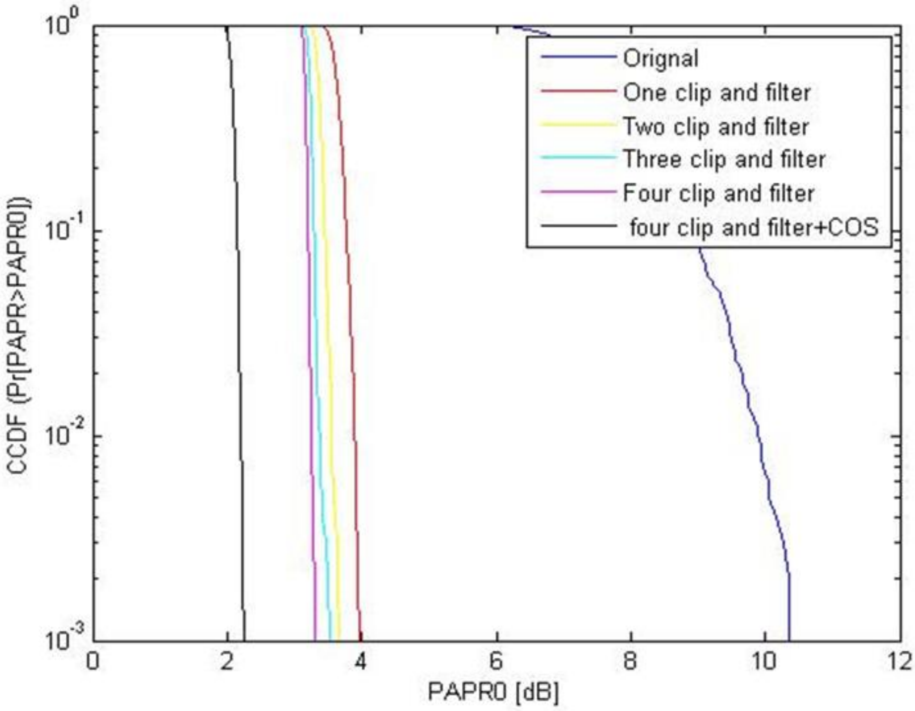

Figure 6.24 PAPR V/S CCDF CURVE Y=.6, CR=2

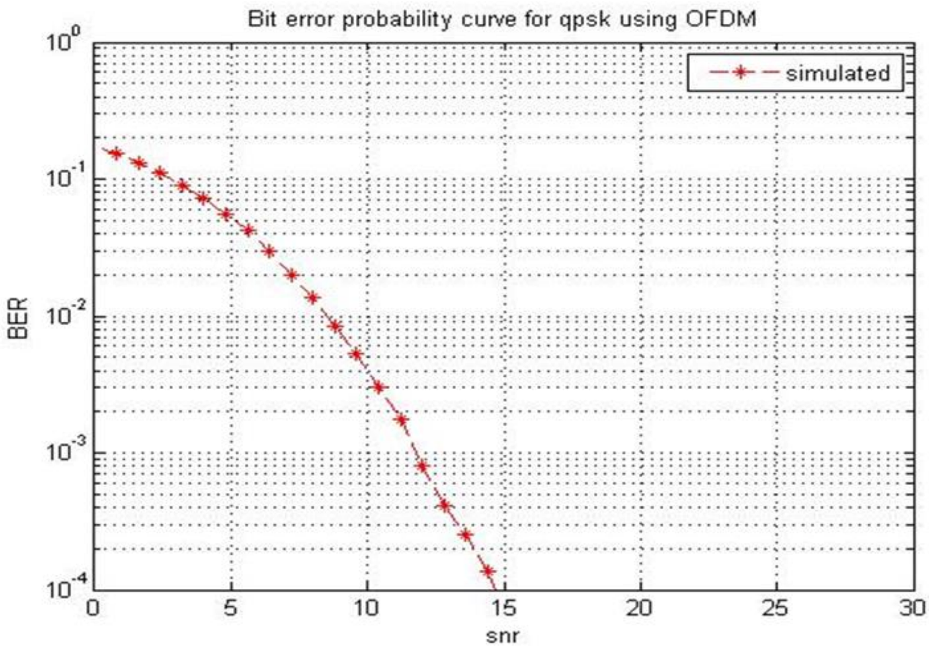

Figure 6.25 SNR V/S BER CURVE Y=.6, CR=2

6.3.1.1.5 Y= .6, CR= 3

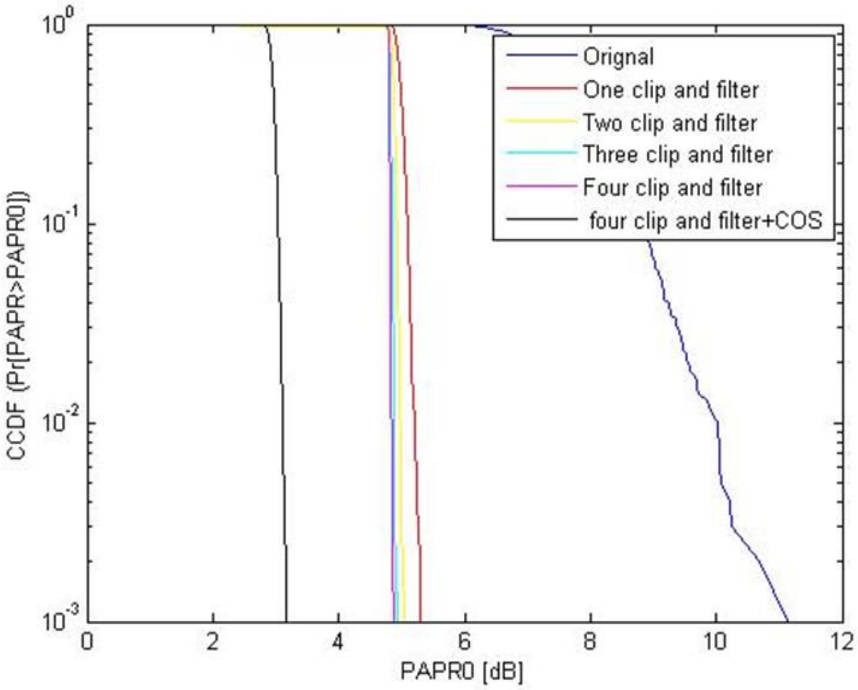

