PERFORMANCE ANALYSIS OF PAPR REDUCTION TECHNIQUES IN OFDM SYSTEM

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CERTIFICATE

This is to certify that the Dissertation-I entitled “**Performance Analysis of PAPR Reduction Techniques in OFDM System**” which is being submitted by ***Shiwani*** in partial fulfillment of the requirement for the award of degree Masters of Technology in Electronics and Communication Engineering to Lovely Professional University, Jalandhar, Punjab is a record of the candidates own work carried out by her under my supervision. The matter embodied in this report is original and has not been submitted for the award of any other degree.

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DECLARATION

I, Shiwani, student of M.Tech under the department of School of Electronics and Electrical Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

This Dissertation-II does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is mostly considered because of its highly efficient bandwidth capability, its high data rate and ability to prevent multipath fading. Communication is one of the imperative parts of life. With the progression in age and its developing requests, there has been fast development in the field of communications. Signals, which were at first sent in the analog form, are being sent increasingly in the digital domain now a day. For better transmission, even single-carrier waves are being supplanted by multi-carriers. Multi-carrier frameworks like CDMA and OFDM are presently a-days being executed usually. In the OFDM framework, orthogonally set sub-carriers are utilized to convey the information from the transmitter end to the receiver end. Presence of guard band in this framework manages the issue of ISI and noise is minimized by bigger number of sub-carriers. In any case, the vast Peak-to-Average Power Ratio of these signal have some undesirable impacts on the framework.

In this Dissertation II we have concentrated on taking in the rudiments of an OFDM System and have attempted different techniques to diminish the PAPR in the framework so that this framework can be utilized more normally and successfully. Here Clipping, Selective mapping and Companding reduction techniques with different transform like DCT, DST, DWT etc. to get the good result for PAPR and BER which are the major issues in a system which reduces the efficiency of a system. Sometimes recution technique alone do not produce required outcome which it can do with the combination of transform. In case of Clipping PAPR is good for OFDM signal but BER is very high but when we are using this technique with transforms BER decreases at a very appropriate level. Also by making the use of both blocks i.e. Transforms and IFFT block which is called Precoding technique we get high PAPR with Precoding but with reduced BER in case of Clipping technique. Same analysis is done for SLM and Companding. With hybrid combination of SLM with transform and Precoding PAPR and BER both factors are reduced. So the problem which is associative in case of clipping i.e. tradeoff between PAPR and BER is solved in SLM technique. SLM used side band information which increase the complexity is decrease by using Companding technique with transform s and precoding , we get the lower values of PAPR and BER .

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ADC	Analog to Digital Converter
BPSK	Binary Phase Shift Key
BER	Bit Error Rate
CC	Convolution Codes
CP	Cyclic Prefix
DCTM	Discrete Cosine Transform Matrix
DAC	Digital to Analog Converter
FFT	Fast Fourier Transform
FDD	Frequency Domain Duplexing
FEC	Forward Error Control
IEEE	Institute of Electrical and Electronic
IP	Internet Protocol
ISI	Inter Symbol Interference
IFFT	Inverse Fourier Transform
IM/DD	Intensity Modulation/Direct Detection
MCM	Multicarrier Modulation
OFDM	Orthogonal Frequency Division Multiplexing
PAPR	Peak to Average Power Ratio
PTS	Partial Transmit Sequence
QPSK	Quadrature Phase Shift Key
QAM	Quadrature Amplitude Modulation
SLM	Selective Mapping
TDD	Time Domain Duplexing

CHAPTER 1 INTRODUCTION

High information rate is attractive in numerous current remote media applications [1]. Conventional single transporter balance systems can accomplish just constrained information rates because of the confinements forced by the multipath impact of remote channel and the beneficiary multifaceted nature. In single carriers system, as the information rate in correspondence framework expands, the image term gets diminished. In this way, the correspondence frameworks utilizing single bearer regulation experience the ill effects of Inter symbol interference image impedance (ISI) brought about by dispersive-channel drive reaction, and subsequently require an unpredictable balance plot. Orthogonal Frequency Division Multiplexing (OFDM) is a potential contender to satisfy the prerequisites of present and cutting edge remote correspondence frameworks.

1.1 Background

By Chang [3], in 1996, initially presented the idea of multicarrier correspondence. Along with this, he recommended a multicarrier plot using the parallel transmitted information by methods for 10 recurrence division multiplexing (FDM) by covering all subcarriers. It is also said that it is a productive plan for data transfer capacity use and to alleviate the impact of multipath engendering. Also, it likewise disposed of the prerequisite of fast leveling strategy. KINEPLEX, ANDEFT and KATHRYN and so forth belongs to OFDM derived frameworks used by US military frameworks which is meant for high frequency applications. Framework of KINEPLEX was produced by Collins Radio Company for transmitting the information at high frequency over multipath blurring medium. In this framework, 20 tones are adjusted by DQPSK without shifting, which brought about covering channels.

Numerous models have been proposed for remote neighborhood (WLANs) that works on ISM band that depend on spread-range innovation. First OFDM which is based on WLAN standard, in 1997, was discharged and belongs to IEEE 802.11 standard. IEEE 802.11 can bolster an information rate up to 2Mbps. In 1999, confirmation to OFDM based standard 802.11a was affirmed by IEEE, which supports rate of information up to 54 Mbps [2]. Amid all these and moving further, ETSI has likewise institutionalized Hiper LAN/2 standard that has embraced OFDM regarding its PHY principles [1]. 2001 was the year in which FCC accompanied few current guidelines for balances plot working for the value of 2.4 Ghz, that permits IEEE to stretch out 802.11b to 802.11g standard. Presently today, it is utilized similarly as a part of WiMAX (IEEE 802.16), and versatile remote area to get (MBWA) IEEE 802.10. Additionally, it is used by 4G remote correspondence frameworks, for example, IMT-A. Also, it is taken similar contents for 3GPP long term evolution under organization.

1.2 OFDM and Multicarrier Modulation

OFDM is an uncommon type of multicarrier balance conspire, which separates the full frequency selective channel fading components to numerous narrowband orthogonal level sub channels for flat fading, which includes transmission of high-piece rate information stream in parallel using various information subcarriers rate which gets lower consequently and significantly decreases inter symbol interference because of bigger image length [4]. As probably aware of OFDM framework is a multicarrier balance framework in which through serial-to-parallel port, input information stream changes over into N parallel information stream. Because of the closeness of subcarriers they can sees level blurred channel. The procedure of regulation and demodulation in OFDM is finished by quick DSP applications (FFT/IFFT) [2]. After the era of parallel image, balance is done on each stream and they conveyed at remarkable focal frequencies and they should be orthogonal to each other. This undertaking which is most capable elements of OFDM i.e. orthogonality is finished by utilizing IFFT. To expel impedance between the progressive OFDM images watch groups are embedded.

Frequency division multiplexing (FDM) develops an idea about using bearer regulation alone through utilizing numerous sub-channels inside provided bands of frequency for the corresponding channel. Aggregate channel transfer speed yet separated among various sub-channels [5-6]. One of the real focal points of FDM framework is that diverse sub-channels in the band can use distinctive tweak conspire and transmit different information. Yet, FDM needs shielded frequency bands between neighboring sub-channels to permit their partition with minimal effort channels at the collector. Monitor groups debase the data transfer capacity effectiveness of the FDM framework in contrast with single transporter framework without need of doing multiplexing.

Multicarrier modulation is a propelled type of Frequency Division Multiplexing (FDM), where various recurrence sub-groups called subcarriers are designated to a client [7-8]. An improved piece outline of MCM modulator is appeared in Fig. 1.1. Information stream of serial is gone to through a serial-to-parallel converter, which parts the information stream into various parallel sub-channels. On connecting sub-channel information to modulator, with the end goal which requires N sub-channels for N modulators whose bearer frequencies starts from f_o, f_1......f_k......f_{N-1} . These N adjusted subcarriers are then joined to give a multicarrier regulated signal.

Fig. 1.2 represents the essential multicarrier demodulator comprising of a bank of correlators, one for each of the sub-channel or subcarrier. Under perfect conditions, the neighborhood oscillators used to produce the subcarrier frequencies are thought to be synchronized with comparing nearby oscillators utilized at the transmitter; along these lines subcarriers don't make any impedance each other at the collector.

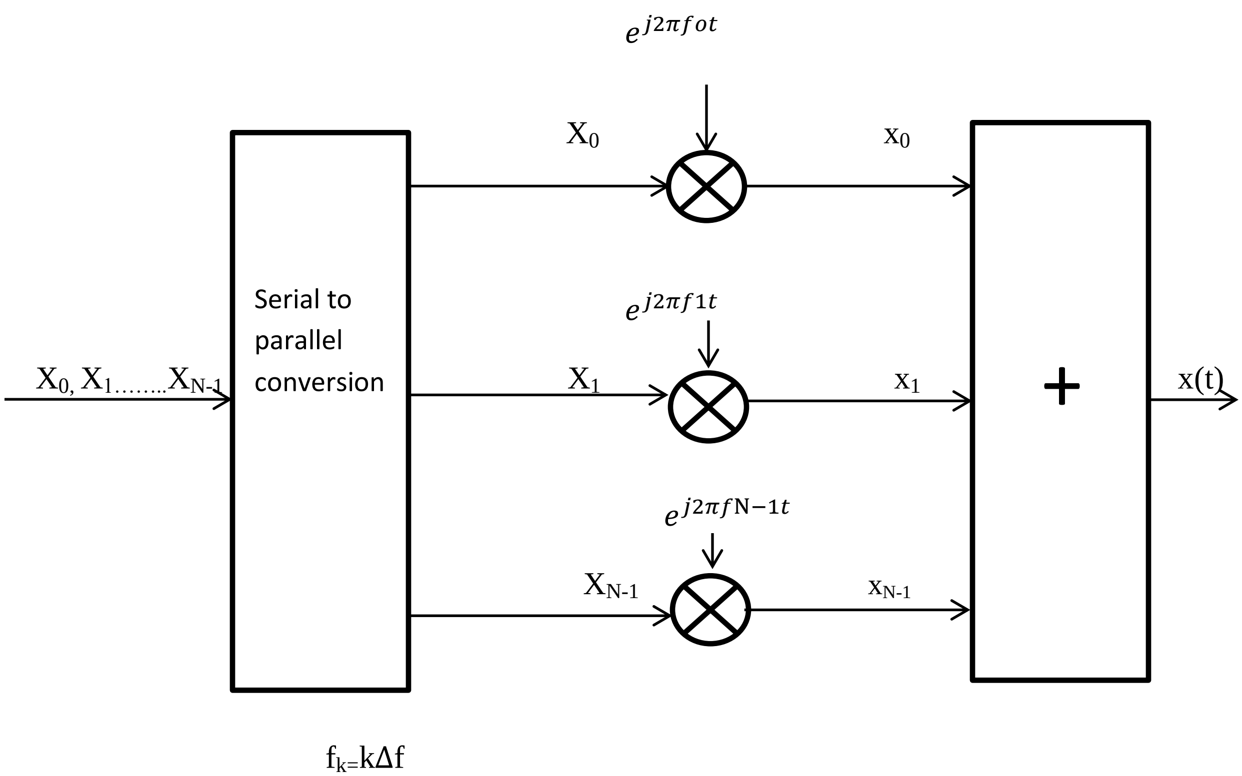


Figure 1.1: Fundamental Principle of Multicarrier Modulation

Of late, the need of mixed media remote information administrations has developed indulgently which get the correspondence the time of fourth era remote correspondence framework. In this time where number of clients are more with confined transfer speed , the need of present day computerized remote correspondence is embraced in light of the fact that it furnishes better otherworldly productivity with effective data transmission and furthermore powerful to multipath channel condition which is known as multi-carrier modulation framework [9]. This kind of correspondence framework gives simplicity of rapid information rate at shoddy cost for some clients with high dependability. The fundamental distinction between single carrier framework and multi carrier framework is that in single carrier framework, single carrier possesses whole correspondence data transmission yet in multicarrier accessible transfer speed is conveyed among many sub-carriers so that each subcarrier conveys the helpful measure of transmission capacity as indicated by its need as contrast with the entire data transmission as if there should arise an occurrence of single carrier framework

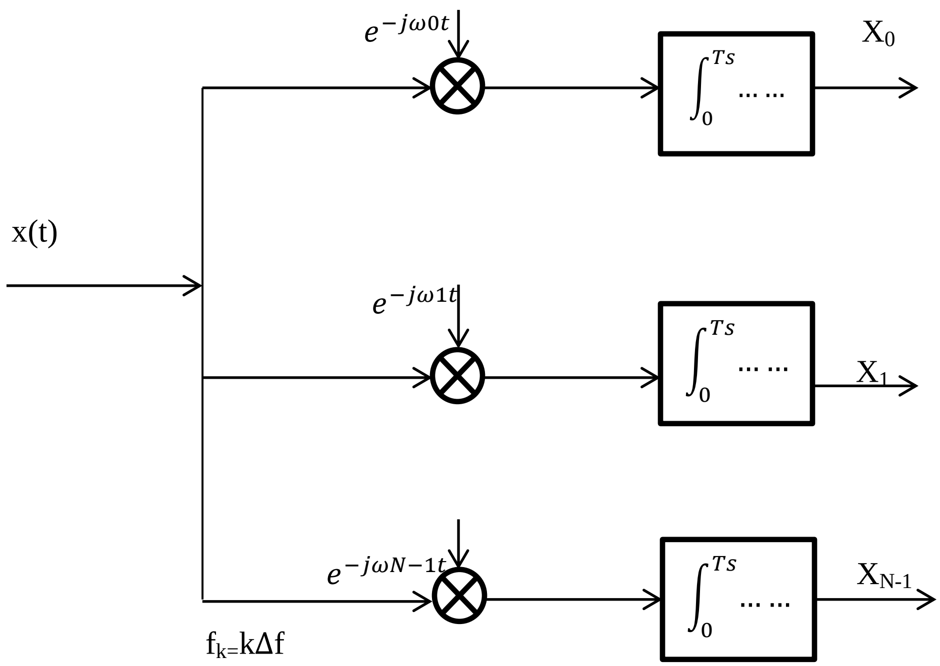


Figure 1.2: Fundamental principle of multicarrier demodulation

1.3 Advantages of OFDM

• Robustness against multipath proliferation.

• Make proficient utilization of the spectrum as the carrier is additionally subdivided into sub carrier by permitting overlap.

• By utilizing cyclic prefix ISI and IFI impacts are expelled [10].

• Using sufficient channel coding and interleaving procedure one can recoup back the lost images because of the frequency selectivity of the channel.

• Computation intricacy lessened utilizing FFT systems for the actualize the balance strategy.

• Eliminate co-channel interference.

• High spectral efficiency.

1.4 Disadvantages of OFDM system

• OFDM signals with their high peak to-average power ratio (PAPRs) require very straight intensifiers. Something else, execution corruption happens and upgraded out of band power is needed [11].

• More dedication is given to Doppler spread rather than modulation of single carrier frameworks by OFDM.

• Phase commotion created by the defects of the transmitter and beneficiary oscillators corrupts the framework execution. Accurate recurrence and time synchronization is required.

• Because of cyclic-prefix (CP) operation happens in OFDM frameworks causes' loss in spectral efficiency

1.5 Application of OFDM system

• It is utilized as a part of Digital Broadcast Services to handheld administrations.

• It is utilized as a part of LTE and LTE progressed as it gives higher execution, better spectral efficiency, diminished cost, productive administrations, and better nature of administration.

• It is utilized as a part of High-Definition TV (HDTV).

• It has extensive variety of use in remote LAN.

• Mobile Broadband Wireless get to advances additionally incorporate into the use of OFDM.

1.6 Major Problem in OFDM

Despite of many advantages and application areas, the major problems in OFDM system is PAPR, BER, and synchronization at the receiver which restrict the OFDM application areas to some extent.

- PAPR

One new problem that comes in OFDM systems is PAPR. The main reason of occurring of PAPR is that there is uniform power spectrum at the input symbol stream of IFFT but at the output side non uniform spectrum is there.

PAPR is defined as the peak signal power versus the average signal power. The PAPR of a signal is expressed by the following formula:

$$PAPR_{dB} = 10log\left(\frac{max(x(t)x^*(t))}{E\ (x(t)x^*(t))}\right) \qquad [1]$$

Where ()* represents the conjugate operator.

- Impact of high PAPR on a OFDM system

OFDM fundamental issue is high PAPR on the grounds that when OFDM signal transmits over an optical fiber channel, because of high PAPR contortions is there brought about by nonlinear gadgets, for example, analog to digital converter, transmission fiber and so forth [12-13].

Vast PAPR brings about band mutilation and in addition out of band radiation which the real issue is endured by transmitted OFDM signal. Likewise it builds the trouble for analog -to-digital converter and digital- to-analog converter. It additionally diminishes the efficiency of radio power enhancer. Primary reason of happening the PAPR is that In Multicarrier framework diverse subcarriers are out of phase with each other [14]. At each moment they show distinctive phase with each other. At the point when focuses accomplish most extreme esteem at the same time then this will come about that the yield envelope abruptly to shoot up and becomes the reason of causing peak in the output envelope. In multicarrier framework many modulated subcarriers are there so more peak value will be there when contrasted with the average of the entire framework. This proportion is called PAPR. Because of expansive PAPR control speaker ought to be worked with extensive power back-offs brings about costly transmitters and wasteful amplification will bring about.

- BER (Bit Error Rate)

BER is the proportion of mistaken bits to the aggregate number of bits that have been transmitted over a given time period [15]. It is communicated as 10 to the negative power. It is the major problem in OFDM system because as we reduced the PAPR, BER further goes on increasing at a drastic rate. Consequences of BER are interference, increase transmitted power, lower order modulation, reduce bandwidth.

1.7 PAPR Reduction Techniques

Numerous PAPR decrease strategies are proposed in the Literature [16]. The PAPR lessening plans are significantly isolated into two classifications

a) Distortion Based Techniques: The plans that belong to spectral re-development have a place with this class. Distortion based techniques are the most clear PAPR decrease techniques [17]. Besides, these techniques misshape the range, this range distortion or "spectral re-development" can be rectified to a specific degree by utilizing filtering operation.

b) Non-Distortion Techniques: These sorts of PAPR diminishment plans don't bend the state of the OFDM signal and in this way no spectral re-development happen.

1.8 Objectives

- **Efficient PAPR reduction**: By using different reduction techniques i.e. Clipping, Selective Mapping and Companding PAPR of a system is reduced to a very great extent. To remove the in-band distortion due to clipping SLM technique is used and to remove the complexity factor companding is used to get the good result of PAPR parameter of an OFDM system.

- **Reduction of Probability error**: BER is reduced by using the various combination of reduction technique with transforms as well as with precoding technique. BER of OFDM signal with DWT transform is getting lowered down but when reduction technique is implemented i.e. clipping it again increased.

- **Complexity Reduction:** Clipping technique having lower complexity among all the techniques but performance of PAPR and BER is not up to good level. SLM is the best technique but it require side information to be sent with the transmitted signal which increases the complexity so Companding is used because here no side information is need to be sent with the transmitted signal.

- **Hybrid system design:** It contains the combination of three techniques i.e. Transform, Precoding and Reduction. With the combination of the hybrid technique trade off between PAPR and BER is reduced up to certain level.

1.9 Organization of work

This theory is sorted out into five sections. The section shrewd stream is outlined beneath:

Chapter 1: Introduction of OFDM system

This section displays the specialized foundation and prologue to OFDM expected to clarify the work in the accompanying parts. This chapter include the advantages, disadvantages, applications and problems occur in the OFDM system and give the short view of solution for these problems.

Chapter 2: Literature Review

In this chapter various papers are evaluated related to the research topic and summarize them. It includes what researchers have already done in a given field and what will be the next step to overcome the shortcomings suffered in previous system.

Chapter 3: Orthogonal Frequency Division Multiplexing

It subtle elements the essential portrayal of standard OFDM frameworks and clarifies its critical ideas, for example, orthogonality of subcarriers and the utilization of cyclic prefix among others. It also includes the main issues in OFDM system and its effect on the system. Also tells about how to mitigate these effects from the system.

Chapter 3: PAPR Reduction Techniques

In this chapter various techniques are elaborated to reduce the effects of PAPR. How these techniques are using in the existing system and how these techniques helpful to reduce the effect on the system are also explained in a very detailed form. Proposed methodology is explained and then comparison is done between these techniques.

Chapter 4: Results and Discussion

After that results are discussed for the proposed scheme which is explained in above chapter. For this MATLAB software is used.

Chapter 5: Conclusion

This is the finishing up part of the postulation, which condenses the finish of each of the contributing sections and rundown conceivable headings for future work.

Writing audit is the essential channel for analysts to pick up the learning in a specific research region. This work has been finished by the investigation of distributed archive for clear comprehension of that specific region and picking up the learning about how much function has been done in that devoted territory and what will be the future objective to accomplish in this scenario. Hence, this section provides a profound literature review on the PAPR of OFDM system and how various techniques are used to reduce this factor with other advantages like better BER etc. In this chapter, detailed study of PAPR how it impacts the system, causes of it and parameter to analysis PAPR and various techniques used for it are included.

- **X. Wu et al.** [18] proposed that to reduce PAPR we have various reduction, companding, coding techniques but PTS is the best reduction techniques out of all as it reduces complexity as well as out of band distortion which is helpful in reducing PAPR. Also the PAPR of IP-PTS (Interleaved partitioning partial transmit sequence) is inferior than the AP-PTS (Adjacent portioning partial transmit sequence) as candidates generated in IP-PTS are not fully independent. Also to improve IP-PTS C-IP-PTS i.e. conjugate IP-PTS is proposed which overcomes the shortcomings of IP-PTS scheme and obtain better PAPR as compared to AP-PTS scheme. Computational complexity is also less in case of C-IP-PTS scheme. In IP-PTS Cookey Tukey FFT is used which helps to reduce computational complexity factor. In C-IP-PTS conjugate operation are computed on some blocks to increase the number of candidates and we cannot perform this operation on each block as it will increase the complexity factor. In this paper authors shows that IP-PTS candidates are not fully independent to each other and also find the effective phase factor vectors. In C-IPPTS scheme conjugate operation perform on some frequency domain data sub blocks results in increasing number of candidates. It has six steps: a) The original frequency domain sequence is portioned into different frequency sub blocks. b) These sub-blocks are transformed to generate multiple independent candidates. c) C-IP-PTS scheme is performed some sub-blocks of frequency domain while others remain unchanged. d) Then IDFT is performed on each sub-blocks in order to convert them in time domain sub- blocks. e) The time domain sub-blocks combined with different phase factor vector to generate candidates, f) Selection of the candidate having lower PAPR and send it on the channel.

- PTS is a best technique as it removes the out of band distortion but it is inefficient technique for high speed data transmission. Here, novel tree like structure which is given by **B. M. Lee et al.** [19] used to reduce the complexity as well as PAPR. This technique is controlled by two factor i.e. width and depth while performing good performance. Also this tree structured searching algorithm is the generalized version between simple PTS and iterative flipping scheme. In iterative flipping scheme a signal is divided into different sub-blocks and calculated there PAPR with assumption that bm = 1. Then for first sub block phase is change b1=-1 and again PAPR is calculated. If PAPR of the previous phase vector is more than the current one then phase will change i.e.-1 otherwise it will remain same. This procedure is performed at the end of the sub-block. The proposed scheme i.e. tree structured searching technique is better than that because in flipping technique performance is degraded as it is based on comparison of PAPR technique. It is Natural that the enhanced performance can be achieved if the decision is made with the information on phase factor as many as possible. When all the combination of phase factor are considered we can achieve the optimal performance through comparison over all the possible combination and it would be ordinary PTS.

- To reduce PAPR SLM technique is used in which different level of powers are assigning to sub blocks. In addition to this RC-SLM (reduced complexity selective mapping) is used to reduce the complexity. This proposed scheme given by **E. S. Hassan** [20] includes portioning the frequency domain signal into various sub-blocks and each sub-block gets multiplied with different phase factor whose length is shorter than the used conventional SLM and then a kind of low complexity is used to replace IFFT blocks. The SLM scheme is effective to reduce PAPR in decibels at a great level but the major disadvantage is that this scheme require an additional side band information is to be send in order to receive the or recover the original signal. The second disadvantage is that it requires bank of IFFT for each sub-blocks which increases complexity. To remove this RCSLM technique is used in which unequal power distribution is there. To reduce the complexity conversion matrices are used. Also by reducing the length of phase sequence and IFFT complexity this scheme is conventional to reduce PAPR. Length of phase sequence can be reduced by assigning the different length of phase factor to each sub-block whose length is shorter than that of conventional SLM.

- A companding techniques i.e. compression and expansion of signals in order to achieve lower PAPR with greater performance gain. In this paper companding plan is proposed by **L. Renze et al.** [21] whose transfer function is less difficult than the traditional companding method. At the transmitter side baseband signal is compressed in order to reduce the PAPR and at the receiver side it is expand in order to get useful information and reject the effect to some degree. Additionally this method is contrasted and customary SLM, PTS plot and here QPSK (quarter phase shift keying) modulation is utilized with 128 sub-carriers likewise impact of channel is not tended to for expecting the perfect channel pay can be accomplished. Perfect synchronization is additionally expected in this paper. Like in SLM additional information is to be send along the signal which causes overhead and complexity is also increases. Complexity factor is also happened in case of PTS but companding overcome all the shortcomings of these techniques and give better performance of the system with lower PAPR.

- Auto Regressive Filtering to remove the nonlinear distortion which is big problem in case of implementation of high power amplifier. In this method signal brightening property of error filtering is used as a reprocessing dare to wipe out the predictable substance of stationary stochastic methodology which diminishes the autocorrelation of the data groupings and **M. M. Hasan** [22] said that it is astoundingly effective response for reducing the PAPR issue in OFDM systems without degenerate the mix-up execution. The principal great position of this proposed plan is that this arrangement can work under any modulation conspire and can work for any number of subcarriers under both added substance white Gaussian noise and also remote Rayleigh fading channel.

- A hybrid technique which is the combination of both PTS and SLM which reduces the overhead as compared to other techniques and less distortion as compared to the µ-law compression technique and less BER than clipping technique proposed by **C. Duanmu et al.** [23]. The combination of both SLM and PTS technique uses there advantages and overcome their disadvantages in order to achieve low PAPR, information overhead and good BER ratio. In this paper PTS calculation is used after SLM calculation, with the end goal that the some advantages of the main randomization by utilizing the SLM calculation will be alleviate in the second rando*mization by utilizing the PTS calculation will go about as an obstruction the randomization in the first run through by utilizing the SLM calculation. To evacuate this issue for some OFDM information PTS calculation is utilized and for rest of the information SLM calculation is utilized so that they do not meddle with each other.

- A combined scheme which is the combination of SLM and Clipping. Clipping provide less complexity and easy to implement and SLM provides good PAPR as it reduces the out of band distortion. In this paper **B. M. Lee et al.** [24] only discussed theoretical analysis is there which is compared the performance of combined technique with the simulation results with the faded channel. Here clipping at different level and SLM at different phase level is analyzed theoretically and comparison is done so that in future one can do this practically to achieve good BER and PAPR performance with this combined technique.

- A new combined technique which is iterative clipping and filtering which reduced the major problem of OFDM system i.e. PAPR to a great extent but it requires numerous iteration to minimize the peak regrowth problem. To mitigate this problem **A. Chakrapani et al.** [25] explained the novel clipping is used for noise cancellation as well as to mitigate the effects of in-band and out of band distortion and PAPR as it needs only one iteration. It requires 3 FFT/IFFT operations. More the number of iteration more FFT/IFFT operations are required and computational complexity will increase but more the iteration will be done less will be PAPR. Also comparison is done with Exponential Companding technique and BER, computational complexity, spectral efficiency is also checked with this method.

- In the proposed scheme given by **I. Baig et al.** [26], ZCMT portion is connected to the constellation symbols which likewise diminish the BER with PAPR execution. Additionally it boosts the power effectiveness. Zadoff-chu successions are class of poly sequences having ideal connection properties having perfect intermittent autocorrelation and consistent magnitude. ZCMT performed before IFFT in OFDM framework at the transmitter side and after IFFT at the receiver side. Subsequent to getting reenactment results, they are contrasted and different precoding system i.e. WHT (Walsh Hadamard change), DHT (Discrete Hartley transform) etc.

- Hadamard Precoding used to reduce PAPR ratio in optical direct detection OFDM system. In this paper 2.5 Gbits/binary phase shift keying (BPSK) optical OFDM signals with Hadamard precoding are created and transmitted through single mode fiber. Additionally **Z. P. Wang et al.** [27] shows the simulation results that comes about demonstrates that PAPR lessen up to 1.5Db and interim they got affectability is enhanced by 2dB with 100km fiber transmission when contrasted with the standard optical recognition OFDM framework.

- A mixture strategy which is mix of piece coding method and DCT (Discrete Cosine Transform). DCT is used to think the vitality of the first signal into two or three coefficients. After that this data managed into IDFT, the yield signal of OFDM appeared to have uniform scattering. Execution of DCT to take the advantage of which allows the truncation number of components expected to make a focus. Another great position of using DCT to shade the information and can weigh the frequency component and furthermore in transform domain coefficients for the frequency domain is effectively accessible. With the assistance of recreation acquired by **Y. C. Hsu et al.** [28] it is acquired that DCT demonstrated its superiority in the data transfer capacity pressure of extensive variety of signals, for example, discourse, TV signals, shading print pictures and so on.

- A new technique to reduce PAPR as other proposed technique cause out of band distortion, reduce the available bandwidth and increase the power. The proposed Hadamard precoding technique given by **Z. P. Wang et al.** [29] is applied to optical OFDM system based on IM/DD (intensity modulation direct detection) channel and both parameters i.e. PAPR and BER are improved. However with precoding technique complexity of an OFDM system increases as compare to the system without precoding because precoding matrix is multiplied with each modulated data before IFFT at the transmitter side and same process is done at the receiver side after the FFT. In this paper grouped DCT precoding method is used for IM/DD OFDM system as it reduces the complexity of both precoding as well as inverse precoding and improves the PAPR and BER ratio. By computer simulation its performance is checked on plastic optical fibers. The simulation results shows that the complexity is reduced with grouped DCT precoded as compared to the conventional

IM/DD OFDM system. Also system performance improves because precoding takes the advantage of frequency selectivity of the communication channel. In the IM/DD optical system the information is carried out on the intensity of the optical signal which can be positive or real valued signal. The optical system requires direct current bias to make the system non-negative. The basic idea behind this approach is that the N/2 data is divided into M groups and every group data is firstly transformed by a DCT matrix.

- A tone reservation (TR) method which depends on IFFT/FFT structure then this is supplanted by Fast DCT(Discrete Cosine Transform) which lessens the computational complexity nature. Additionally with the recreation result this strategy demonstrates that framework BER is not affected and PAPR decreases as it were **K. Zhou et al.** [30] proposed that Unlike SLM this system does not require any side band data so no overhead is there. The principle thought behind this Tone reservation is to observe the time space signal to be added to the first run through area motion with a specific end goal to decrease PAPR of a framework. A vast piece of carrier are utilized to transmit the data bits and rest of are for cancellation bits which can configuration to get the time area images to balance the pinnacles. The utilization of IFFT/FFT to create the cancellation signals. Right off the bat target esteem sets then approaching time space information is contrasted and target esteem if its esteem is more than the objective esteem then the signal is cut then figure the distinction to get the frequency domain signal. At that point DCT is utilized after that having distinctive preferences i.e. great unearthly proficiency, diminishing PAPR with influencing the BER of a framework.

- An efficient technique i.e. the combination of DCT precoding with clipping to reduce the main problem of OFDM system i.e. PAPR. The methodology given by **Z. P. Wang et al.** [31] behind this technique is that the data is send by DCT precoding technique before being processed with the IFFT operation which reduces the PAPR and then clipping is done for further reduction of PAPR of OFDM signals after the IFFT operation. In this paper IM/DD scheme is considered. By analyzing the simulation result it shows that by adding the clipping with DCT it does not increase the complexity of the system.

- A conspire which is high exceptional enthusiasm for optical communication as it gives high spectral efficiency and solid resistance to dispersive channels. In this paper, a DCT post-coding calculation for optical OFDM signals is proposed **N. F. Chen et al.** [32] said that When DCT post coding is connected on real signal, the changed signal is likewise a real signal. Accordingly DCT grid can likewise be utilized as a post-coding lattice with a specific end goal to decrease the PAPR of the real optical OFDM signal. Here IM/DD optical OFDM framework is considered. Recreation results are thought about between the DCT post coding strategy and regular precoding QPSK method and it comes about superior to the ordinary precoding procedure and demonstrated that post coding is superior to the precoding system.

- As OFDM suffers from PAPR problem which can be reduced by using different reduction techniques but SLM gives the better result of PAPR as well as BER but computational complexity is more because it requires major number of IFFT to generate a transmitted signal **A. Singal et al.** [33] suggested the remedy to reduce the complexity by using additive mapping approach. The great benefit of this approach is that BER is not affected by it. In this technique mapping signal is added to the alternative OFDM symbol in time domain to reduce the complexity of SLM technique in an efficient manner.

- To remove the need of side information as in the case of SLM reduction technique for lowering the PAPR in OFDM system a new technique named Tone Injection is introduced which does not require any side information as explained in the literature **W. Wang et al.** [34]. Be that as it may, the ideal TI scheme requires an exhaustive search over all combinations of the possible perturbations of the expanded constellation over all perturbed subcarriers, which is not reasonable for down to practical applications. ,in this literature, propose a low complexity TI scheme in view of distortion signals to diminish the PAPR of OFDM signals. With the exploitation of the factual data conveyed by the distortion signals, author find that the conditional probability of the perturbation vector and the information vector has the counter symmetry property, and that the perturbation subcarrier with substantial number shows up once in a while. As indicated by the perceptions, here limit the search scope of the extended constellations and the subcarriers to be perturbed.

- In many literatures various reduction techniques are used but they have adverse effect on OFDM system. Clipping causes distortion, PTS and SLM requires additional large number of signals to be sent at the same time when the transmitted signal is transmit. More on Block coding firstly choose the sequence having low PAPR and it requires look up table which increases the complexity. So **L. Renze et al.** [35] proposed a new simple technique named as companding having complexity value lower than any other technique. The main purpose of companding is to expand the small signal and contract the large signal without any loss of information. Here simple transform function is used as compared to the conventional companding to reduce the complexity to a great extent.

- Hybrid combination of various techniques is used to achieve a better PAPR and BER rate in a OFDM system. **C. Anjaiah et al.** [36] proposed a new hybrid scheme which is the combination of mu-law companding with PTS scheme. Circuit complexity is increased with the increase in the number of sub-blocks in case of PTS using 4 sub-blocks but in this Hybrid technique it reduces the number of sub-blocks 4 to 2 to reduce the complexity of the circuitry.

- SLM is the best method as it reduces the PAPR with no loss in the value of BER but it has many limitations as it increases the system complexity because it require side information bits for transmission which causes the loss in data rates. **S. Y. Le Goff et al.** [37] introduced a new SLM technique which does not require side information but the complexity at the receiver side is increased in this technique. In this literature, also showed that the probability of erroneous detection of the side information can actually be made very small in a realistic OFDM transmission environment.

- .In the PTS technique, the information piece to be transmitted is apportioned into disjoint sub-blocks and the sub-blocks are consolidated utilizing stage elements to limit PAPR. As standard PTS system requires a comprehensive inquiry over all mixes of permitted stage considers, the pursuit intricacy increments exponentially with the quantity of sub-blocks. In the proposed method, given by **S. H. Hana et al.** [38] gradient descent search is performed to find the phase factors. It is demonstrated that the proposed procedure accomplishes significant diminishment in inquiry multifaceted nature with little execution corruption.

- In this paper author **I. Hosseini et al.** [39] propose a novel calculation for PAPR decrease of an OFDM framework, in light of a companding scheme. In this strategy a compressing polynomial is affixed to the IFFT obstruct at the transmitter and at the collector the FFT piece is consolidated with an reverse expanding function where the iterative Jacobi's technique is utilized for comprehending conditions. The proposed strategy involves less multifaceted nature at the transmitter in examination with other PAPR decrease calculations. It likewise requires less increment in SNR for the same BER contrasted with other companding strategies. An exchange off amongst multifaceted nature and execution can set the request of compacting polynomial and the quantity of iterations for the proposed calculation at the receiver. More the iterations less will be the BER and make the system more accurate with lowering PAPR.

- OFDM is one of the multicarrier adjustment procedure, which is promising innovation in clipping edge remote communication frameworks. In which the impact of ISI is least. One of the real issue in Orthogonal Frequency Division Multiplexing (OFDM) System is high Peak –to-Average Power Ratio (PAPR).So the framework requires high power enhancer with vast element extend. It is extremely hard to outline such an intensifier with high efficiency Numerous scientists **V. Sudha et al.** [40] taking a shot at PAPR decrease strategies, they proposed distinctive techniques; one of the least complex strategy is Clipping, Clipping and filtering. Different strategies are Partial Transmit Sequence (PTS), Selective Mapping (SLM), Tone reservation (TR) and so on. These are twisting less techniques. In this paper we examined the PAPR decrease execution of OFDM framework utilizing both bending and contortion less strategies i.e.(i) Clipping (ii) Clipping and Filtering with various section Ratios (CR's) and(iii) PTS technique with various number of sub blocks. From reenactment comes about clipping technique indicates great PAPR decrease with noteworthy measure of BER debasement. Cutting and sifting technique demonstrates slight increment in PAPR with little corruption in BER execution than Clipping strategy and both strategies are computationally less unpredictable.

CHAPTER 3 OFDM

The interest for fast remote applications and constrained RF signals data transmission is expanding step by step. New applications are developing in the wired frameworks, as well as in the remote portable frameworks. At present, just low rate information administrations are accessible for portable applications. Be that as it may, there is an interest for high information rates for interactive media applications. In single bearer framework, the image term decreases with an expansion in information rate and along these lines the impact of Inter symbol Interference (ISI) turns out to be more extreme. ISI, in remote correspondence frameworks, is delivered because of the memory of dispersive remote channels [41]. When in doubt, the impact of ISI on blunder execution of the framework is insignificant; the length of the delay spread is altogether shorter than the term of one transmitted signal. This infers the symbol rate bolstered by the correspondence framework is for all intents and purposes restricted by ISI. On the off chance that the information rate surpasses the maximum furthest reaches of information transmission over the channel, a component must be actualized to battle the impacts of ISI. Channel equalization methods can be utilized to smother the echoes brought on by the channel. In any case, such equalizers posture challenges progressively frameworks working at a few Mbps speed with minimized, ease equipment. Multicarrier modulation methods act the hero in such circumstances.

These enormous features of multicarrier system draw our attention to study Orthogonal Frequency Division Multiplexing (OFDM). OFDM is the base for all 4G wireless communication systems because it has large capacity (number of subcarriers), high data rate (excess of 100 Mbps), and efficient use of bandwidth, receiver simplicity, and ubiquitous coverage with high mobility. As we know OFDM system is a multicarrier modulation system in which through serial-to-parallel port, input data stream converts into N parallel data stream. Due to the closeness of subcarriers they can sees flat faded channel. The process of modulation and demodulation in OFDM is done by fast DSP applications (FFT /IFFT) [2]. After the generation of parallel symbol, modulation is done on each stream and they carried at unique central frequencies and they must be orthogonal to each other. This task which is most powerful features of OFDM i.e. orthogonality is done by using IFFT. To remove interference between the successive OFDM symbols guard bands are inserted.

Three methods are there for this purpose which are cycle suffix, cycle prefix and zero padding. Also one more advantage of adding guard band is that OFDM convert wideband frequency selective channel into collection of parallel narrow band flat fading channel in which one channel across each subcarrier is there.

3.1 ISI Elimination Using Multicarrier Modulation

The dispersive method for remote channel makes the spreading of the modulation symbol in the time space, which is known as delay spread (τm). The effect of the time disseminating is reflected by the ISI phenomenon. A single carrier with high data rate is exceptionally affected by ISI issue. Multicarrier adjustment has surfaced to lighten the effect of ISI made in single carrier structures under the condition $\tau m > T$[41]. In this way, the essential believed is to assemble the symbol duration to decrease the effect of ISI. Decreasing the effect of ISI yields a less requesting parity, which in this way infers a less complex reception strategy.

Multicarrier modulation partitions the high rate bit stream into N lower rate sub-streams, each of which has symbol duration ($Ts = NT) >> \tau m$, and thus the impact of ISI can be dispensed with as it were. These individual low information rate sub-streams are sent over N parallel subcarriers or sub-channels, keeping up the aggregate coveted data rate of the system. Expecting a single carrier structure with total available transmission capacity (BT) of 1MHz, we transmit the data at symbol length of 1 μs. Consider an average outdoor situation where the most extreme delay spread can be as high as 10μs, so in the most critical result conceivable, no fewer than 10 consecutive symbols will be impacted by the ISI in light of the delay spread. A circumstance for differentiating the single carrier adjustment conspires and multi-carrier modulation is appeared in Table 1. The number of sub-streams is guaranteed that each sub-channel has a bandwidth less than the coherence bandwidth of the channel, and subsequently, the subcarriers encounter generally flat fading. In this manner, the ISI on each subcarrier is little.

As saw from Fig.1.1 that the multicarrier modulation plots with N subcarriers requires a bank of N neighborhood oscillators to adjust N data symbols. Along these lines, when the amount of subcarriers is considerable then it is difficult to suit endless oscillators in the system. As saw from Fig. 2, we moreover require a bank of N correlators for demodulating the multicarrier signal. The beforehand specified issues can be avoided by using OFDM as a MCM. The above arrangement can be illuminated by considering the accompanying case:

Table 3.1: Comparison of single-carrier and multi-carrier approach in terms of channel frequency selectivity

Design parameters for outdoor channel	Required data rate	1 Mbps
	RMS delay spread, τ_{rms}	10 μs
	Channel coherence bandwidth,	Bc = 1/5 τ_{rms} =20 kHz
	Frequency selectivity condition	σ >symbol duration / 10
Single-carrier Modulation	Symbol duration,	T = 1μs
	Frequency selectivity	10 μs >1μ*s/10* **YES**
	ISI occurs as the channel is frequency selective	
Multi-carrier Modulation	Total number of subcarriers	128
	Data rate per subcarrier	7.8125 kbps
	Symbol duration per subcarrier	T_s = 128 μ*s*
	Frequency selectivity	10 μs >128μ*s/10* **NO**
	ISI is reduced as flat fading occurs.	

3.2 Orthogonality of the Subcarriers and OFDM

Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation plan, where the frequencies of the subcarriers are pleasingly related. At the end of the day, a multicarrier modulation scheme with orthogonal subcarriers is called as OFDM. Let $\{X_k\}$ k= 0 to N-1 be the arrangement of complex symbols to be transmitted by multicarrier modulation, the continuous time space MCM signal can be communicated as:

$$x(t) = \sum_{k=0}^{N-1} Xk \exp(j2\pi f_k t) \quad 0 \le t \le T_s \qquad [2]$$

$$= \sum_{k=0}^{N-1} Xk\, \varphi k(t) \quad 0 \le t \le T_s$$

$$Where\ f_{k=} f_0 + k\Delta f \ \ and\ \ \varphi k(t) = \begin{cases} \exp(j2\pi fkt) & 0 \le t \le Ts \\ 0 & Otherwise \end{cases} \qquad [3]$$

For k = 0,1, 2...N −1. The subcarriers become orthogonal if $Ts\ \Delta f$ =1, and such a modulation scheme is called OFDM, where Ts and Δf are known as the OFDM symbol duration and the subcarrier frequency spacing individually. If there should be an occurrence of orthogonal subcarriers x(t) signifies a time domain OFDM signal[42]. The orthogonality among sub carriers can be viewed in time domain as shown in Fig. 3.1. Each curve represents the time domain view of the wave for a subcarrier. As seen from Fig. 3, in a single OFDM symbol duration, there are integer numbers of cycles of each of the subcarriers.

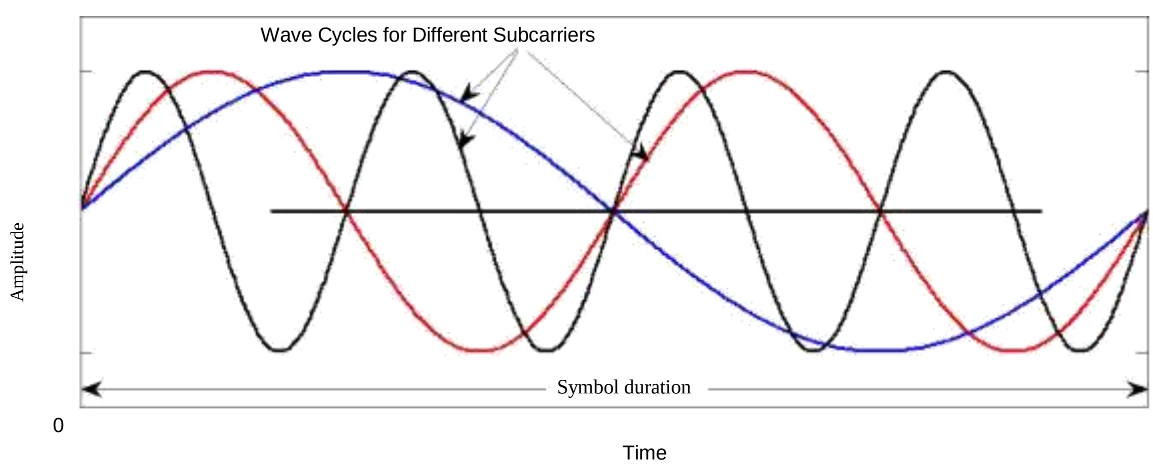


Figure 3.1: Time domain representation of the signal waveforms to show orthogonality among the subcarriers

In view of the orthogonality condition, we have φ_k

$$1/T_s\int_0^{Ts} \varphi k(t)\varphi_l^*(t)dt$$

$$=\frac{1}{Ts}\int_0^{Ts} e^{j2\pi(fk-fl)t}dt$$

$$=\delta[k-l] \qquad [4]$$

$$Where\ \delta[n]=\begin{cases} 1 & if\ n=0 \\ 0 & otherwise \end{cases} \qquad [5]$$

$$=\sum_{l=0}^{N-1} xl\delta[k-l]$$

Condition (2.2) demonstrates that { (φ_k(t))}k=0 to N-1 is an arrangement of orthogonal functions. Utilizing this property the OFDM signal can be demodulated as:

$$\frac{1}{Ts}\int_0^{Ts} x(t)e^{j2\pi fkt}dt \quad \varphi_k$$

$$=\frac{1}{Ts}\int_0^{Ts}\left(\sum_{l=0}^{N-1} x(t)\varphi k\ (t)\right)\varphi * l(t)dt$$

$$= x_k \qquad [6]$$

3.3 Cyclic Prefix

As we realize that wireless communication frameworks are more inclined to multipath channel reflections, a cyclic prefix is required to lessen the Inter symbol Interference (ISI) [4].A cyclic prefix is only just a reiteration first section of a symbol that is appended to the end of the symbol. Likewise it is extremely helpful as it empowers the multipath representations of the first signal to fade so they don't meddle with the subsequent symbol [43]**.**

To manage this issue and to make an OFDM signal really obtuse to time dispersion of the radio channel, cyclic-prefix (CP) inclusion is regularly utilized. As represented in Fig. 5 , cyclic-prefix addition suggests that the last some portion of the OFDM symbol is replicated and embedded toward the start of the OFDM symbol. Cyclic-prefix inclusion is accordingly expands the length of the OFDM symbol term from T_s to Ts + Tcp, where Tcp is the length of the cyclic prefix.