Figure 6.26 PAPR V/S CCDF CURVE Y= .6, CR= 3

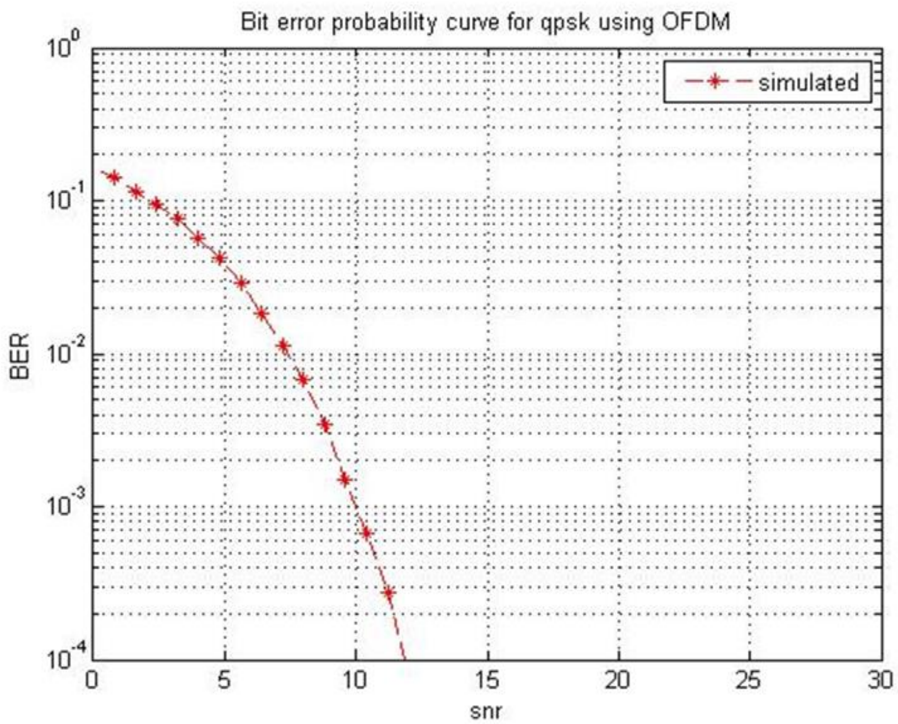

Figure 6.27SNR V/S BER CURVE Y=.6, CR=3

6.3.1.1.6 Y=.5, CR=2

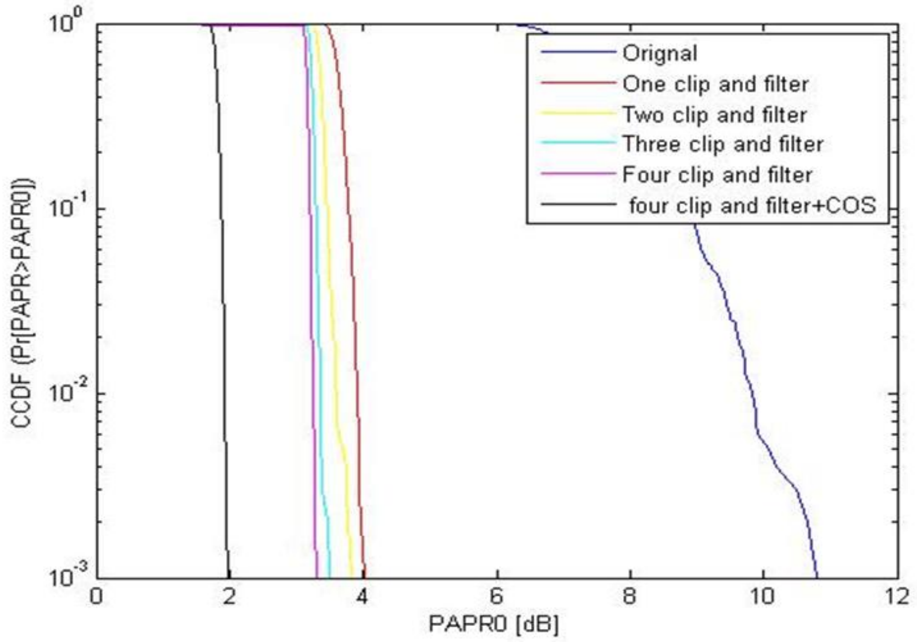

Figure 6.28 PAPR V/S CCDF CURVE Y=.5, CR=2