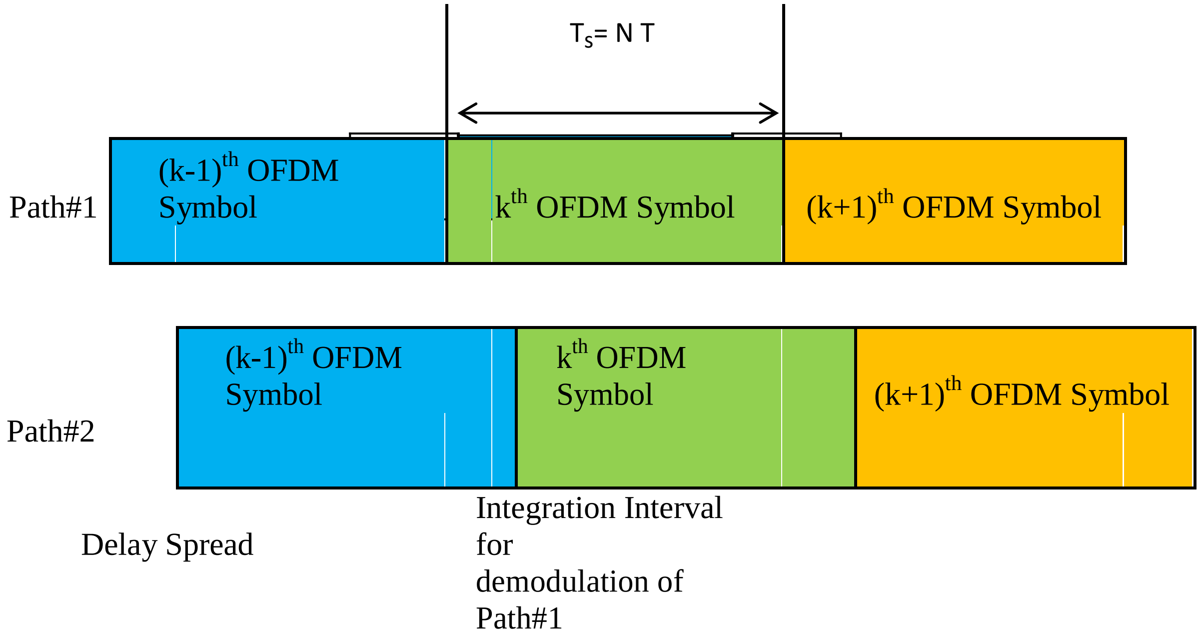


Figure 3.2: The time dispersion and corresponding received signals timing

As outlined in Fig. 3.2, if the connection at the beneficiary side is still completed over a period interim Ts, subcarrier orthogonality will be saved if there should be an occurrence of a time dispersive channel, the length of the traverse of the time dispersive is shorter than the length of cyclic-prefix. At the collector side, the relating samples are disposed of before OFDM subcarrier demodulation i.e. before DFT preparing.

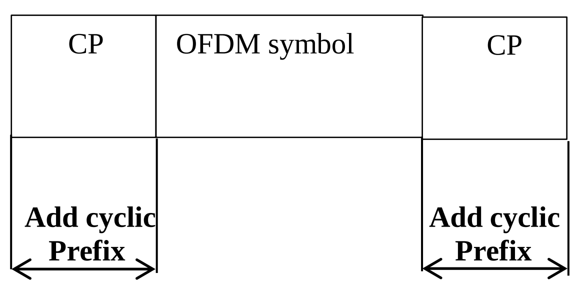


Figure 3.3: Cyclic prefix insertion

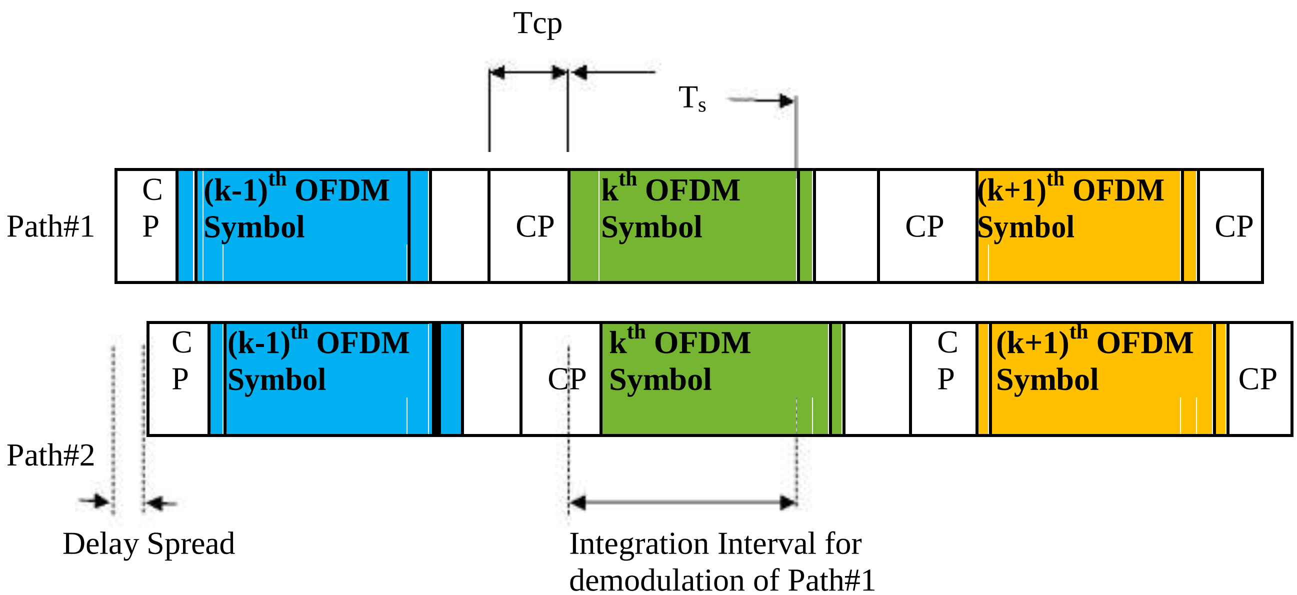


Figure 3.4: Time dispersion and corresponding received signal using cyclic prefix insertion

A cyclic-prefix addition of N_{CP} samples is valuable, when an OFDM image x[n] is gone through dispersive channel (h[n]) with greatest delay spread of NCP +1 samples. Since CP values are redundancy of the last (NCP) samples estimations of the symbol, it is identical to transformation of the linear convolution of x[n] and h[n] into circular convolution. because of the circular convolution operation in time domain, the DFT of the got symbol is a straightforward duplication of the DFTs of x[n] and h[n], which makes it minor to recoup the transmitted symbol by a basic one tap equalizer [44-45].

Cyclic prefix addition likewise keeps away from inter block interference (IBI), in light of the fact that by definition, when an input signal of length $N+N_{CP}$ is connected to a time dispersive channel of length $N_{CP}+1$, yield of the channel produces $N+2N_{CP}$ samples. Out of $N+2N_{CP}$ samples, first N_{CP} samples may contain obstruction from going before OFDM symbol, and in this manner these are disposed of, comparatively the last N_{CP} samples may scatter into resulting OFDM images and these are additionally disposed of leaving precisely N samples. By utilizing these N samples of the yield symbol, the N data information symbol can be effortlessly recouped without IBI. The downside of cyclic-prefix addition is that exclusive a portion $T_S/(T_S + T_{CP})$ of the got signal power is really used by the OFDM demodulator, inferring a comparing power loss in the demodulation.

3.4 OFDM Transceiver

An adjusted piece layout of OFDM modulator is showed up in Fig.3.2. The data serial data stream is experienced a serial-to-parallel converter, which parts the information data stream into different parallel sub-channels. The data in each of the sub-channel is associated with a modulator, to such a degree, to the point that for N sub-channels there are N modulators whose carrier frequencies are f0, f1, f2… … fk… … fN-1. The carrier frequency isolating between two neighboring sub-channel is f likewise, the general information exchange limit of N directed sub-channels is N f . We may see the serial-to-parallel convertor as applying each Nth symbol to a modulator. This has the effect of interleaving the symbol into each modulator, e.g. X0 , XN ,...X2N ,...XkN ... are associated with the subcarrier carrier frequency is f0.

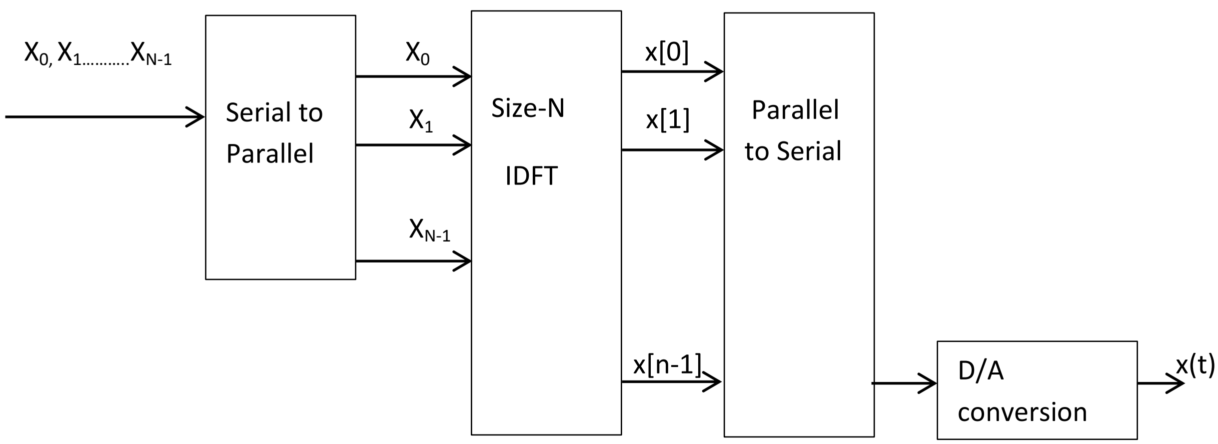


Figure 3.5: OFDM modulator

The sampled form of time domain baseband OFDM signal of (2.1) can be communicated as

$$\mathrm{x}\left(\frac{nTs}{N}\right) = \sum_{K=0}^{N-1} Xkexp\left(\frac{j2\pi fknTs}{N}\right) \quad 0 \leq n \leq N-1 \qquad [7]$$

Without loss of simplification, setting f_0 =0 , then f_k T_s = k and (6) moves toward becoming

$$x\left(\frac{nTs}{N}\right) = \sum_{K=0}^{N-1} Xkexp\left(\frac{j2\pi kn}{N}\right) \qquad [8]$$

In this way, the discrete time baseband OFDM signal of (7) can be communicated as

$$zx[n] = \sum_{K=0}^{N-1} Xkexp\left(\frac{j2\pi kn}{N}\right) = IDFT\{X_k\} \qquad [9]$$

Where IDFT demonstrates the opposite discrete Fourier transform. Along these lines, in OFDM structure sub-carrier adjusts can be performed by using the IDFT piece [46]. The turnaround Fast Fourier transform (IFFT) computation gives a beneficial technique for completing the IDFT operation. Thusly, when the quantity of subcarriers is substantial, then structure's computational capriciousness may be decreased by using IFFT for playing out the subcarrier regulation as showed up in Fig. 7. Remembering the true objective to deal with the defer spread of remote channels, a cyclic prefix (CP) is ordinarily added at the transmitter to keep up the orthogonality between the sub-carriers. Fig. 8 diagrams the central rule of OFDM demodulation. The continuous time space OFDM signal got at the beneficiary side is first changed over into advanced and after that associated with serial to parallel converter. After that FFT of the signal got from is performed to finish the subcarrier demodulation. As saw from Fig. 8, that FFT operation used as a piece of OFDM demodulator discards the essential of N correlators working in parallel to demodulate the multicarrier modulator showed up in Fig. 1.2. Fig. 9(a) exhibits the waveforms of five orthogonal subcarriers used for balance and relating recurrence space signal is showed up in Fig. 2.9(b). Here, most of the subcarriers ensure orthogonality between them by having whole number of cycles per OFDM symbol length. Fig. 9(c) demonstrates the continuous time OFDM signal, when the greater part of the subcarriers are modulated by binary information "1" and its frequency space signal is appeared in Fig. 9 (d).

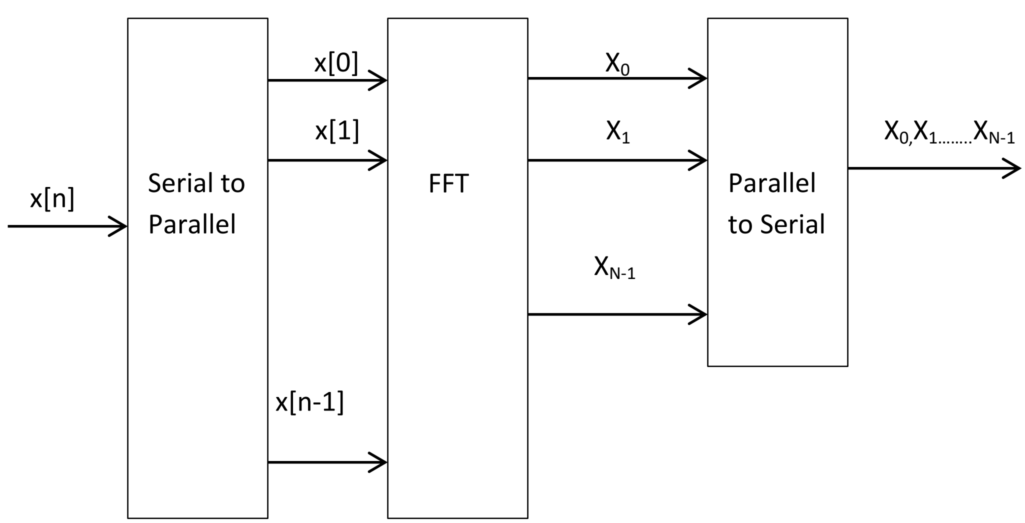
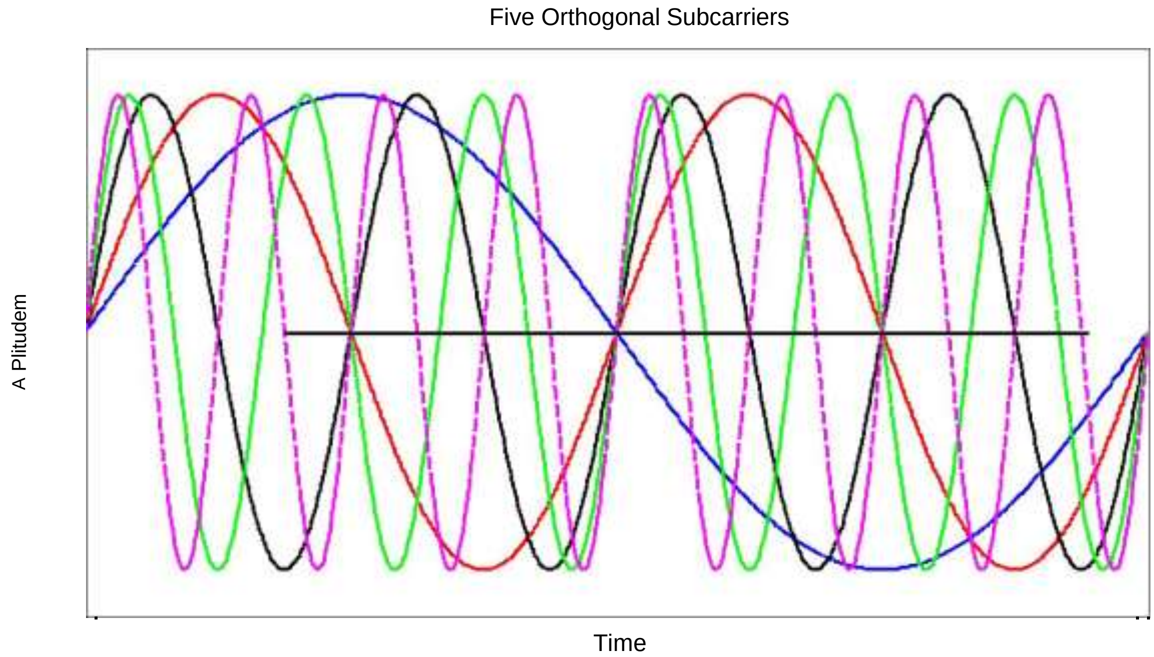
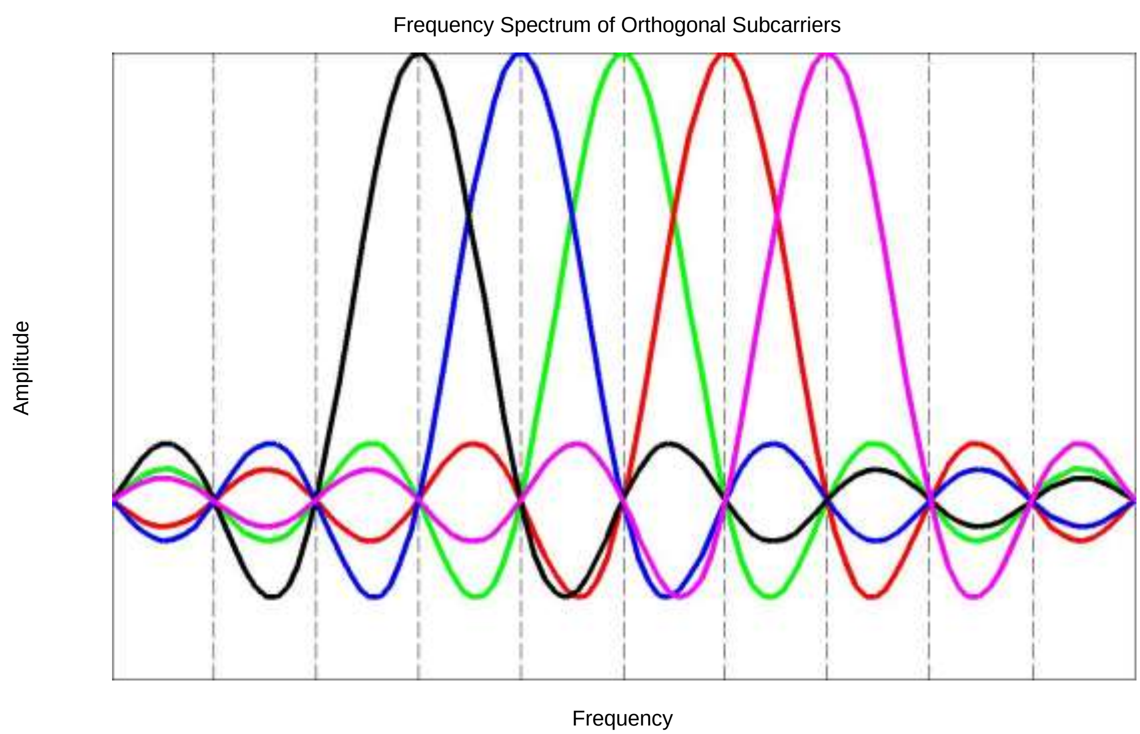


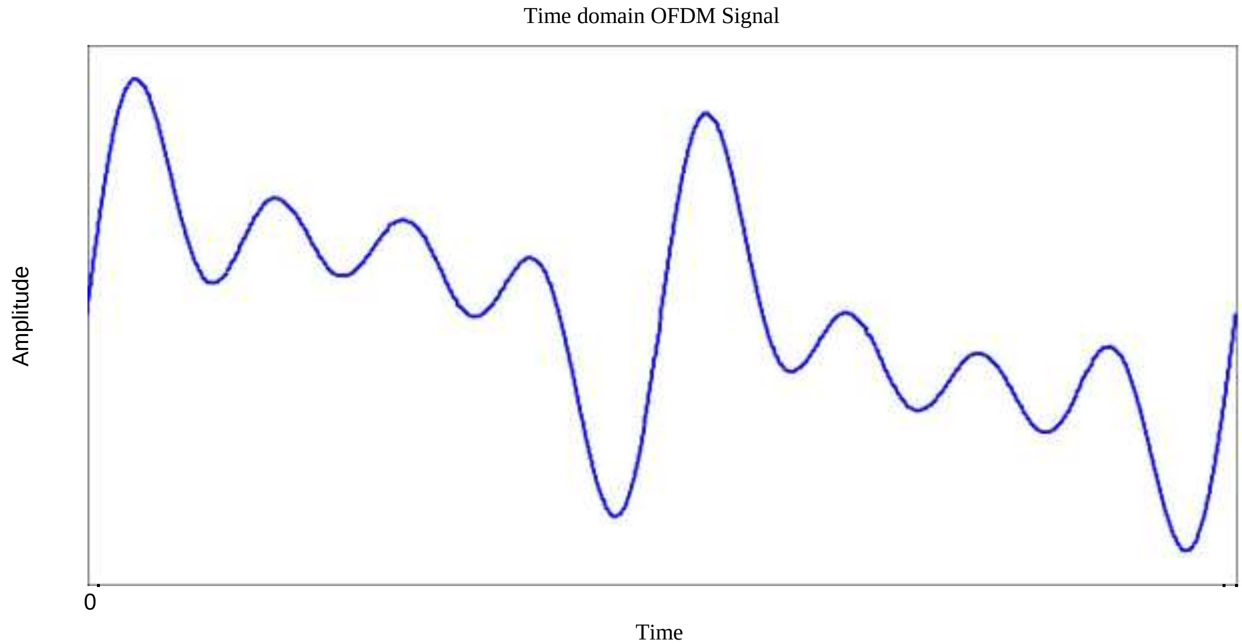
Figure 3.6: OFDM demodulator


Five Orthogonal Subcarriers
A Plitudem
Time

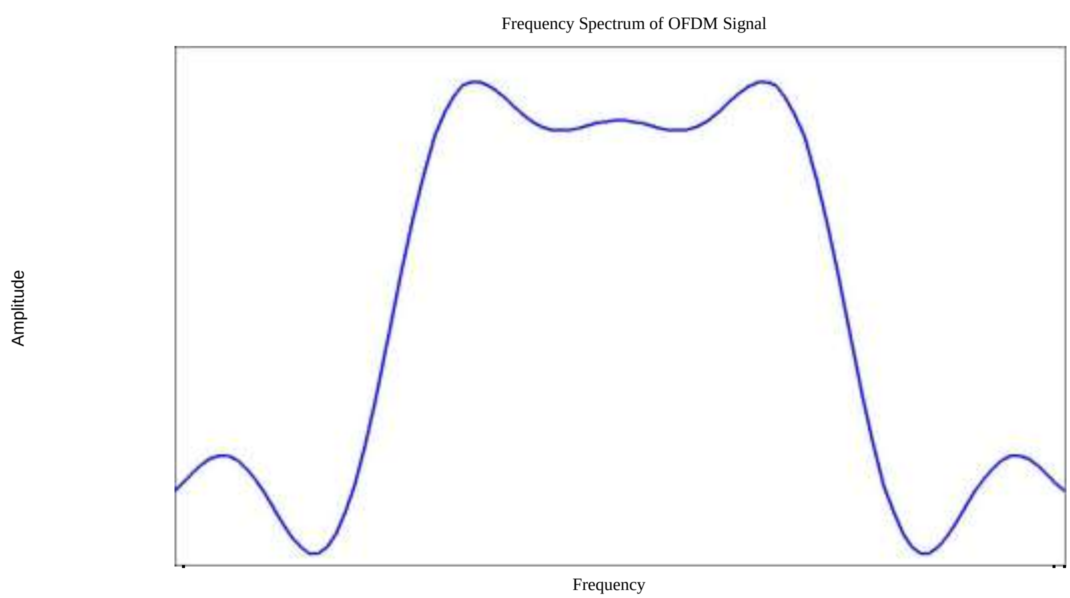
(a)


Frequency Spectrum of Orthogonal Subcarriers
Amplitude
Frequency

(b)



(c)



(d)

Figure 3.7: Construction of OFDM with 5 subcarriers (a) Time area portrayal of all subcarriers (b) Frequency space portrayal of subcarriers (c) Overall whole of subcarriers (Time space) (d) Overall joined frequency response of subcarriers

A whole square diagram of an OFDM Transceiver is showed up in the Fig. 3.8. As saw from Fig. 10. In an OFDM framework, every channel is broken into different sub carriers and the utilization of these sub-carriers make the ideal utilization of frequency spectrum and then again they likewise requires an extra preparing by the transmitter too for the receiver [43]. This extra handling requires the transformation of serial piece stream into parallel piece streams separated among the individual subcarriers. On the consummation of this errand these sub-carriers assist go for a modulation task as though it was an individual channel before all channels are consolidate back together and transmitted overall at the transmitter side and vice and versa handle has been done at the recipient side [47].The unpredictable waveform of modulation information happen toward the end of the Inverse Fast Fourier Transform arrange at the transmitter side. Here modulation scheme is picked which is autonomous of the particular channel being utilized and this is picked by channel necessities.