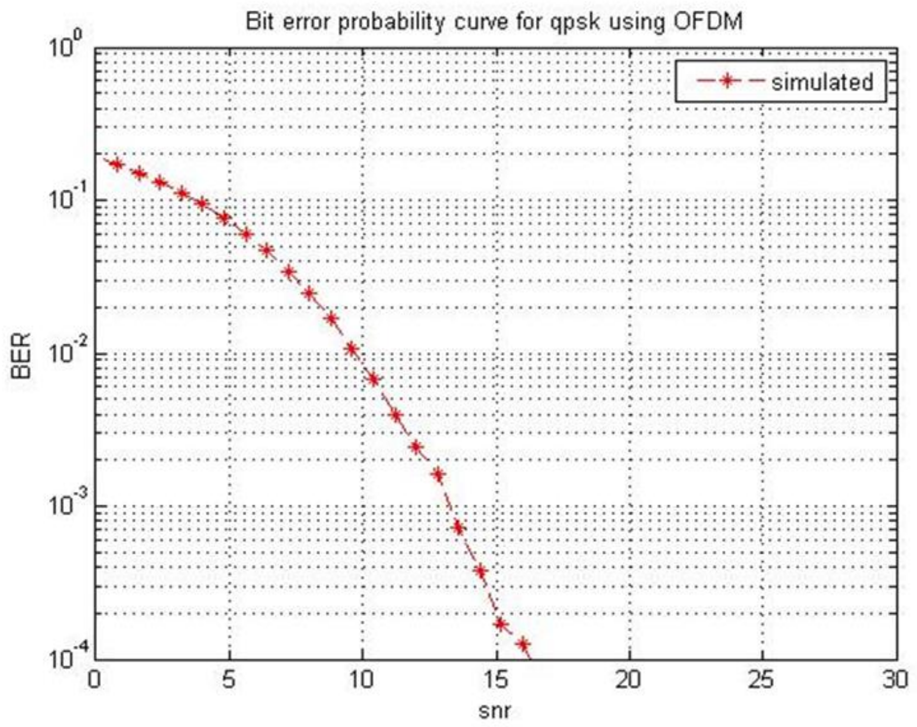

Figure 6.29 SNR V/S BER CURVE Y=.5, CR=2

6.3.1.1.7 Y=.3, CR=3

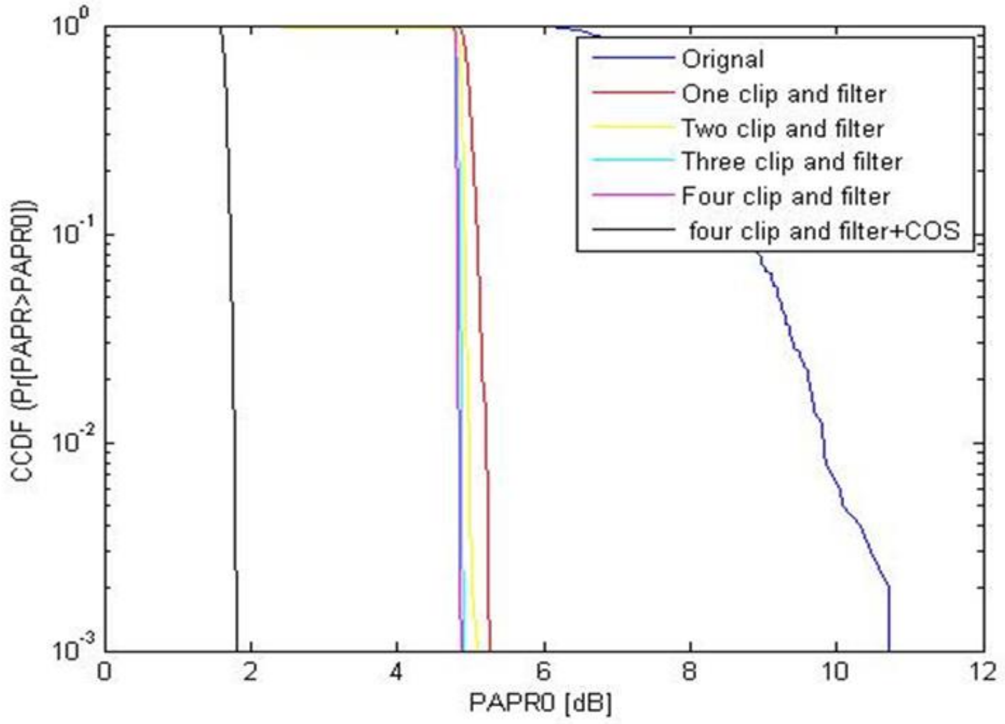

Figure 6.30 APR V/S CCDF CURVE Y=.3, CR=3

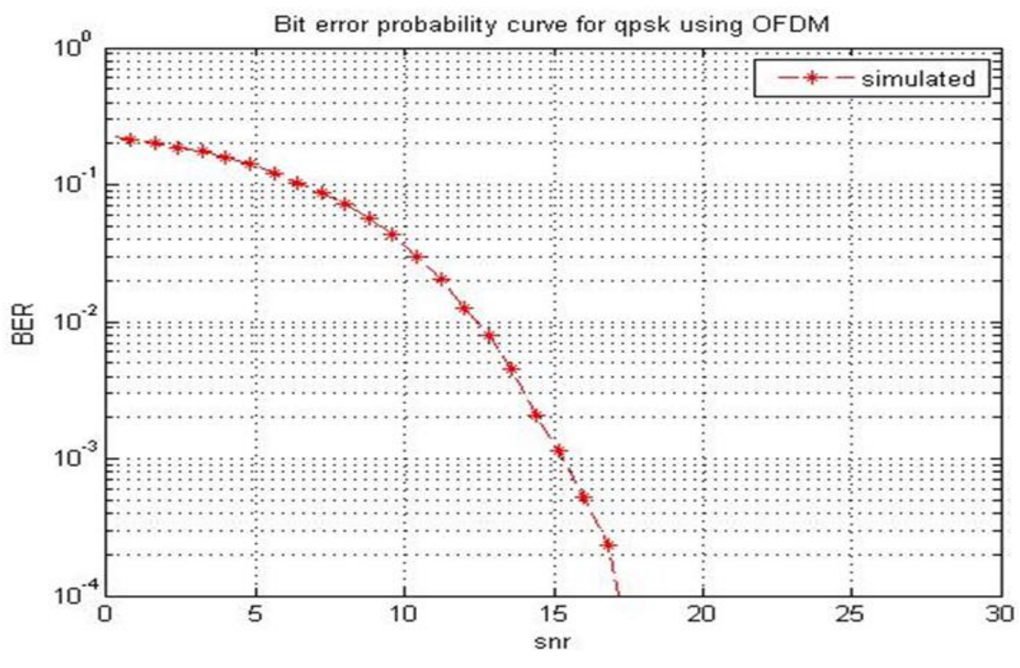

Figure 6.31 SNR V/S BER CURVE Y=.3, CR=3

6.3.1.1.8 Y =.2, CR=3

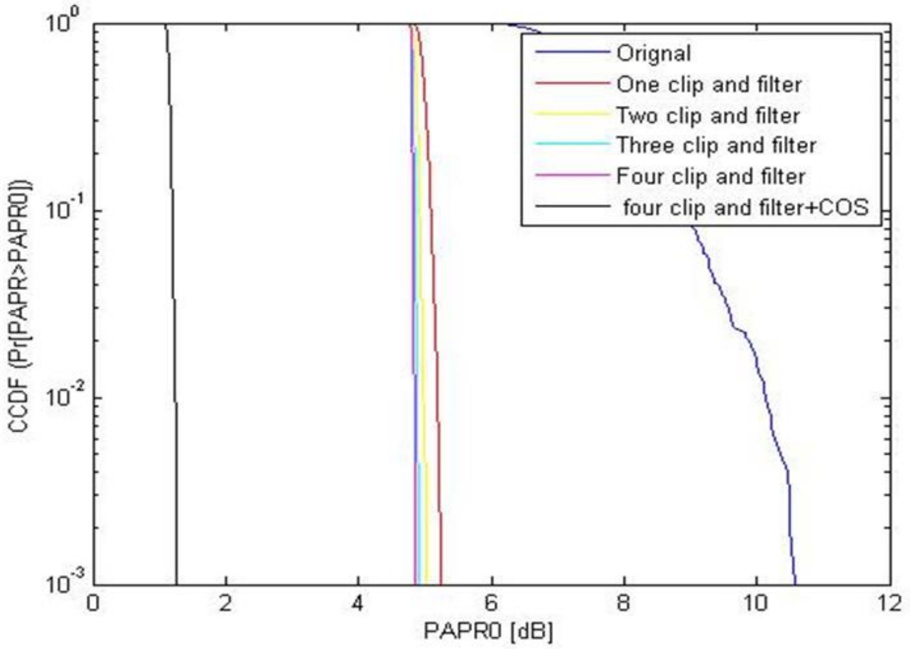

Figure 6.32 APR V/S CCDF CURVE Y =.2, CR=3

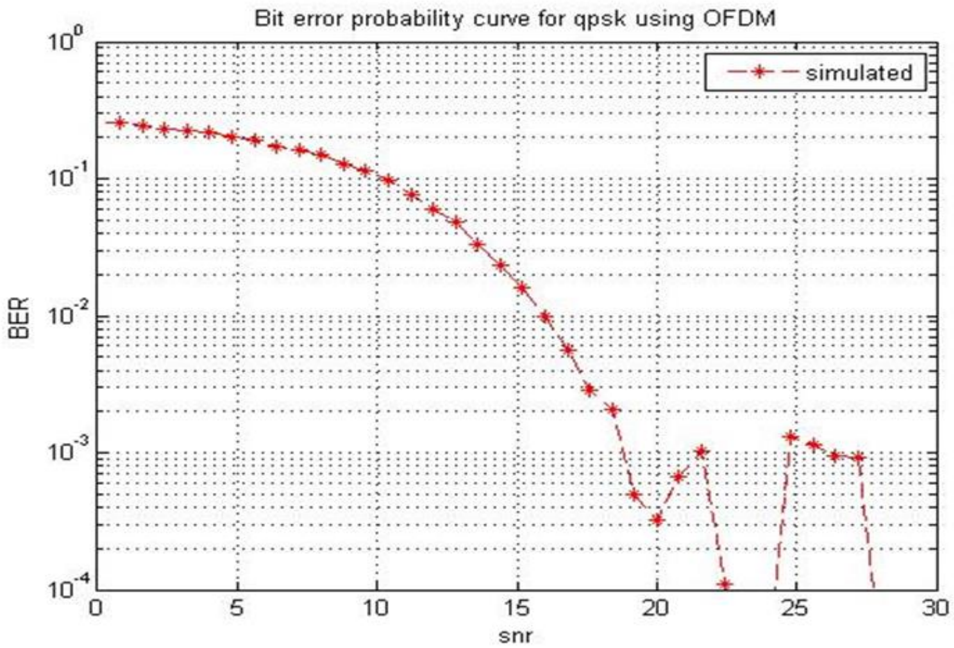

Figure 6.33 SNR V/S BER CURVE Y =.2, CR=3