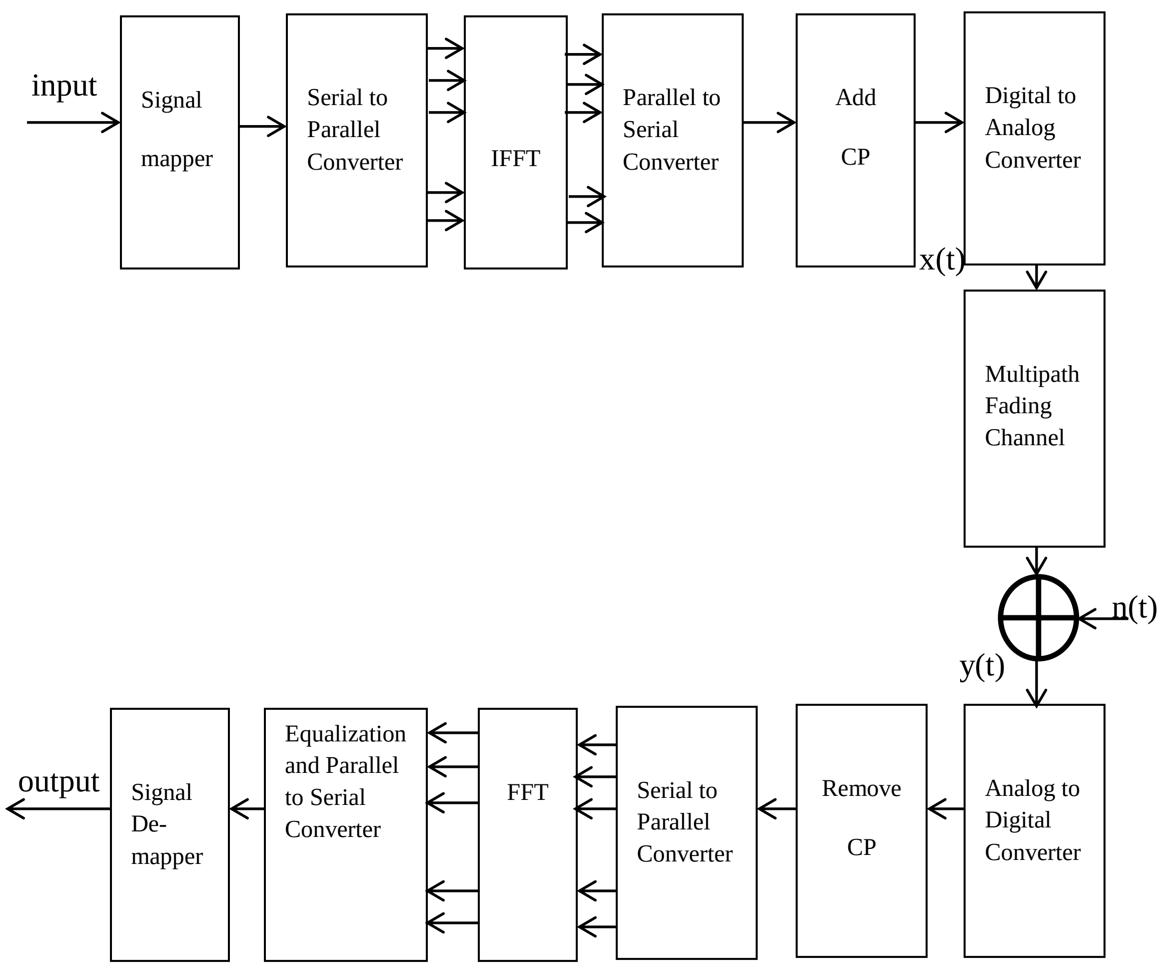


Figure 3.8: OFDM Transceiver

3.5 Issue in OFDM system

The real issue in OFDM framework is PAPR. For all intents and purposes correspondence systems are by and large pinnacle control compelled. An OFDM signal involves a broad number of freely modulated subcarriers, which on intelligible development may make a high immediate peak in regards to the typical signal level. High power amplifiers (HPA's) are used to increase the time space OFDM signal to the pined for power level. Remembering the ultimate objective to deal with the enormous changes in the envelope of OFDM signal, HPA's are required to have a tremendous direct range. Such HPA's are costly, cumbersome and difficult to plan. In case a HPA with obliged linear range is utilized for enhancement, it may work close to immersion trigon and, can realize out-of-band (OOB) radiations and in-band bending. The OOB distortion/noise is an essential concern, especially in remote interchanges, where sweeping differences in signal quality from a versatile transmitter constrain stringent necessities on adjacent channel interference (ACI) [48].

To suit enormous envelope vacillation of the OFDM signal, the digital to analog converter (DAC) and analog to computerized converter (ADC) are moreover required to have a wide element extend, which also constructs the cost and multifaceted nature of the OFDM framework. The present excitement for the utilization of OFDM to present and cutting edge remote frameworks has set off the headway of different arrangements to fight this issue. Besides, OFDM framework requires tight frequency synchronization conversely with single carrier framework, in light of the way that in OFDM, the subcarriers are narrowband. Thusly, it is fragile to little frequency balance between the transmitted and the got signal, which may rise as a result of Doppler Effect in the channel, or due to disorder among transmitter and beneficiary neighborhood oscillator frequencies. This carrier frequency balance (CFO) maddens the orthogonality of the subcarriers and the on a particular subcarrier won't remain free of whatever is left of the subcarriers. This marvel, known as Inter carrier interference (ICI) [56], is another test in the error free demodulation and recognizable proof of OFDM signal. To mitigate these problems from OFDM system various techniques are discussed in next section so as to improve the efficiency of a system with better BER.

Numerous PAPR lessening systems are proposed in the literature [23-39]. In this section, such systems are elaborate and talk about their focal points and shortcoming as far as PAPR lessening capacity and BER degradation. The PAPR diminishment schemes are significantly separated into two classes:

(a) Distortion Based techniques
(b) Non- Distortion techniques

4.1 Distortion Based techniques

The plans that acquaint unearthly re-development have a place with this class. Contortion based frameworks are the most direct PAPR decreasing procedures. In addition, these techniques contort the range, this range twisting or "spectral re-development" can be helped to a specific degree by using separating operation**.**

4.1.1 Clipping and Filtering

Clipping is one of the minimum complex techniques to decrease the PAPR of OFDM signal. It decreases the peak of the OFDM motion by cut-out the signal to the coveted level. This operation can be executed on discrete time tests before the DAC or by delineating the power enhancers with immersion level lesser than the OFDM signal dynamic range [45]. The BW effectiveness of the OFDM system decreases because of ghastly re-development. The computational many-sided quality of the section plan is seen to be the base conversely with other twisting PAPR diminishes contrives yet meanwhile its BER execution is amazingly poor. Separating can likewise bring about same i.e. range development yet it lessen the out of band radiation in the wake of cut-out however may bring about some peak regrowth, which the signal of peak surpasses in the clasp level.

The combination of clipping and filtering reduces the PAPR without any expansion in spectrum but computation complexity is there in OFDM transmitter. Also we have to perform interpolation before clipping to prevent out of band radiation. But it causes peak re- growth. So iterative clipping and frequent domain filtering is used to remove or prevent the peak re-growth.
In this technique it clips the level to those signal components that exceed some unvarying

amplitude called clip level. It is very effective as well as very simple technique. But the main problem suffered in this is that due to clipping distortion power is there which is known as clipping noise and it also expands the spectrum of transmitted signal which results in interference. It is nonlinear process so it cause in band noise distortion and also degrades the performance of BER. It also reduces the spectral efficiency because of out of band noise.

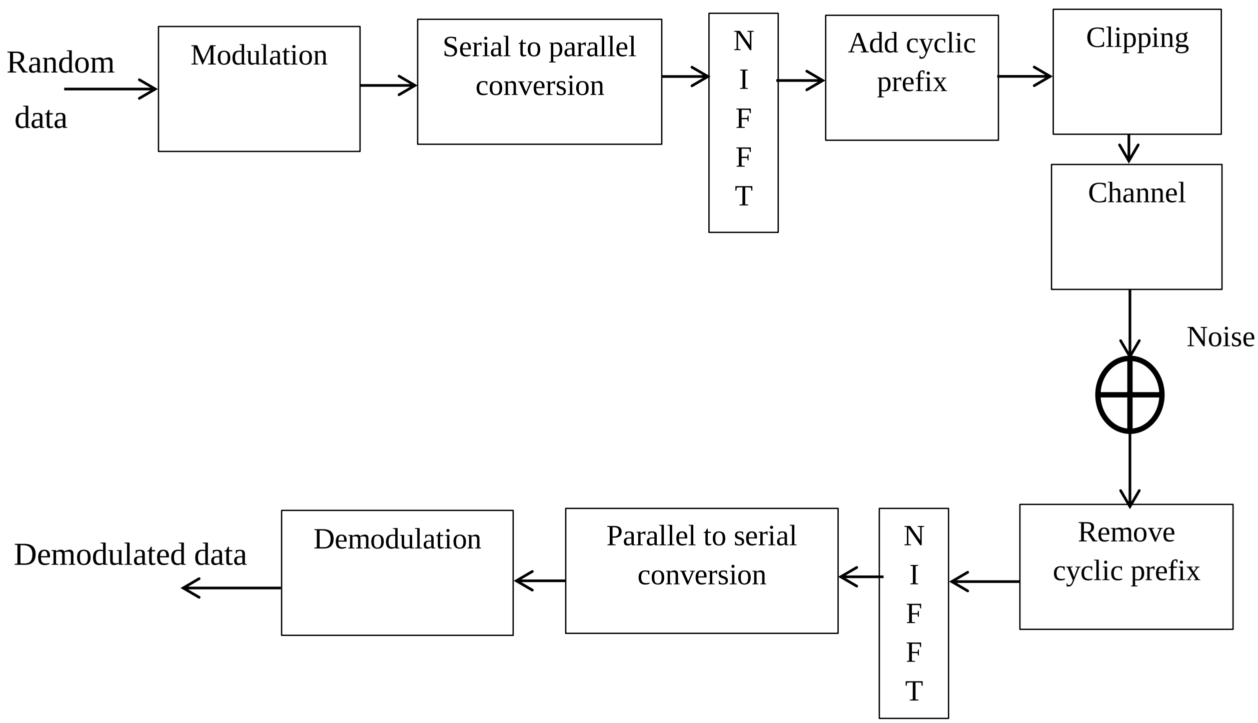


Figure 4.1: Clipping technique using in OFDM Diagram

4.1.2 Companding

Companding is another conspicuous PAPR diminish plot. Companding is a composite word encircled by merging compacting and augmenting. In this arrangement, at the transmitter a signal with high element range is associated with a compander and at the collector side a decompanding capacity (the invert of companding capacity) is used to recover the first signal. At to begin with, it was used as a piece of computerized correspondence framework to construct the dynamic scope of advanced to simple converters (DACs) [17-18]. The μ-law and A-law are the two most understood compacting capacities used far and wide.

The basic equation used for a- law and μ-law compression in this system is:

$$S(x)= \begin{cases} Smax\frac{A\frac{|x|}{xmax}}{(1+A)}Sgn(x), & 0 < \frac{|x|}{xmax} \leq \frac{1}{A} \\ Smax\frac{\left[1+loge\left(A\frac{|x|}{xmax}\right)\right]}{1+logeA}Sgn(x), & \frac{1}{A} < \frac{|x|}{xmax} \leq 1 \end{cases} \quad [10]$$

$$S_u(t) = \frac{ln\left[1+\mu\frac{|S(t)|}{Smax(t)}\right]}{ln(1+\mu)}.Smax(t).Sgn(S(t)) \quad [11]$$

Where Sgn is a sign function having positive as well as negative values.

A 87.6 defined by CCITT.

S(t) is instantaneous amplitude.

S_{max} is a peak amplitude.

$|x|$ is absolute value.

4.1.3 Tone Reservation (TR)

In this method we keep a little arrangement of tones having low SNR for decreasing the PAPR. These subset tones convey no data and adding to the current OFDM image in order to summation will give us a lessened PAPR [49]. It is a strategy in which information piece included and time domain signal. Information piece is needy time domain signal to the first multicarrier signal to decrease the high peak. At the transmitter of framework the time domain signal can be ascertained basically and peeled off at the beneficiary. It relies on number of saved tones, intricacy that the display, area of held tones and enabled control on saved tones to the amount we can diminish the PAPR.

4.1.4 Peak Windowing

Here, we can evacuate extensive peak yet at the slight cost of self-obstruction when substantial peaks emerge rarely. The fundamental inconvenience is that BER increments and out of and radiation increment. The main contrast amongst cut-out and crest windowing is that we show signs of improvement otherworldly effectiveness if there should be an occurrence of pinnacle windowing. In pinnacle windowing strategy we duplicate pinnacle of vast flag with particular window for instance Kaiser Window, hamming window, Gaussian shaped window.

4.2 Non Distortion Techniques

These sorts of PAPR decrease plans don't contort the state of the OFDM signal and Therefore no spectrum re-development occur.

4.2.1 Coding Techniques

The basic idea behind this technique is that it uses set of codes to reduce the PAPR. The code words are used before the application of IFFT. “When N signal are added with same phase they produce peak power which is N times greater than the average power”. This doesn’t do out band radiations and creates Do distortion signal but due the reason it uses set of code words .the bandwidth efficiency is lesser when code rate is reduced [16]. Complexity with this type of technique is that it needs to find best and suitable code words for reduction of OFDM and need to maintain the look up tables for coding and decoding.

4.2.2 Precoding Technique

In this technique we are using the transform before the IFFT block at the transmitter side and after the FFT inverse of that transform is used at the receiver side. Discrete-Cosine transform matrix (DCTM) precoding method is good for improving PAPR as well as BER. In this technique constellation symbols are preceded with linear independent precoder, which diminish the autocorrelation relationship of the IFFT input sequence and disperse the information among subcarriers. Other method Hadamard precoding, Zad-off chu precoding method is used but as compared to DCTM precoding they are more complex. We used different transform like DHT(discrete Hartley transform), DWT(discrete wavelet transform), DFT(discrete Fourier transform), DST(discrete sine transform), DCT(discrete cosine transform) and other transform in combination of IFFT OFDM block which produces precoded scheme and we check the PAPR and BER in each case and check which precoding technique is best.

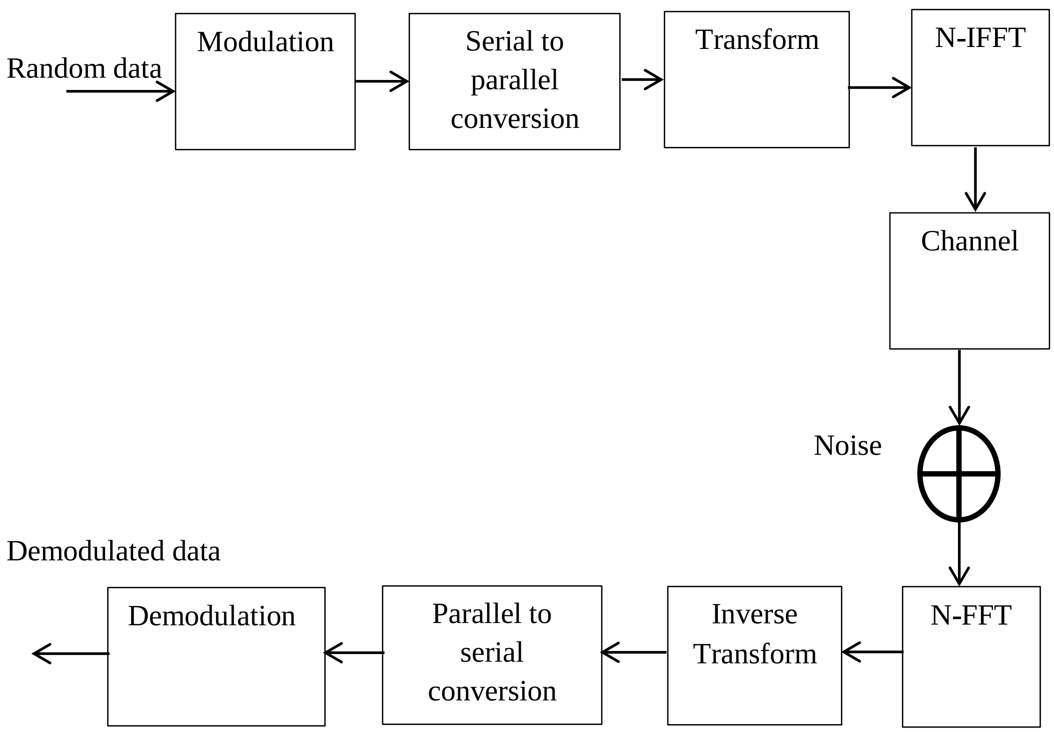


Figure 4.2: Reduction with Precoding Transform in OFDM Diagram

4.2.3 Selective Mapping

SLM is a promising technique which is helpful to reduce the PAPR in an OFDM system. The basic idea behind this technique is that it firstly divides the incoming or transmitted sequence into sub parts and checks the PAPR of each sub sequence and transmits only that sequence which is having lower PAPR [50]. Thus it is helpful to overcome the major problem of OFDM system but on the other hand complexity increases as side band information is also required in this reduction technique.

The SLM plan is a standout amongst the best PAPR lessening plans in OFDM frameworks. It was demonstrated that the SLM plan can accomplish a few decibels of PAPR diminishment and henceforth fundamentally enhances the transmission control productivity. The real impediments of this plan, nonetheless, are as per the following. To start with, the transmission of side data bits so as to empower the beneficiary to recuperate the transmitted information pieces. These repetitive bits diminish the framework transfer speed effectiveness. The second impediment is that it requires a bank of IFFTs to create an arrangement of applicant transmission signals, and this necessity for the most part results in high computational unpredictability.

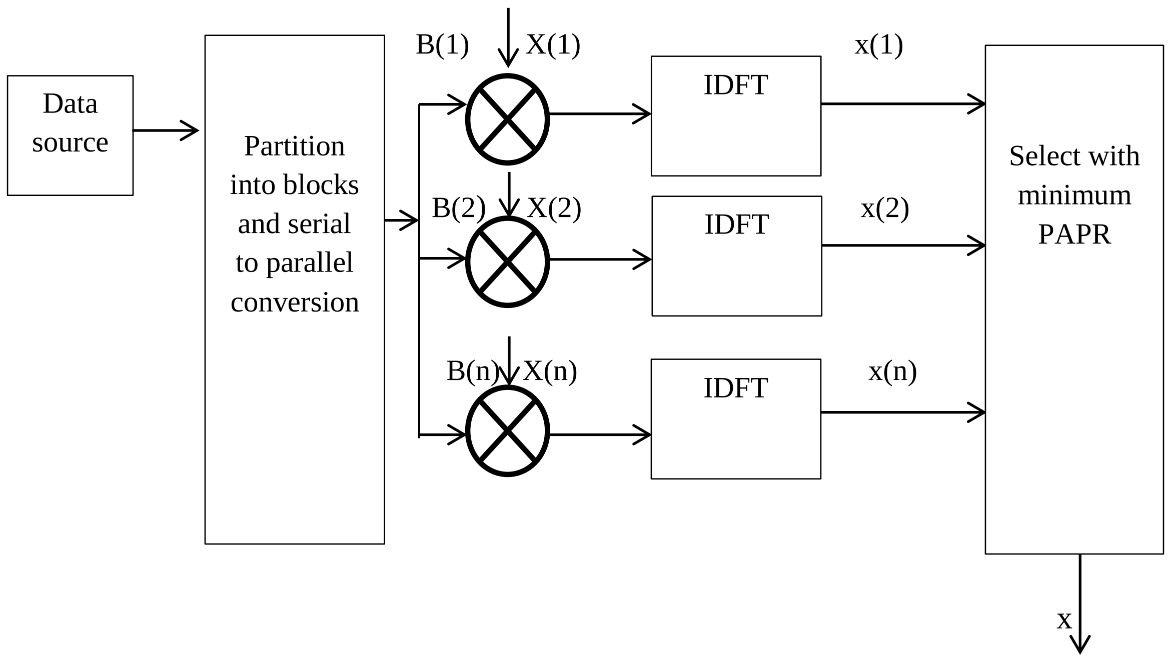


Figure 4.3: Selective Mapping Diagram

We can overcome this by using this technique with some other technique so that its disadvantages can be removed and make the system efficient. The selected signals sent to the receiver along with selected signal as information (SSI) in order to decode information at the receiver. Even though SLM method uses codes it's been limited for only PAPR reduction but not any error correction codes.

4.2.4 Partial transmits sequence (PTS):

The PTS is most popularly used method in reduction of PAPR. The idea behind the PTS scheme is that original sequences of OFDM divided into diverse sequences and multiplies each sequence by distinct weights. The weights which offer better improvement in OFDM signal with less PAPR is the best results. In the other words adding the phase rotated sub-blocks to produce number of candidate signals and pick the one which has smallest PAPR for transmission. Here we only multiply different phase sequence with original OFDM signal as shown in the fig.

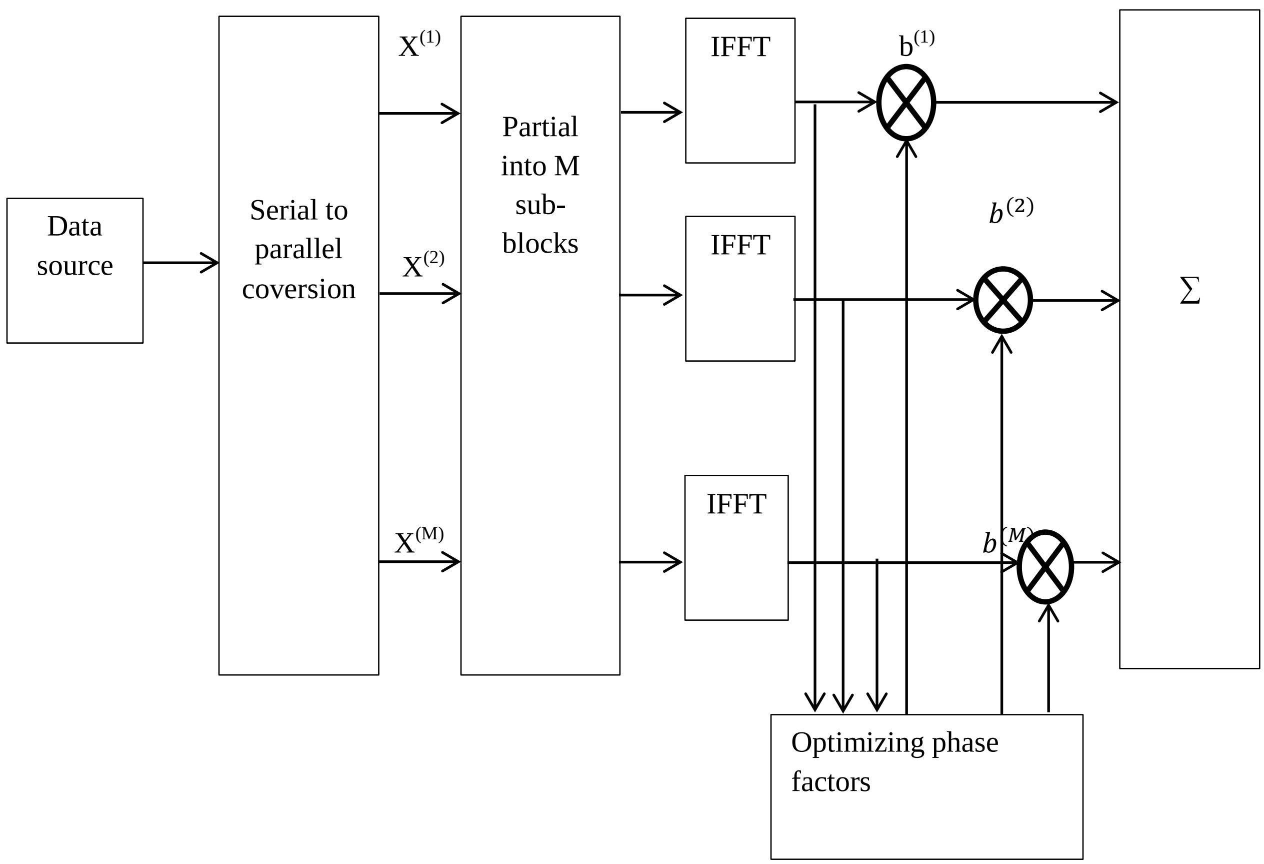


Figure 4.4: Partial Transmit Sequence Diagram

4.2.5 Interleaved OFDM

The method is like alternate of SLM technique, just the difference is that it uses an interleaver instead of using the sequences of phases. Interleaver is a computational device which has specific manner permutation and operates on N symbol block. The interleaved OFDM's block diagram Inter-leavers and de-inter-leavers are usually denoted by the symbol π and π-1. At the receiver side to detect the original signal receiver has to know which type of interleaver is used at the transmitter side so that detection becomes easy. So side band information is also required and PAPR reduced level depends upon which type of interleaver is used at the transmitter as well as receiver side and memory is there on both transmitter and receiver to store the permutation indices.

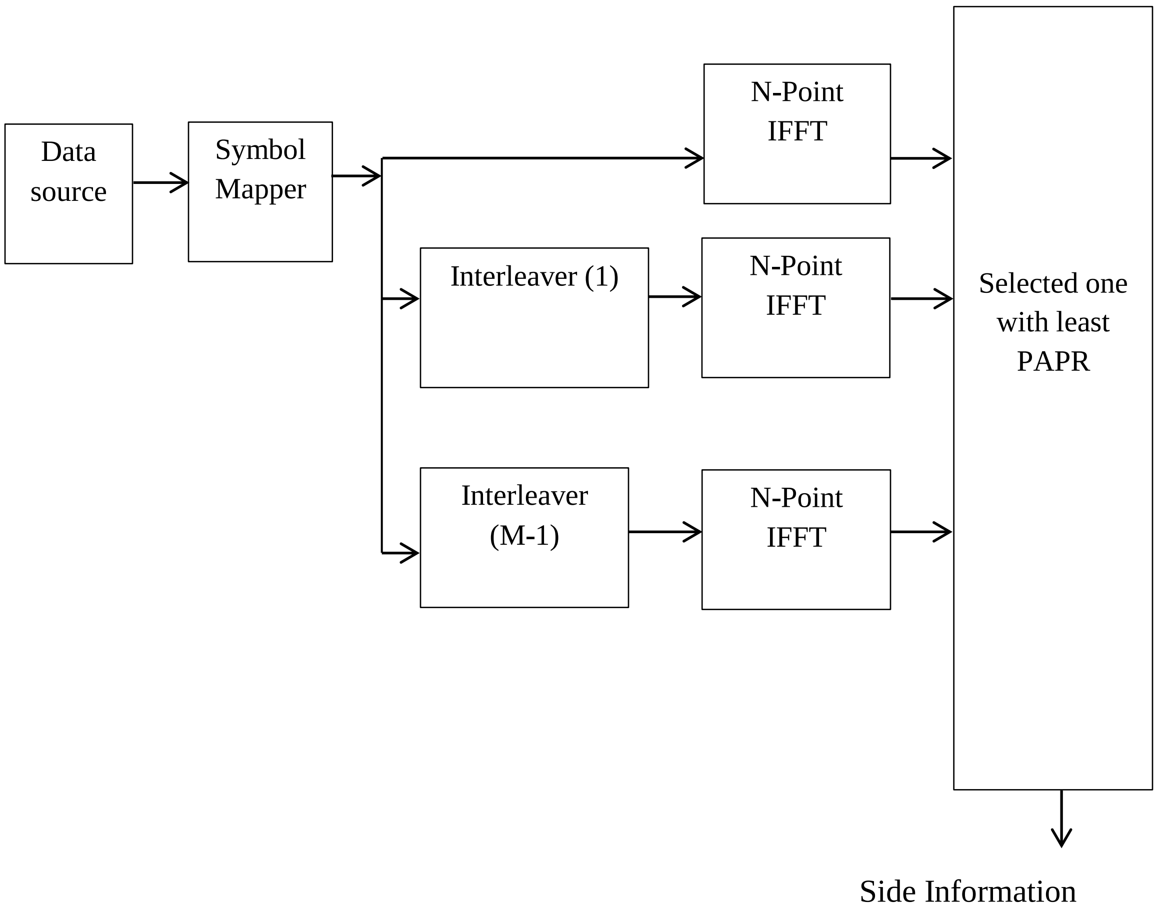


Figure 4.5: Interleaved OFDM Diagram

4.4.3 Hybrid Techniques

4.3.1 Reduction with transform

In this technique we are using different transforms instead of IFFT and similar the inverse of transform which we are using at the transmitter side is used at the collector side. Transform reduces the PAPR and BER appropriate but it has complexity for implementing it like DCT (Discrete Cosine Transform) has leakage effect. We are using different transform to check the PAPR factor after the modulation block like DST, DHT, and DWT etc.

- **DCT**

Progression data f (x) of OFDM is changed with DCT and we will get progression data F(u), which changes the estimations of the segments of progression data. In any case, the progression -

structure won't be changed [5]. In the meantime, many zero parts will appear in the changed progression. That suggests, the energy of the signal focuses on some sub-subcarriers, and PAPR is generally impacted by them.

Besides, energy keeps the same after DCT, so the total energy stays unaltered.

$$[(2.563^2)+(-0.9^2)+(0.601^2)+(-0.51^2)]=8 \quad [12]$$

So plainly DCT can center the signal energy on some little sub-carriers, which can lower down the PAPR.

- **DST**

In arithmetic, the discrete sine change (DST) is a Fourier-related transform like the discrete Fourier transform (DFT), however using a totally real matrix [7-8]. It is equivalent to the whimsical parts of a DFT of by and large two fold the length, taking a shot at real data with odd symmetry (since the Fourier transform of a real and odd capacity is non-existent and odd), where in a couple of varieties the data and also yield data are moved fundamentally a specimen[9]. A related change is the discrete cosine transform (DCT), which is equivalent to a DFT of real and even function.

$$Y(k)= \sum_{n-1}^{N} x(n) \sin \pi \frac{kn}{N+1} \quad k = 1, \ldots\ldots N \quad [13]$$

- **DWT**

The discrete wavelet change (DWT) is a straight change that works on an information vector whose length is integer power of two, changing it into a numerically distinctive vector of a similar length. It is an instrument that isolates information into various frequency parts, and after that reviews every segment with determination coordinated to its scale [10-11]. DWT is processed with a course of filtering's took after by a component 2 subsampling (Fig15).

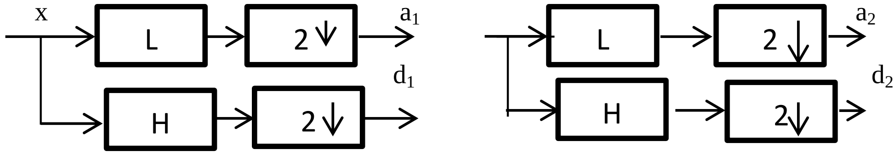


Figure 4.6: DWT Tree

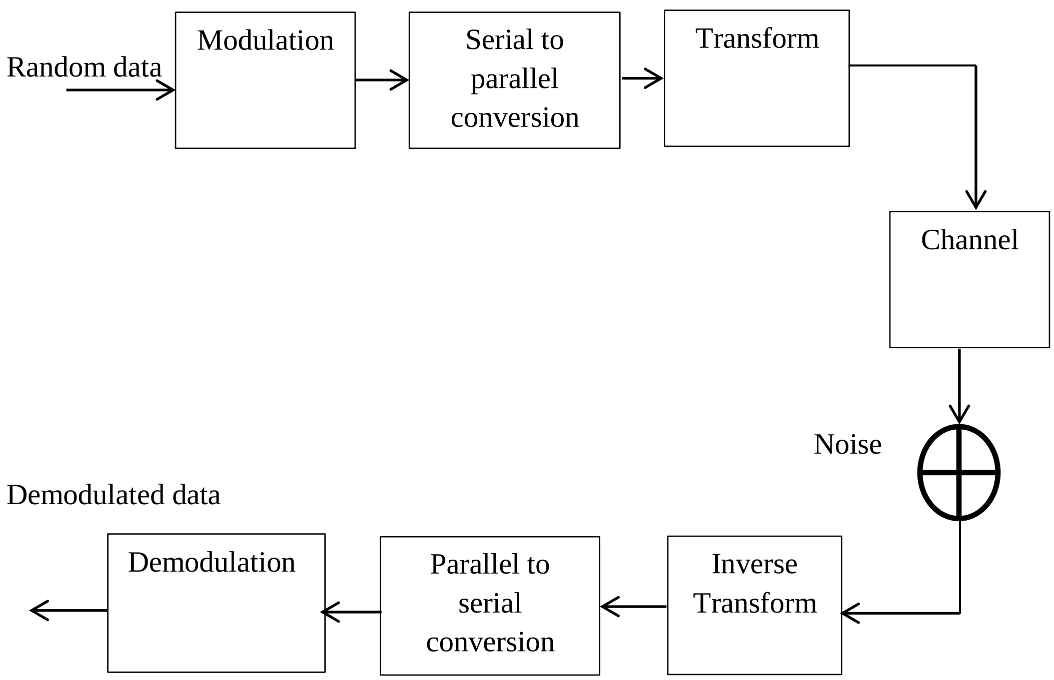


Figure 4.7: Reduction with Transform in OFDM Diagram

4.3.2 Reduction with Precoding

The combination of DCT precoding with clipping can lowered the PAPR in very efficient manner. Firstly, by DCT data is transformed into new modified form. Secondly, the proposed scheme utilizes the reduction method. In this scheme first the transmitted data are transformed with the help of DCT precoding matrix before IFFT operation, which reduces the PAPR. After that reduction technique is done. In place of DCT transform we can use different transforms like DWT, DST, Hadamard transform etc. Also in the place of reduction many techniques like SLM, PTS, Companding, Clipping and Filtering techniques can be used and analyzed which hybrid system is compatible for remote communication with lesser PAPR and BER.

Both blocks are utilized here i.e. FFT block and transform block to see how these blocks are effective to lessen out the PAPR factor from the signal.

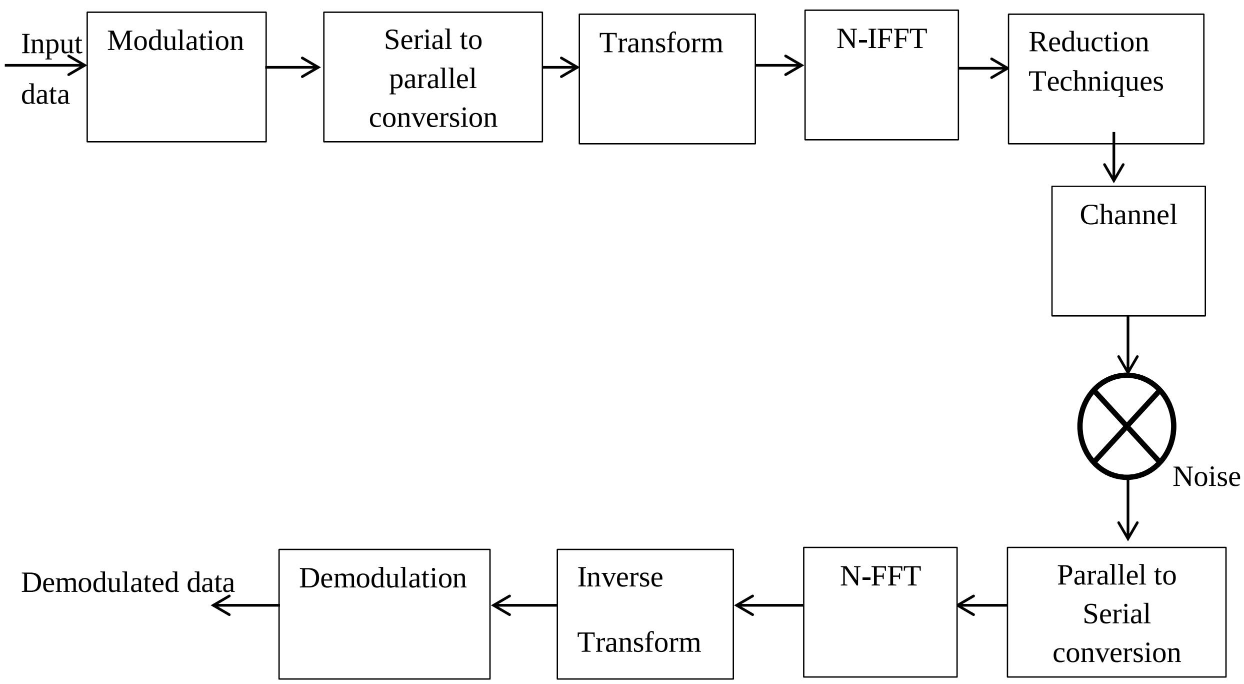


Figure 4.8: Reduction with Precoding Transform in OFDM Diagram

In this chapter different Reduction techniques, Precoding techniques and Hybrid techniques are implemented and finding the PAPR and BER of these systems and finding out the best system with different schemes. Reduction techniques used in this chapter are Clipping , SLM and Companding. With them various combination of transforms are used and also utilized the IFFT block i.e. Precoding method to get the desired level of PAPR and BER.

5.1 Analysis with Clipping Reduction Technique

5.1.1 Analysis of OFDM system

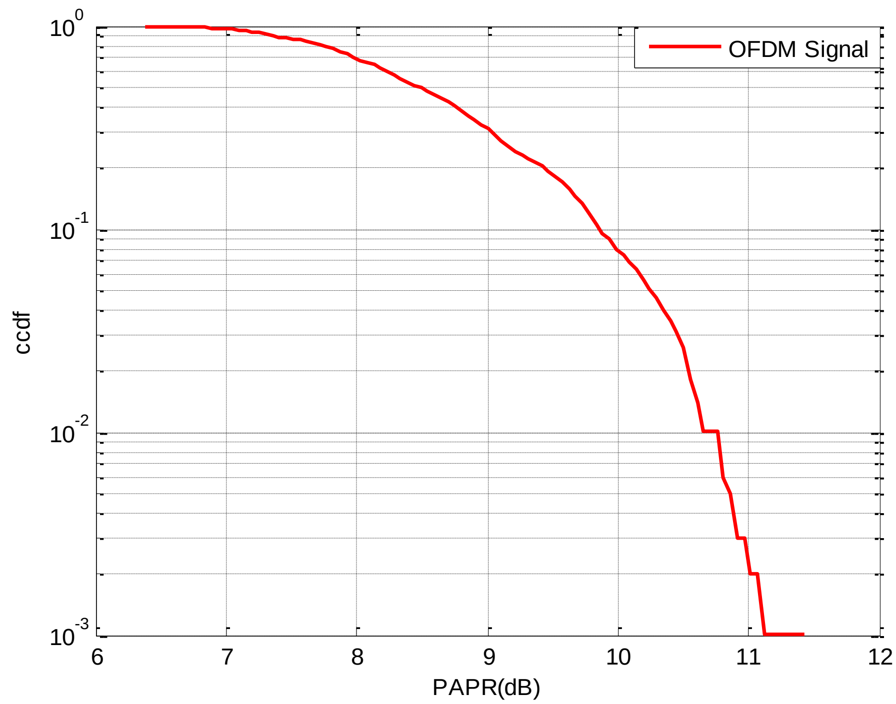


Figure 5.1(a): PAPR vs. CCDF of OFDM signal

Figure 5.1(a) and (b) shows the PAPR and BER of conventional OFDM signal which is 11.2dB and 45dB respectively which is quite high. These results are for simple OFDM signal i.e. without the use of any reduction technique and precoding technique. Also no transforms are applied here. From these graph one can analyze that no worthful PAPR and BER is achieved for making a reliable wireless communication system. To improve these factors in next section reduction techniques and various combination of transforms and precoding techniques are implemented so as to get the lesser value of these major issues as much as possible.

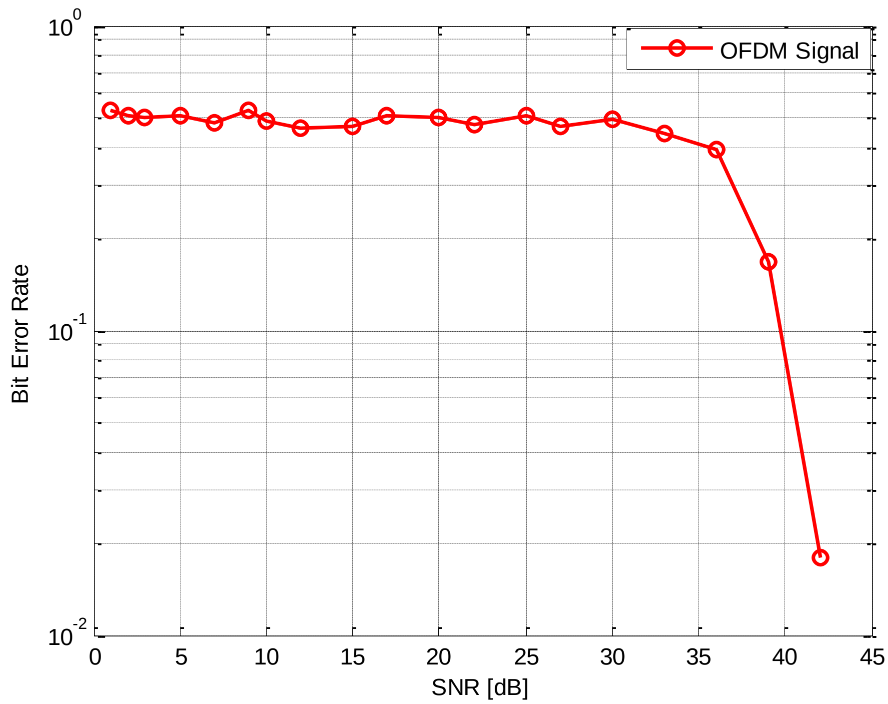


Figure 5.1(b): SNR vs. BER of OFDM signal

5.2 Analysis of OFDM system with Clipping reduction technique

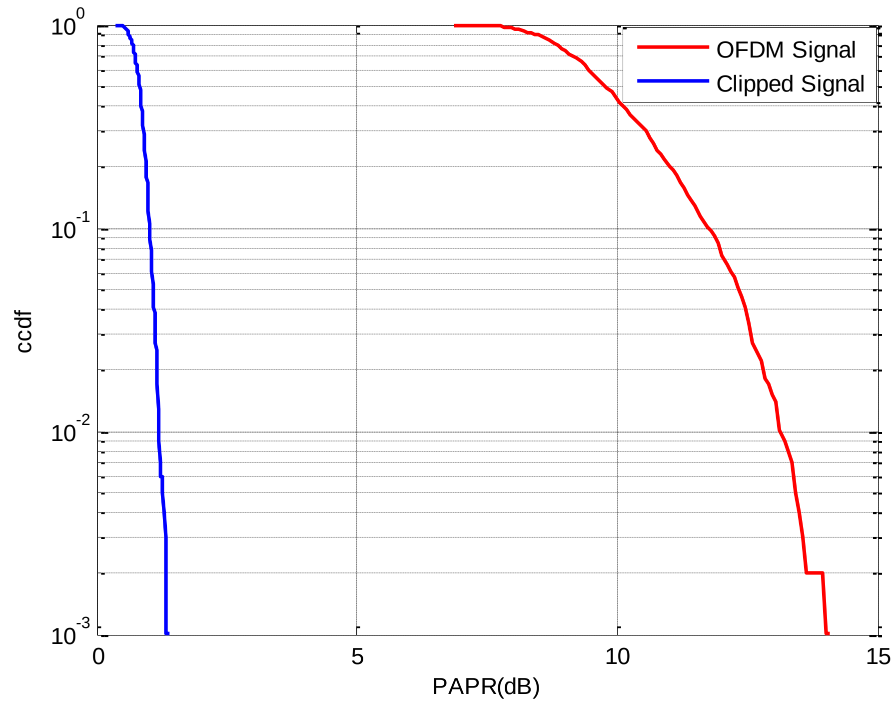


Figure 5.2(a): PAPR vs. CCDF of OFDM signal with Clipped signal

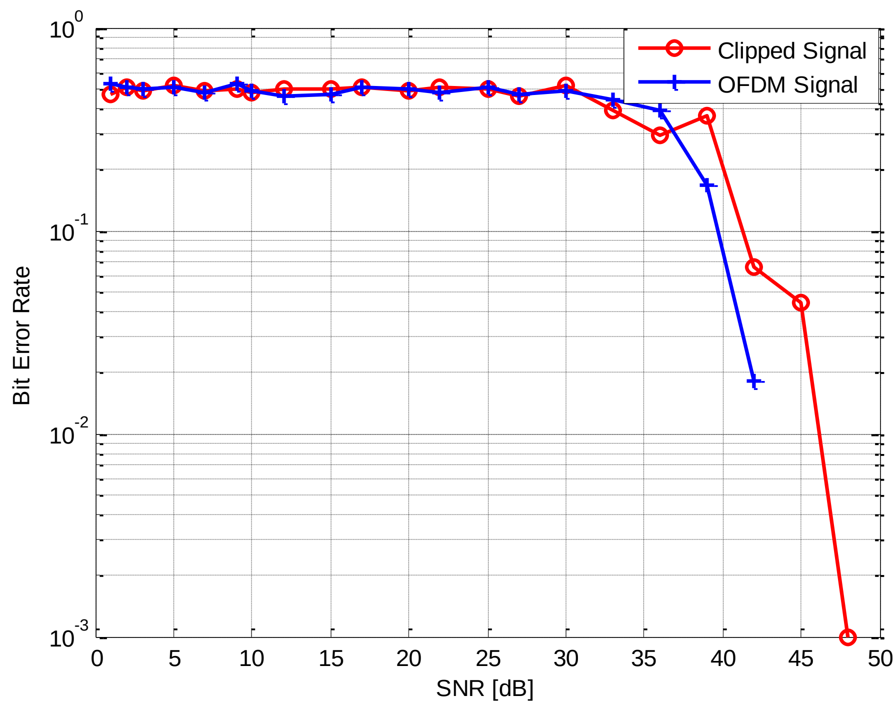


Figure 5.2(b): SNR vs. BER of OFDM signal with Clipped signal

Figure 5.2 (a) and (b) shows the PAPR and BER of OFDM signal with reduction technique clipping is used and comparison analysis made between the OFDM signal and Clipped signal. PAPR of the OFDM system is 14dB approximately and that of Clipped signal it is 2dB which is quite less. This same analysis is made in case of SNR verses BER analysis in which BER of OFDM signal and Clipped signal are approximately same. In this technique certain threshold level is selected for clipping purpose. But the main limitation is the loss of data.

But BER is not sufficiently reduced whether PAPR is reduced at a great level. Both factors are necessary to be reduced to get an efficient system for better communication ahead. So in next scenario clipping is done with combination of some transforms to get a better result of these two parameters.

5.3 Analysis of OFDM system with DCT (Discrete Cosine Transform)

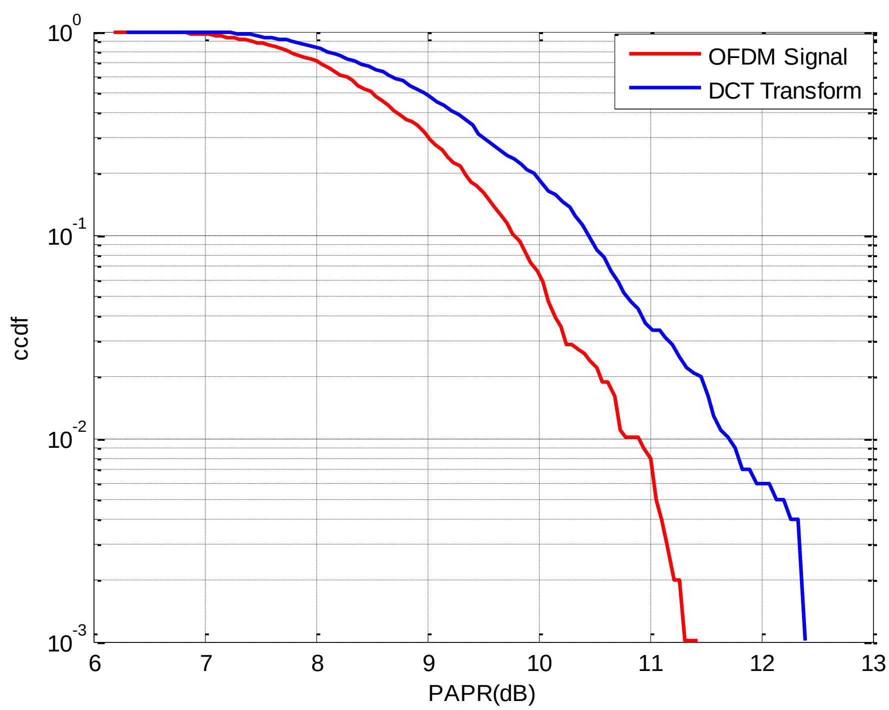


Figure 5.3(a): PAPR vs CCDF of OFDM signal with DCT Transform

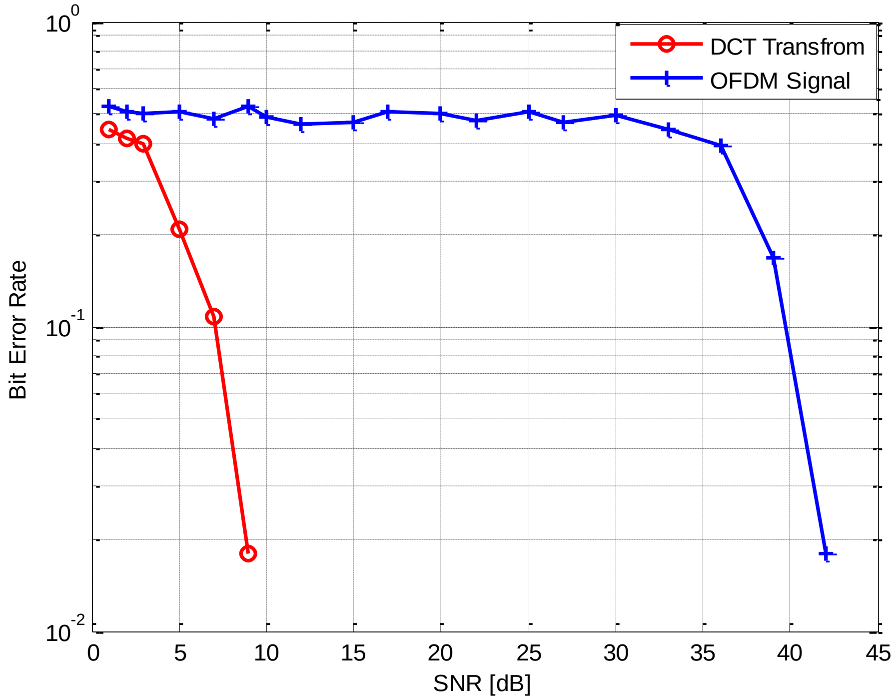


Figure 5.3(b): SNR vs BER of OFDM signal with DCT Transform

Figure 5.3(a) and (b) shows the PAPR and BER- of OFDM signal with Transform technique DCT is used and comparison analysis made between the OFDM signal and Transformed signal. PAPR of the OFDM system is 11.5dB approximately and that of Transformed signal it is 12.5dB which is more. This same analysis is made in case of SNR verses BER analysis in which BER of OFDM signal is 42dB approximately and that of Transformed signal it is 10dB approximately which is very less.