6.3.1.1.9 Y=.3, CR=4

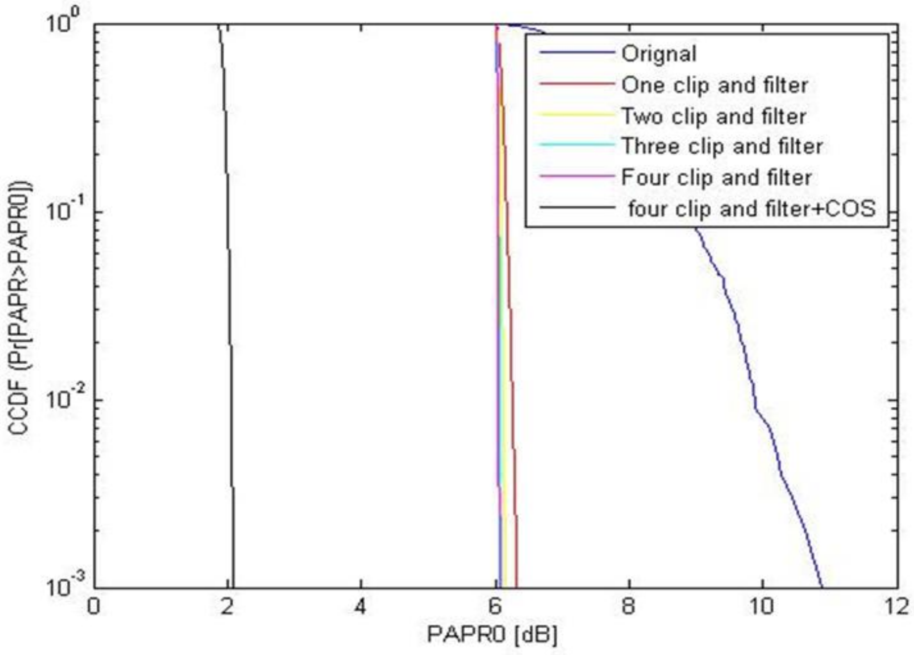

Figure 6.34 PAPR V/S CCDF CURVE Y=.3, CR=4

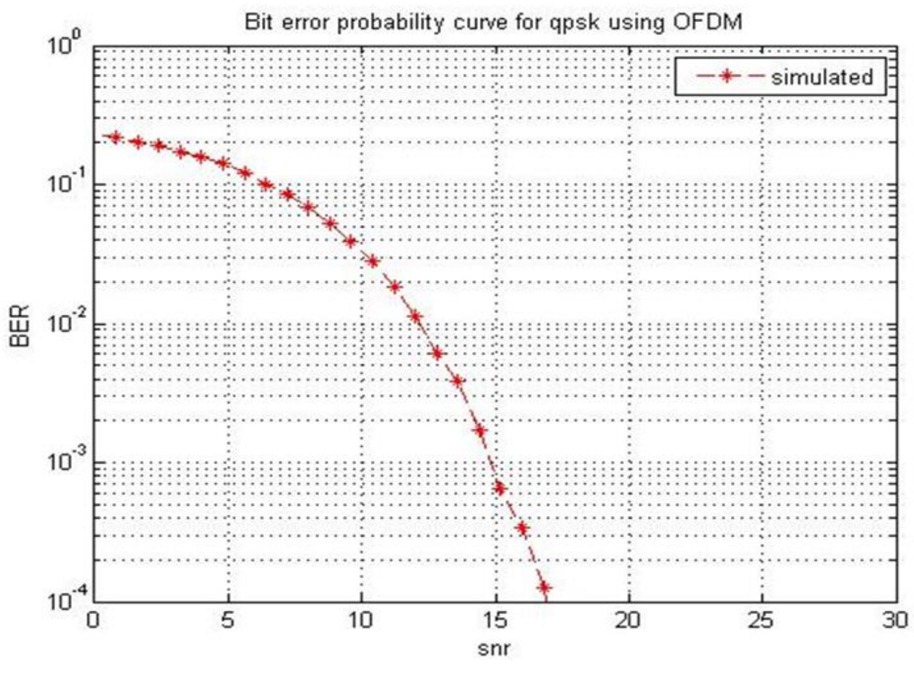

Figure 6.35 SNR V/S BER CURVE FOR Y=.3, CR=4

Table 6-3 RFC + COS COMPANDING Results

Y	**CR**	**PAPR(dB)at CCDF(10^{-3})**	**SNR(dB)at BER(10^{-4})**
1	4	5.40	9.125
1	3	4.50	9.50
1	2	3.20	12.75
0.9	4	5	9.375
0.9	3	4.20	9.75
0.9	2	3.00	12.25
0.8	4	4.65	9.75
0.8	3	3.85	10
0.8	2	2.75	13.125
0.7	4	4.2	10.75
0.7	3	3.45	10.80
0.7	2	2.50	13.50
0.6	4	3.70	11.50
0.6	3	3.15	11.875
0.6	2	2.30	14.75
0.5	4	3.20	12.75
0.5	3	2.80	13.50
0.5	2	2.0	16.50
0.4	4	2.70	14.675
0.4	3	2.25	15
0.4	2	1.65	18.625
0.3	4	2.05	16.875
0.3	2	1.30	25
0.2	4	1.40	25.75
0.2	3	1.25	27.75