5.4 Analysis of OFDM system with DWT (Discrete Wavelet Transform)

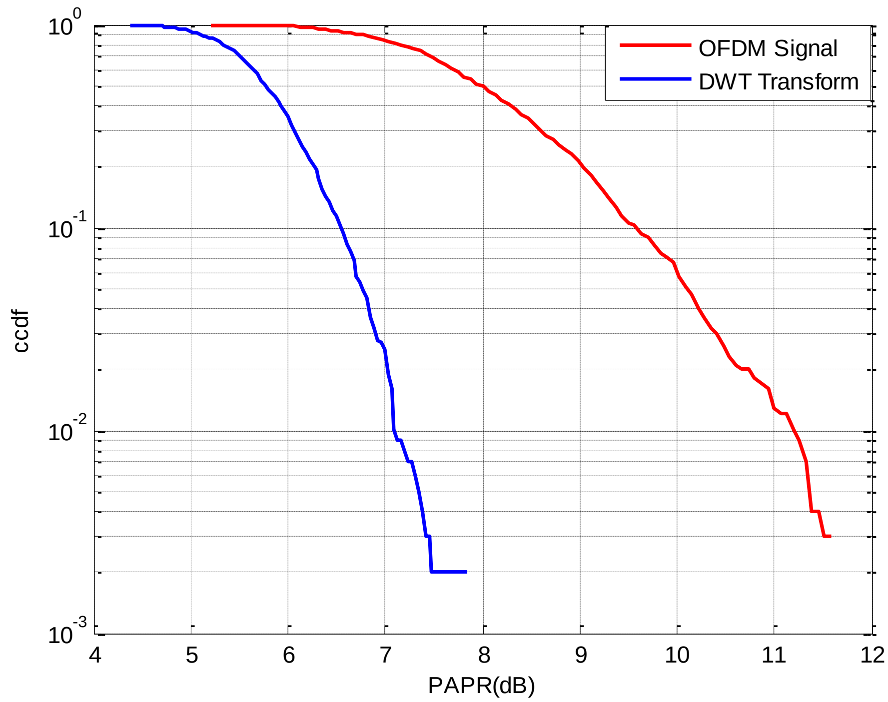


Figure 5.4(a): PAPR vs CCDF of OFDM signal with DWT Transform

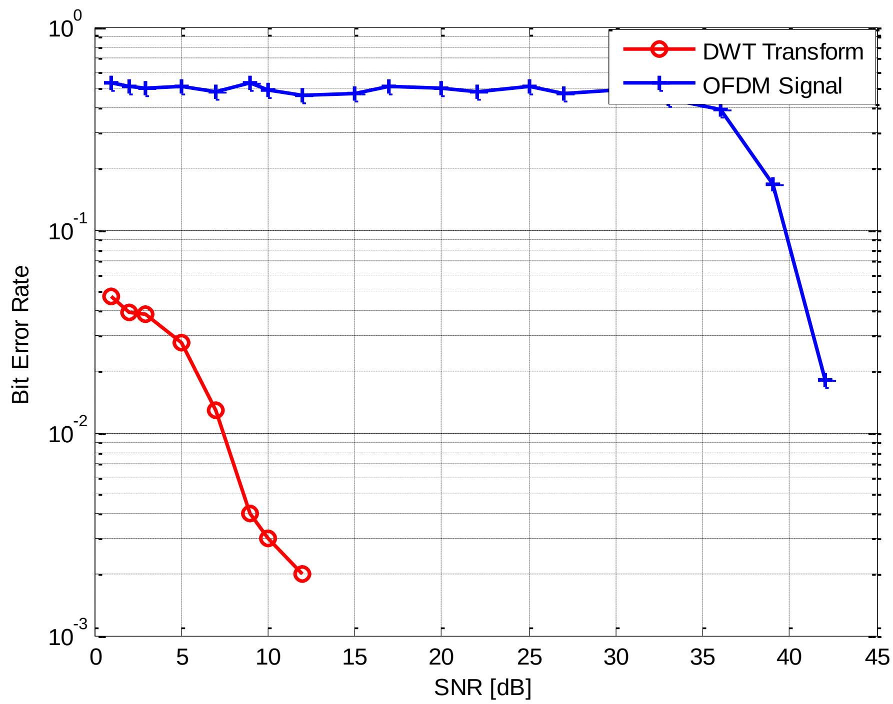


Figure 5.4(b): SNR vs BER of OFDM signal with DWT Transform

Figure 5.4(a) and (b) shows the PAPR and BER of OFDM signal with Transform technique DWT is used and comparison analysis made between the OFDM signal and Transformed signal. PAPR of the OFDM system is 11.5dB approximately and that of Transformed signal it is 7.5dB which is less. This same analysis is made in case of SNR verses BER analysis in which BER of OFDM signal is 42dB approximately and that of Transformed signal it is 12dB approximately which is very less.

5.5 Analysis of OFDM system with Precoding DCT (Discrete Cosine Transform)

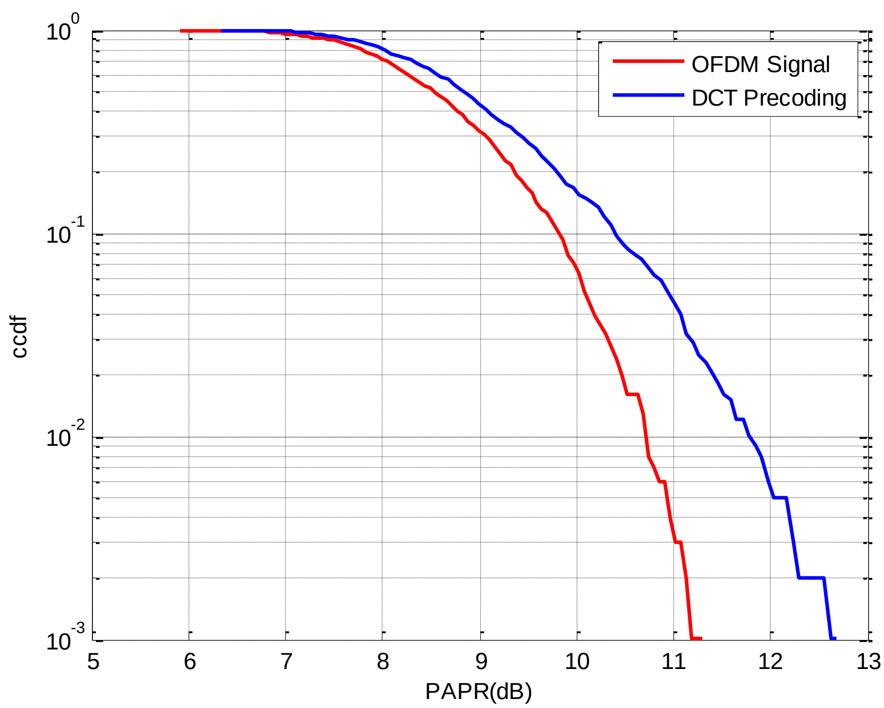


Figure 5.5(a): PAPR vs. CCDF of OFDM signal with DCT Precoding

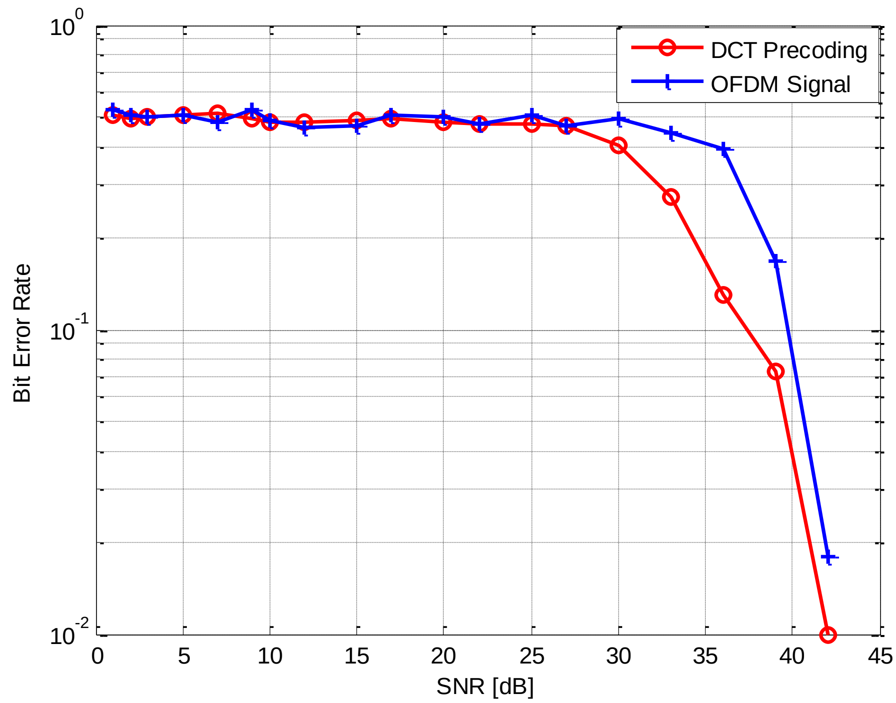


Figure 5.5(b): SNR vs. BER of OFDM signal with DCT Precoding

Figure 5.5(a) and (b) shows the PAPR and BER of OFDM signal with Precoding technique in which DCT Transform is used and comparison analysis made between the OFDM signal and Precoded signal. PAPR of the OFDM system is 11.2dB approximately and that of Transformed signal it is 12.5dB which is more. This same analysis is made in case of SNR verses BER analysis in which BER of OFDM signal is 42dB approximately and that of Precoded signal it is 42dB approximately which is almost same.

5.6 Analysis of OFDM system with Precoding DST (Discrete Sine Transform)

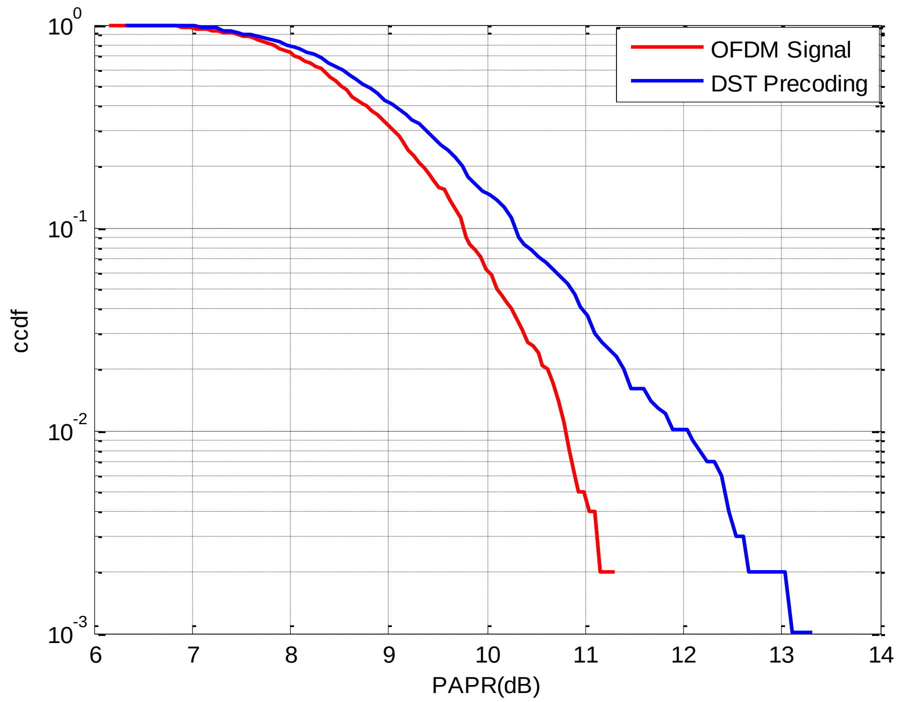


Figure 5.6(a): PAPR of OFDM signal with DST Precoding

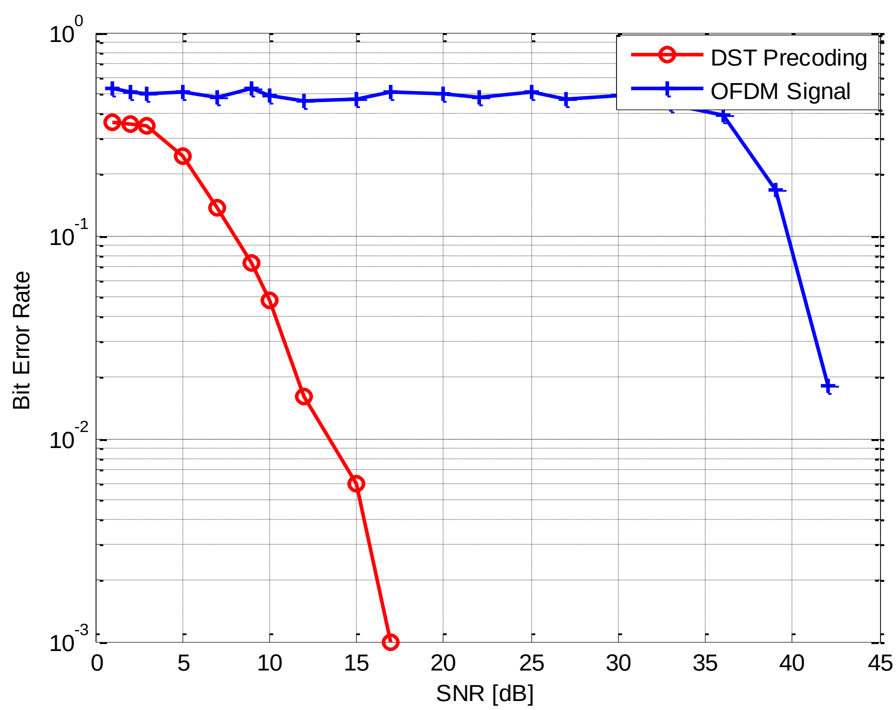


Figure 5.6(b): SNR vs BER of OFDM signal with DST Precoding

Figure 5.6(a) and (b) shows the PAPR and BER of OFDM signal with Precoding technique in which DST Transform is used and comparison analysis made between the OFDM signal and Precoded signal PAPR of the OFDM system is 11.2dB approximately and that of Precoded signal it is 13dB which is more. This same analysis is made in case of SNR verses BER analysis in which BER of OFDM signal is 42dB approximately and that of Precoded signal it is 16dB approximately which is quite less.

5.7 Analysis of OFDM system with Precoded DWT (Discrete Wavelet Transform)

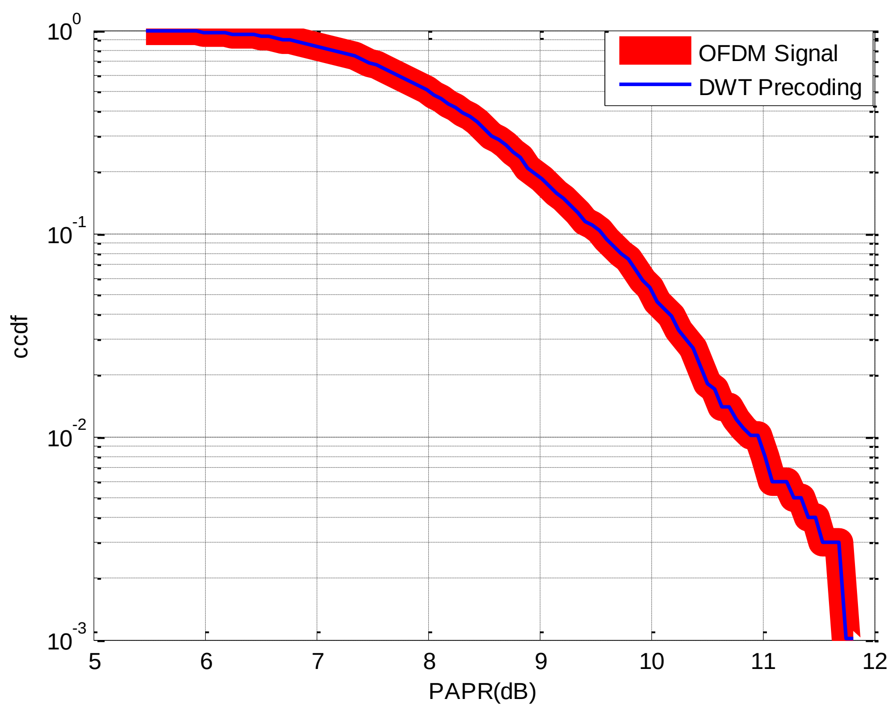


Figure 5.7(a): PAPR vs of OFDM signal with DWT Precoding

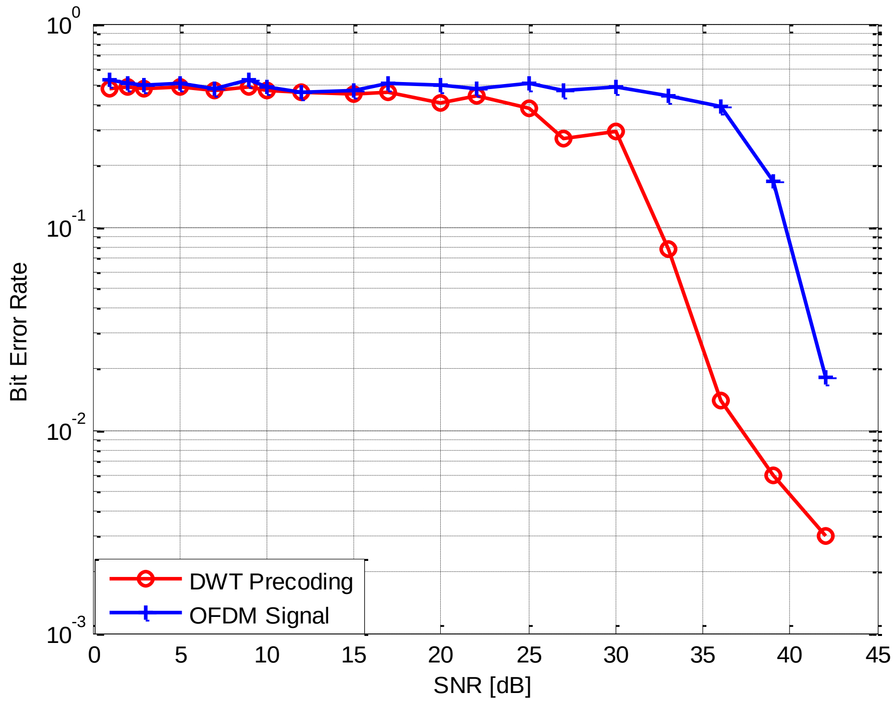


Figure 5.7(b): SNR vs. BER of OFDM signal with DWT Precoding

Figure 5.7(a) and (b) shows the PAPR and BER of OFDM signal with Precoding technique in which DWT Transform is used and comparison analysis made between the OFDM signal and Precoded signal. PAPR of the OFDM system and that of Precoded signal is almost same. This same analysis is made in case of SNR verses BER analysis in which BER of OFDM signal is 45dB approximately and that of Precoded signal it is 42dB approximately which is less.

5.8 Analysis of OFDM system with Precoded DCT with Reduction technique Clipping

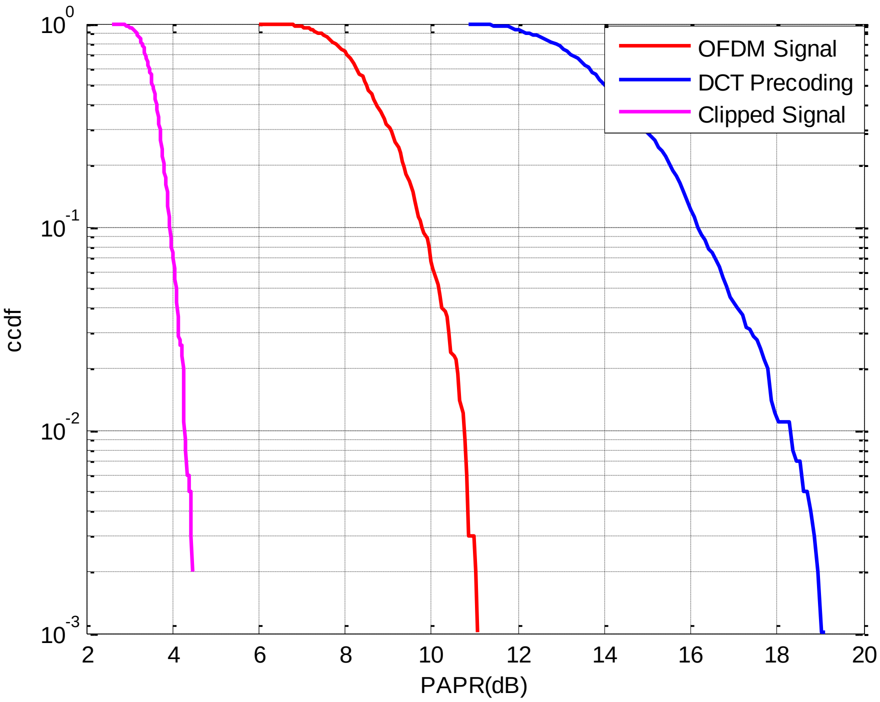


Figure 5.8(a): PAPR vs. of OFDM Signal with Hybrid Clipping and DCT Precoding

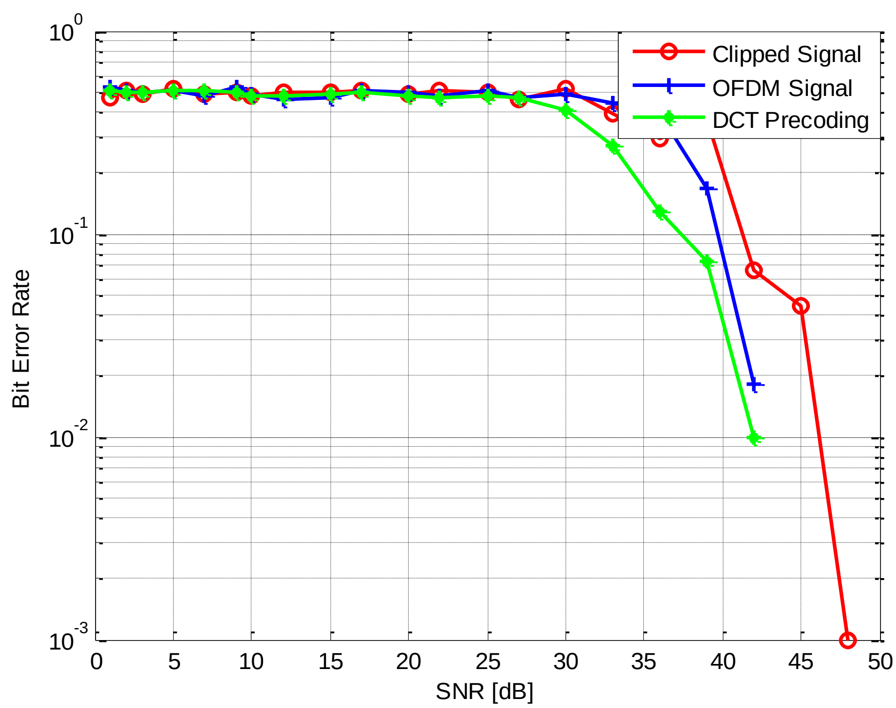


Figure 5.8(b): SNR vs. BER of OFDM Signal with Hybrid Clipping and DCT Precoding

Here, calculating the PAPR of Hybrid technique which is the combination of DCT Precoding and Clipped signal and its comparison is made with OFDM signal. Same process is done for calculating the SNR verses BER analysis. For PAPR, OFDM signal has 11dB value, Clipped has 4dB approximately and DCT Precoding has 19dB value. For BER, OFDM signal has 45dB value, Clipped has 45dB approximately and DCT Precoding has 49dB value.