Chapter 7 CONCLUSION AND FUTURE WORK

7.1 Conclusion

OFDM-QAM modulation performs well over QAM modulation technique with high value of SNR using Rayleigh fading channel. As we are using higher order QAM with OFDM the number of bits per symbol is increased, so the BER is increased. But in mobile communication we need more data rate which is only possible with higher order modulation. OFDM performs well over conventional modulation techniques because of insertion of cyclic prefix. As the number of cyclic prefix increases the BER gets reduced (the effect of Inter-symbol interference gets reduced) results data rate going to be reduced. Instead of cyclic prefix if another alternative would have been found than it might have been resulted in high spectral efficiency. As clear from the previous chapter results OFDM with higher order QAM performs well over QAM at high value of SNR (SNR value greater than 15dB), that's why we are using OFDM with higher order of QAM modulation technique with high value of SNR in wireless communication system.

The performance of RCF+ Companding technique is evaluated for different values of k, y, and CR in terms of CCDF v/s PAPR and SNR v/s BER for improving the OFDM performance as shown in previous chapter.

- To obtain BER 10^{-4} at SNR value less than or equal to 25dB

From that Table 6-1it is clear that better improvement in PAPR at CCDF of the PAPR (10^{-3}) is .80 dB, when (k=40, y=0.2, and CR=3).

- To obtain CCDF of PAPR 10^{-3} at PAPR less than or equal to 1.5dB

From the Table 6-1 it is clear that better improvement in BER (10^{-4}) when the SNR is 17.5 dB, consider the parameters (k=40y=.5, CR=4).

Results show that the BER performance is improved with the addition of tanhR companding with repetitive clipping and filtering technique, it also shows that PAPR also gets reduced due to that technique at a cost of slightly increases complexity.

The performance of RFC+COS Companding technique is evaluated for different value of Y and CR in terms of CCDF v/s PAPR and SNR v/s BER for improving the OFDM Performance.

The following results is given from the previous chapter MATLAB coding result

- To obtain BER 10^{-4} at SNR value less than or equal to 15dB

From the **Table 6-3** it is clear that the better improvement in PAPR at CCDF of PAPR (10^{-3}) the PAPR is 3dB, when (y=.6, CR=2).

- To obtain BER 10^{-4} at SNR value less than or equal to 20dB

From the results it is clear that better improvement in PAPR at CCDF of PAPR (10^{-3}) the PAPR is 1.75dB when (y=.3, CR=3).

- To obtain BER 10^{-4} at SNR value less than or equal to 30dB

From the results it is clear that better improvement in PAPR at CCDF of PAPR (10^{-3}) the PAPR is 1.25dB when (y=.2, CR=3).

Results shows that the BER performance is improved with the addition of COS companding with RFC technique. It also shows that PAPR also gets reduced due to that technique at a cost of slightly increased complexity.

7.2 Future work

- Achieve bandwidth extension using carrier Aggregation (CA) of OFDM signal.
- Study and analyze performance analysis of the carrier aggregated signal with regards to its BER and PAPR.
- Implement PAPR reduction algorithms for carrier aggregation.
- Find a new type of companding to reduce the PAPR with maintaining the BER performance.
- The proposed companding PAPR reduction methods can be combined with different PAPR reduction techniques such as PTS (partial transmit sequence), SLM (selective mapping technique), and etc.

- The proposed RFC can be combined with different PAPR reduction techniques such as coding, interleaving, TI (tone injection) and DSI (dummy signal insertion) etc.
- The proposed PAPR reduction methods can be used with MIMO (multi input multi output) OFDM system.
- Study the impact of these proposed techniques on bandwidth, noise, distortion and the ratio of power saving.
- The proposed PAPR reduction methods can be used with other multicarrier system

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