In preoding IFFT block is not removed so transmitted data is generated by IFFT and after that transform block i.e. DCT transform is performed on the transmitted OFDM signal. PAPR is increased but BER gets lowered down when precoding technique applied on the transmitted signal. So there is always tradeoff between PAPR and BER.To make an efficient system both parameters should have reduced value so no information is lost during the transmission and easily detectable process is carried out for a received signal.

5.9 Analysis of OFDM system with Precoded DST with Reduction technique Clipping

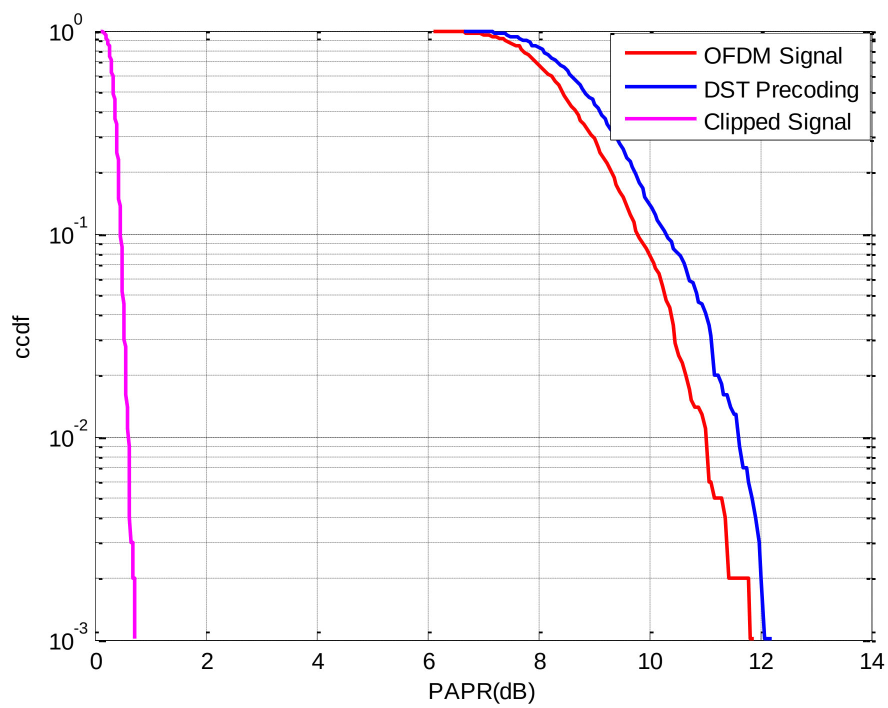


Figure 5.9(a): PAPR vs. CCDF of OFDM Signal with Hybrid Clipping and DST Precoding

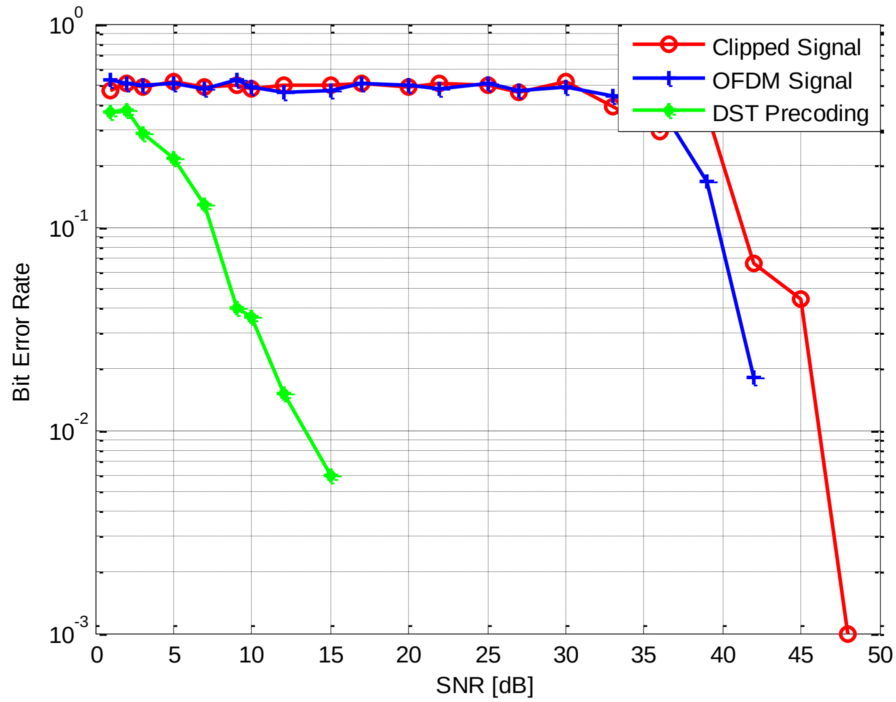


Figure 5.1.9(b): SNR vs PAPR of OFDM Signal with Hybrid Clipping and DST Precoding

Here, calculating the PAPR of Hybrid technique which is the combination of DST Precoding and Clipped signal and its comparison is made with OFDM signal. Same process is done for calculating the SNR verses BER analysis. For PAPR, OFDM signal has 12dB value, Clipped has 1dB approximately and DST Precoding has 12dB value. For BER, OFDM signal has 42dB value, Clipped has 49dB approximately and DST Precoding has 15dB value.

5.10 Analysis of OFDM system with Precoded DWT with Reduction technique Clipping

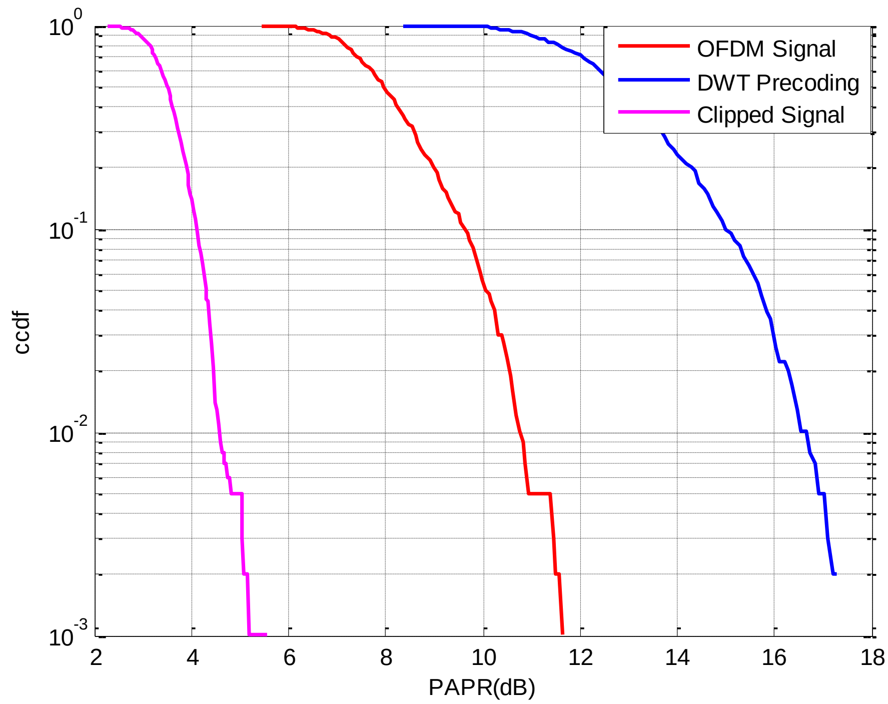


Figure5.10 (a): PAPR vs OFDM Signal with Hybrid Clipping and DWT Precoding

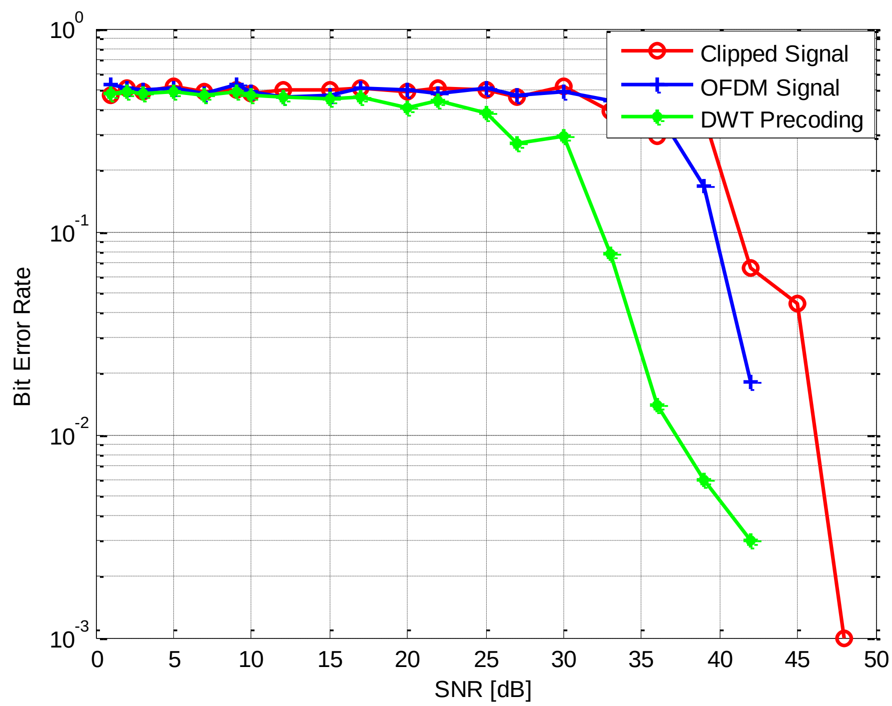


Figure 5.10 (b): SNR vs BER of OFDM Signal with Hybrid Clipping and DWT Precoding

Here, calculating the PAPR of Hybrid technique which is the combination of DWT Precoding and Clipped signal and its comparison is made with OFDM signal. Same process is done for calculating the SNR verses BER analysis. For PAPR, OFDM signal has 11dB value, Clipped has 5dB approximately and DWT Precoding has 17dB value. For BER, OFDM signal has 42dB value, Clipped has 49dB approximately and DWT Precoding has 44dB value.

5.11 Analysis of OFDM system with DCT Transform with Reduction technique Clipping

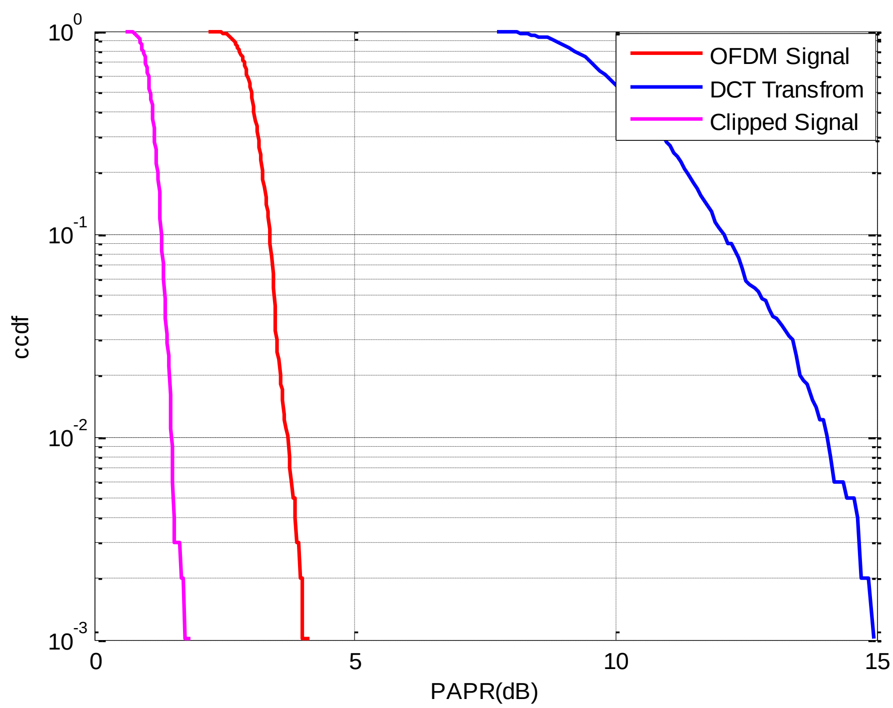


Figure 5.11(a): PAPR vs of OFDM Signal with Hybrid Clipping and DCT Transform

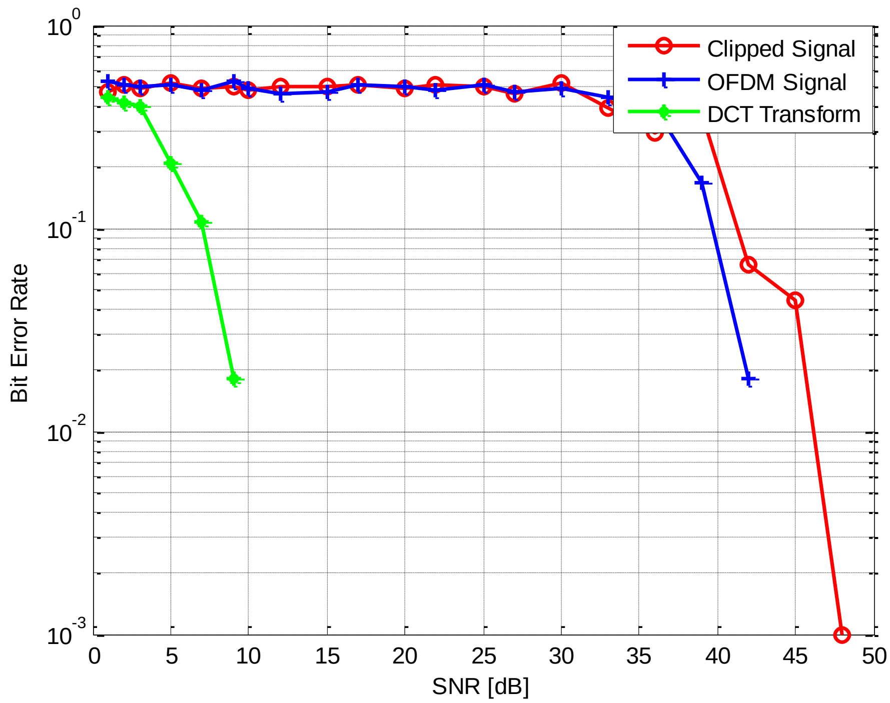


Figure 5.11(b): SNR verse BER of OFDM Signal with Hybrid Clipping and DCT Transform

Here, calculating the PAPR of Hybrid technique which is the combination of DCT transform and Clipped signal and its comparison is made with OFDM signal. Same process is done for calculating the SNR verses BER analysis. For PAPR, OFDM signal has 4dB value, Clipped has 2dB approximately and DCT Transform has 15dB value. For BER, OFDM signal has 42dB value, Clipped has 49dB approximately and DCT Transform has 10dB value.

5.12 Analysis of OFDM system with DWT Transform with Reduction technique Clipping

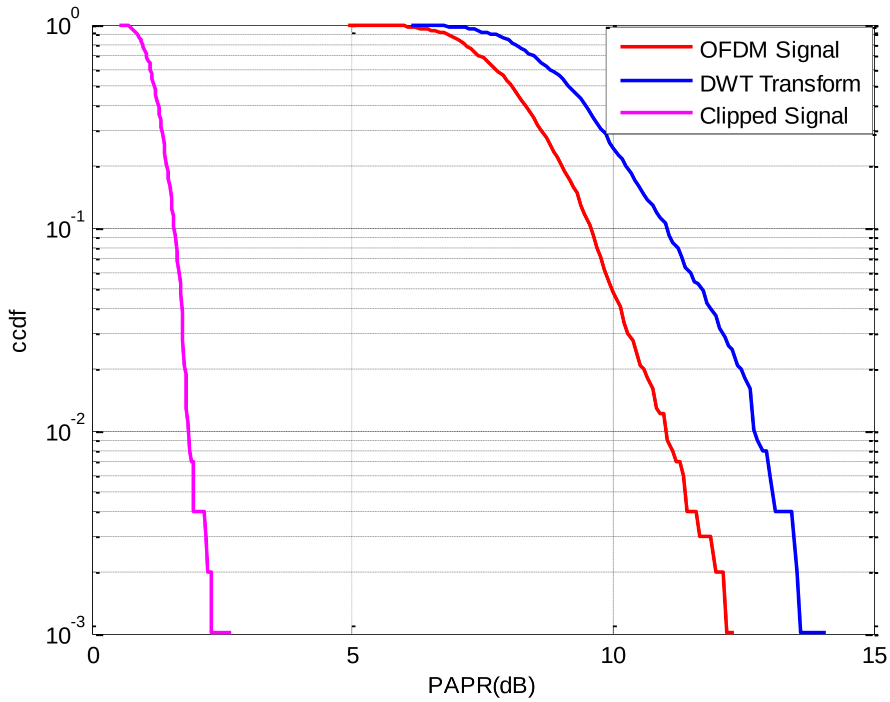


Figure 5.12(a): PAPR vs. of OFDM Signal with Hybrid Clipping and DWT Transform

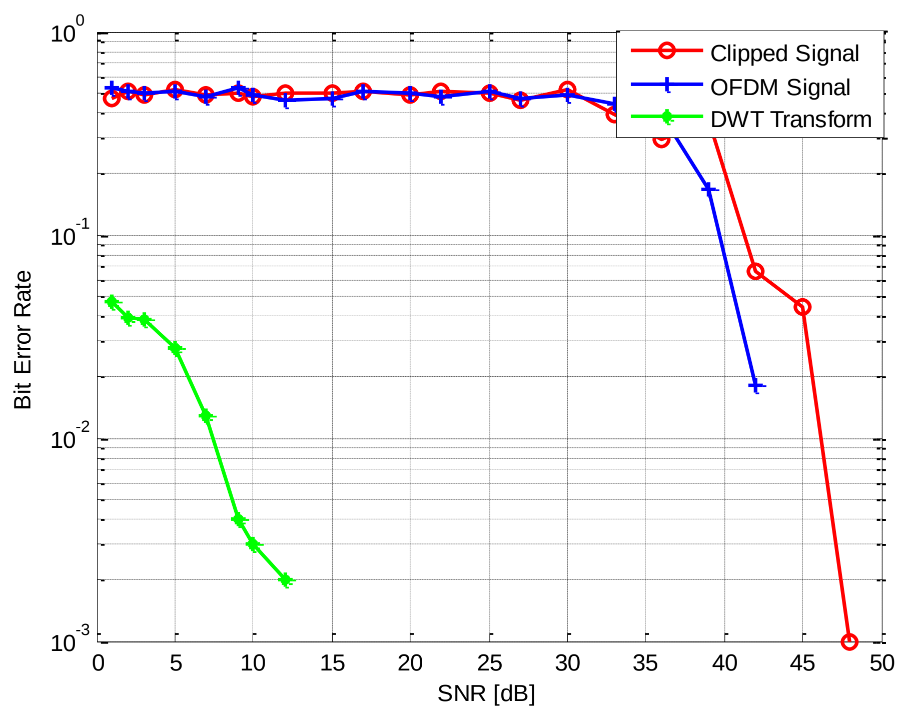


Figure 5.12(b): SNR vs. BER of OFDM Signal with Hybrid Clipping and DWT Transform

Here, calculating the PAPR of Hybrid technique which is the combination of DWT transform and Clipped signal and its comparison is made with OFDM signal. Same process is done for calculating the SNR verses BER analysis. For PAPR, OFDM signal has 12dB value, Clipped has 4dB approximately and DWT Transform has 14dB value. For BER, OFDM signal has 42dB value, Clipped has 49dB approximately and DWT Transform has 12dB value. So with DWT transform PAPR value of a signal is reduced which is the requirement of an efficient OFDM system but with clipped reduction technique BER value is not degrade which lower down the efficiency of a system.

5.2 Analysis with SLM Reduction Technique

5.2.1 Analysis of OFDM system with SLM reduction technique

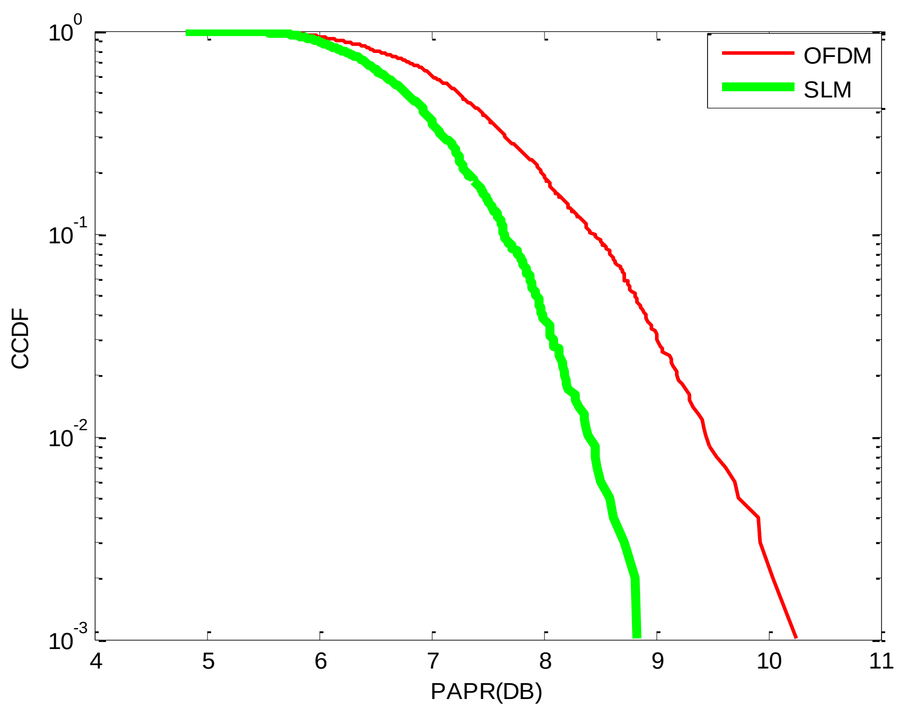


Figure 5.13(a): PAPR vs. CCDF of OFDM Signal with SLM Reduction Technique

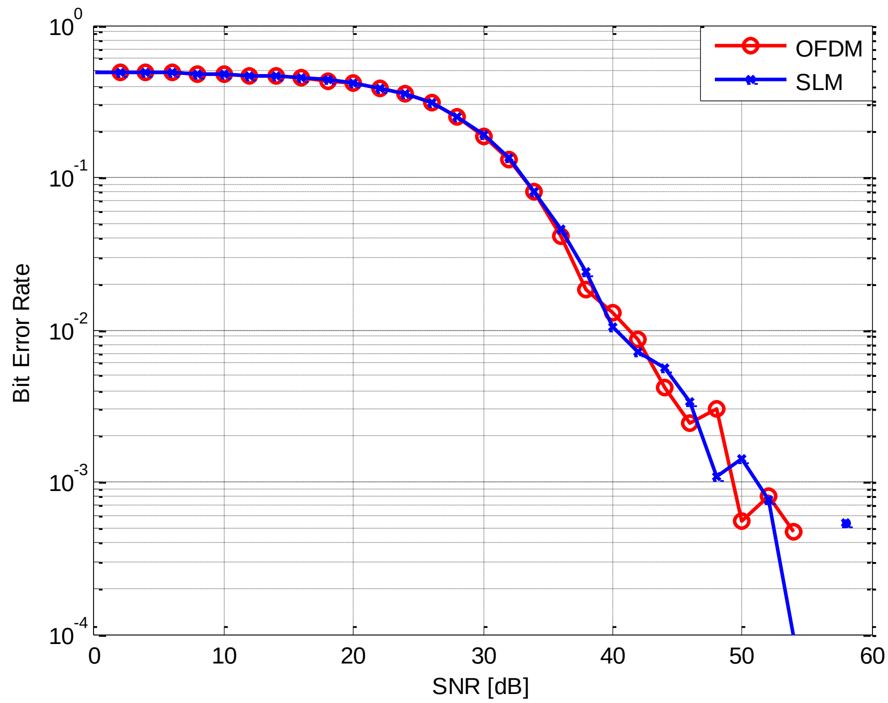


Figure 5.13(b): SNR vs. BER of OFDM with SLM signal

In figure 5.13(a) and (b) recreates the SLM strategy for PAPR and BER. On examination of OFDM signal with SLM flag PAPR is 10.3 dB and 8.7dB roughly which is lesser than the OFDM signal. So by applying the SLM lessening method on the OFDM signal, we improve execution of a signal by dropping down the PAPR of a transmitted signal and BER for SLM is 55dB around which is not exactly helpful for the framework whether PAPR is useful for SLM-based OFDM framework.

5.2.2 Analysis of OFDM with hybrid combination of SLM and diverse transforms

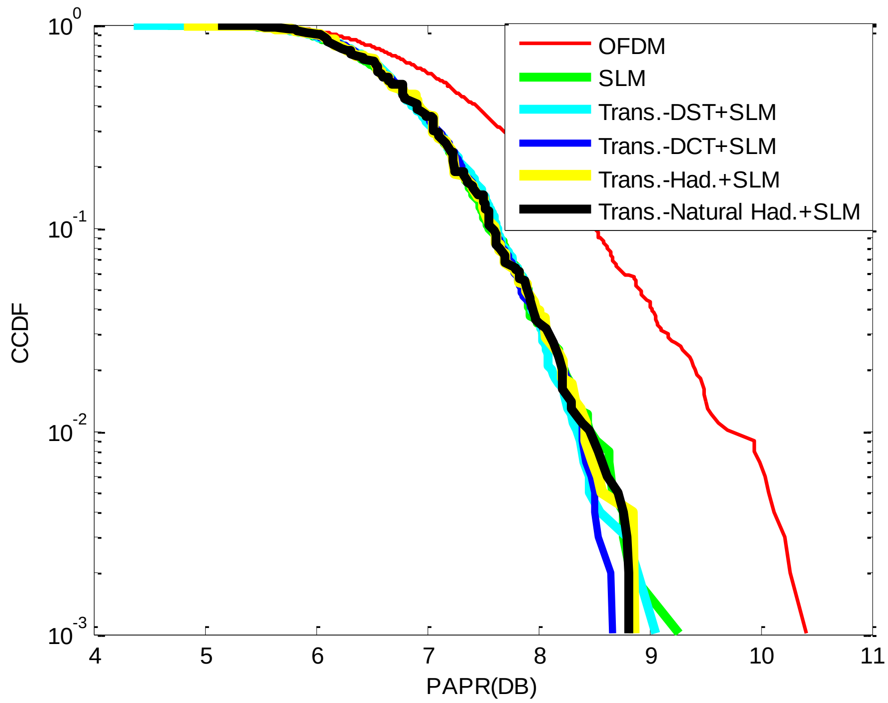


Figure 5.14(a): PAPR vs. CCDF analysis of OFDM with the Hybrid combination of SLM with diverse transforms

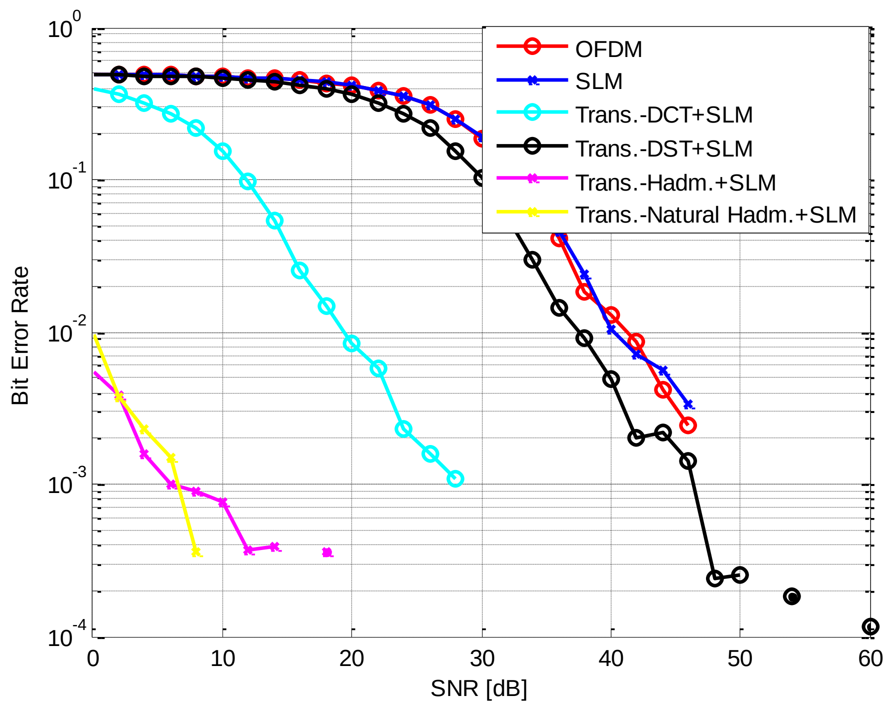


Figure 5.14(b): SNR vs. BER analysis of OFDM with the Hybrid combination of SLM with diverse transforms

Figure 5.14(a) and (b) reenacts the proposed system i.e. Hybrid half SLM with Transform (DCT, DST, Hadamard Transform, Natural Hadamard Transform) which speaks to the PAPR and BER investigation. In this procedure distinctive changes are performed on the SLM information and the collector information backwards operation of the change is performed. No IFFT operation is performed here. PAPR for Hybrid SLM with DST, DCT, Hadamard and natural Hadamard are 9dB, 8.7dB, 8.9dB, 8.8dB individually which is are around same and BER examination for the same are 60dB, 20dB, 30dB, 9dB separately.

5.2.3 Analysis of OFDM with hybrid combination of SLM and precoding technique

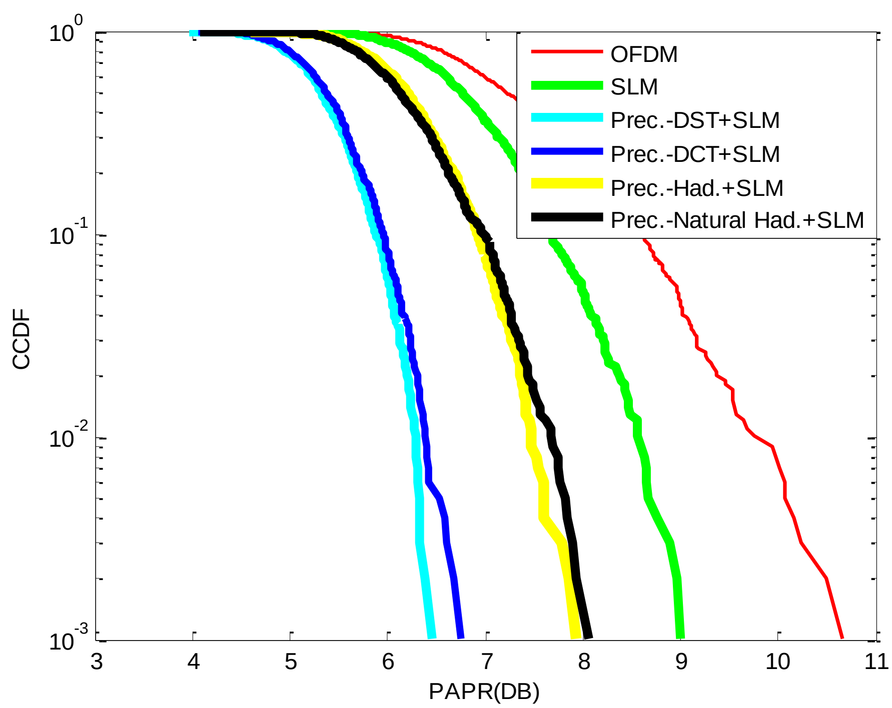


Figure 5.15(a): PAPR vs. CCDF analysis of OFDM with Hybrid combination of SLM and precoding techniques

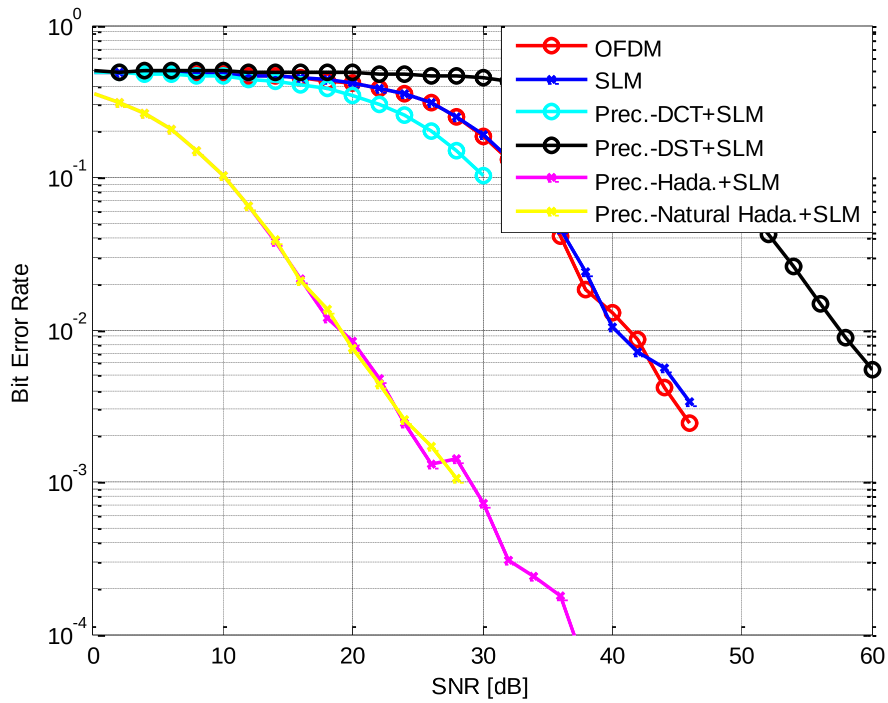


Figure 5.15(b): SNR vs. BER analysis of OFDM with Hybrid combination of SLM and precoding techniques

Figure 5.15(a) and (b) reproduce the proposed method for PAPR and BER examination for the Hybrid procedure which is the mix of decrease strategy SLM with Precoded DCT, DST, Hadamard and natural Hadamard transform. IFFT operation is performed here. PAPR for Hybrid SLM with DST, DCT, Hadamard and natural Hadamard are 6.5dB, 6.8dB, 8dB, 8dB separately and BER investigation for the same are 60dB, 50dB, 38dB, 30dB individually. By applying the precoding, PAPR gets let down on the off chance that we contrast these outcomes with hybrid transorms, yet in the meantime, poor BER results are there.

5.3 Analysis of OFDM system with Companding Technique

5.3.1 Analysis of OFDM with Hybrid Transform Companding

➢ **(a) Simulations With A-law Companding**

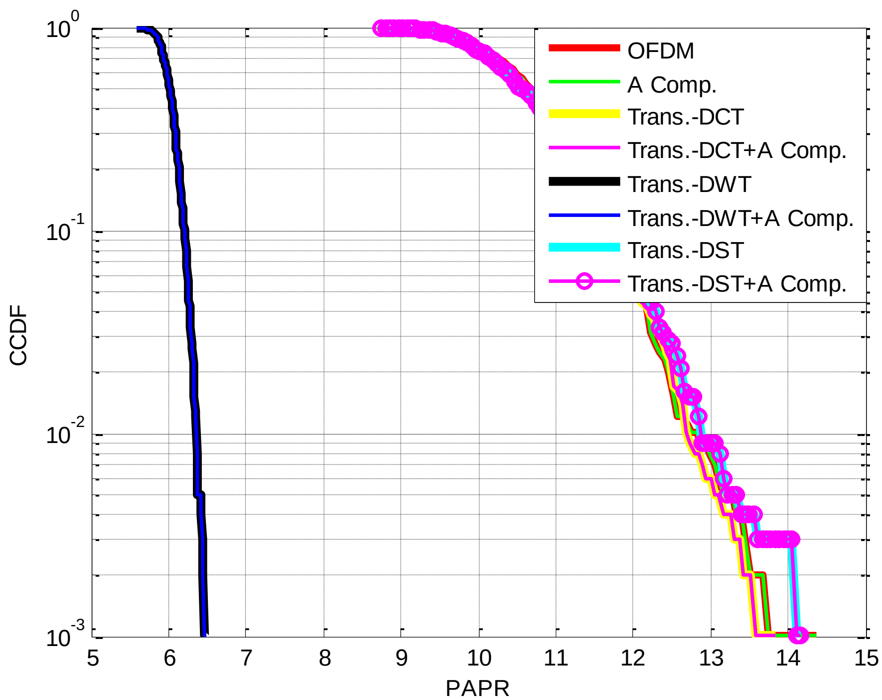


Figure 5.16(a): PAPR vs. CCDF analysis of OFDM with Hybrid A-law Companding with Transforms

In Figure 5.16(a) demonstrates the PAPR and BER execution of different Transforms with A-law Companding and contrast and traditional OFDM. At the point when A-law Companding is done on OFDM signal we get the PAPR roughly same as that of regular OFDM signal i.e. 13.9dB roughly BER for this signal 50dB around which is very high. In the wake of applying the DCT, DST ,DWT Transforms on the OFDM signal we get PAPR 13.5dB, 14dB, 6.5dB separately and BER for these Transforms are 32dB, 50dB, 39dB around.

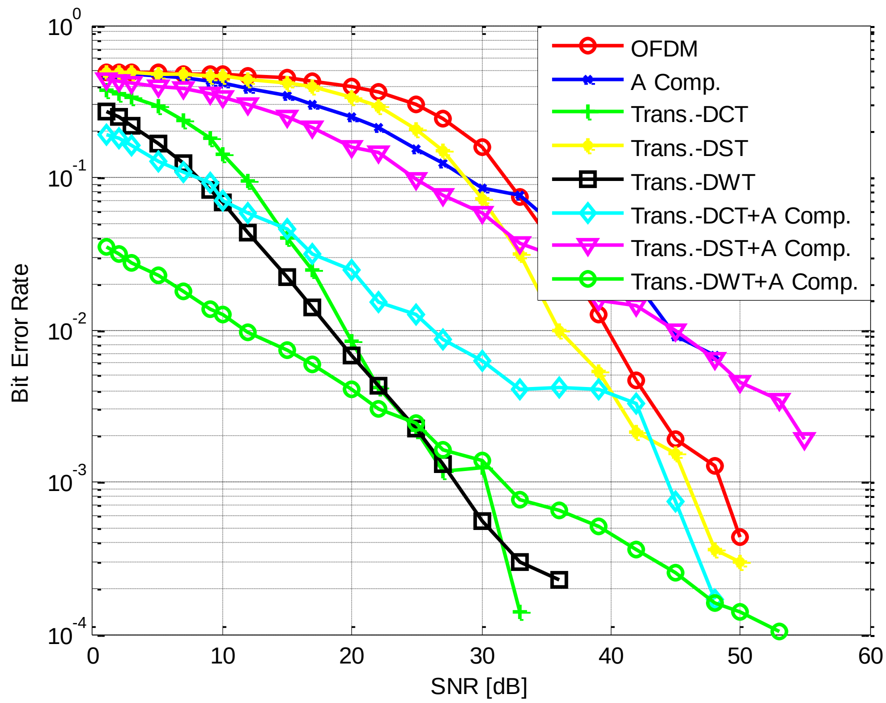


Figure 5.16(b): SNR vs. BER analysis of OFDM with Hybrid A-law Companding with Transforms

So with these BER is decreased when contrasted with customary OFDM. A while later Hybrid method which is proposed system (Combination of A-law Companding with various Transforms) is done on the companded signal having PAPR and BER for Hybrid DCT, DST, DWT with A-law Companding are 13.5dB, 14dB, 6.5dB and 49dB, 55dB, 52dB individually. BER increments at the cost of lessened PAPR which is bad for the framework.

➢ **(b) With µ-law Companding**

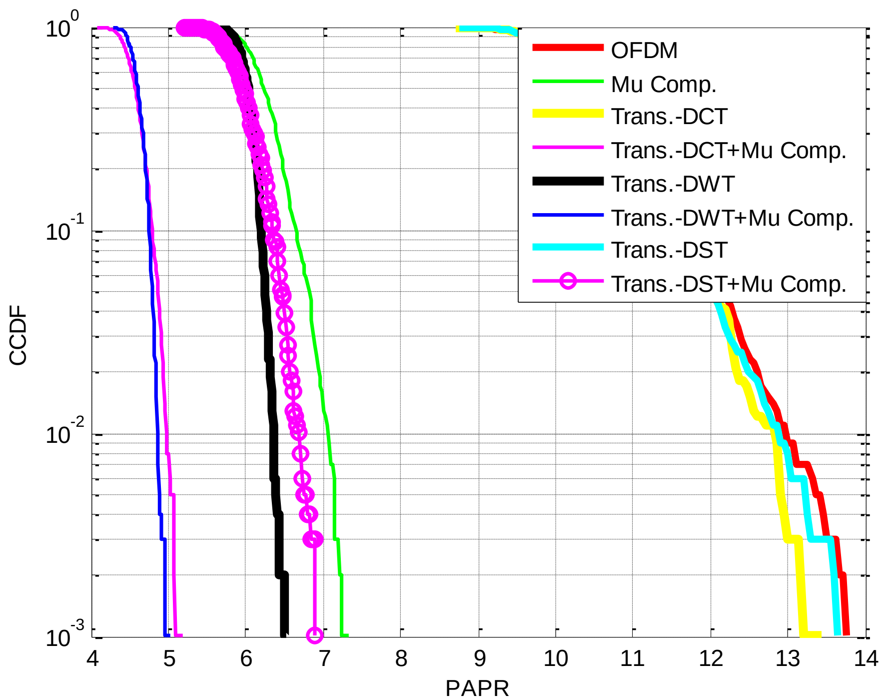


Figure 5.16(c): PAPR vs. CCDF analysis of OFDM with Hybrid Mu-law Companding with Transforms

Same investigation is accomplished for µ-law companding. PAPR and BER for companded signal are 7.3dB and 70dB individually. We get the great PAPR however with high estimation of BER which is not required. So proposed methods are presented. PAPR and BER for changes DCT, DST, DWT are 13.1dB, 13.5dB, 6.5dB and 70dB, 50dB and 39dB roughly. Hybrid schemes of these DCT, DST, DWT transforms with A-law companding BER are 70dB, 70dB, 70dB and PAPR are 5.1dB, 6.9dB, 4.9dB roughly.

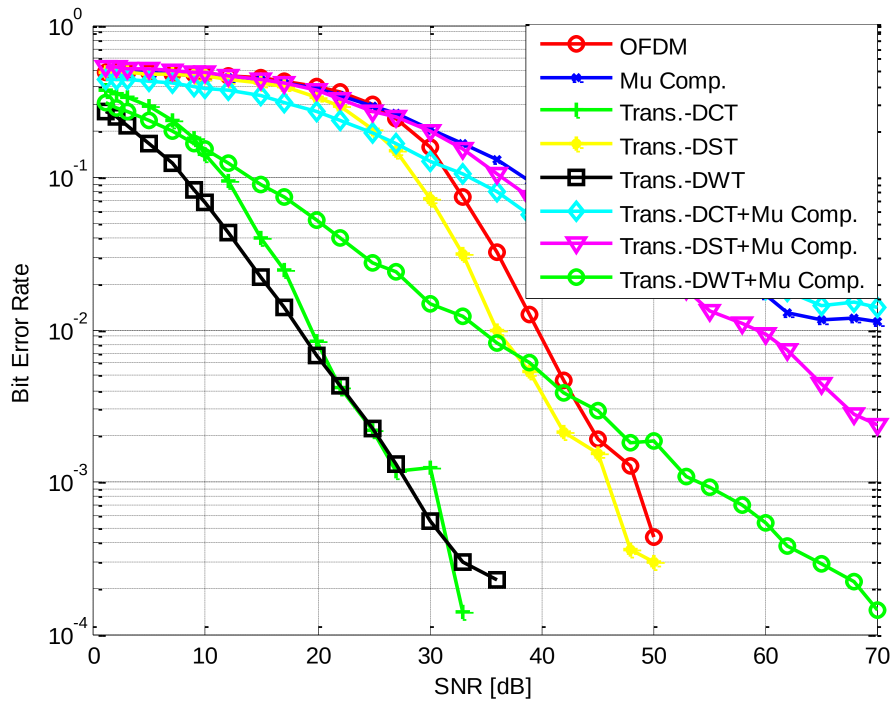


Figure 5.16(d): SNR vs. BER analysis of OFDM with Hybrid A-law Companding with Transforms

5.3.2 Analysis of OFDM with Hybrid Precoding Companding

- **(a) Simulations With A-law Companding**

Hybrid Precoding combination include the combination of Precoding technqies with companding reduction technique. Both blocks IFFT with the combination of different transforms are used here with reduction technique to get the lesser PAPR and BER.

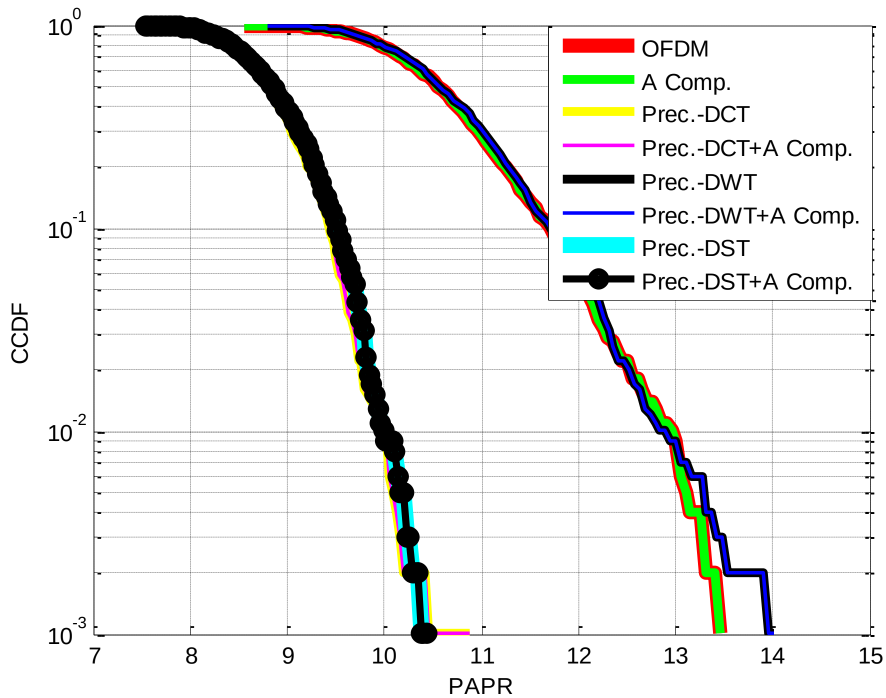


Figure 5.17(a): PAPR vs. CCDF analysis of OFDM with Hybrid A-law Companding with Precoding Techniques

Presently we are assessing the recreation for Hybrid Precoding plans. PAPR for Precoded DCT, DST, DWT are 10.5dB, 14dB, 10.2dB around and for Hybrid DCT, DST, DWT with A-law Companding PAPR are 10.3dB, 14dB, 10.3dB individually. Same recreation is accomplished for BER. BER for Precoded DCT, DST, DWT are 50dB, 70dB, 50dB separately and for Hybrid DCT, DST, DWT with A-law Companding are 50dB, 70dB and 70dB around.

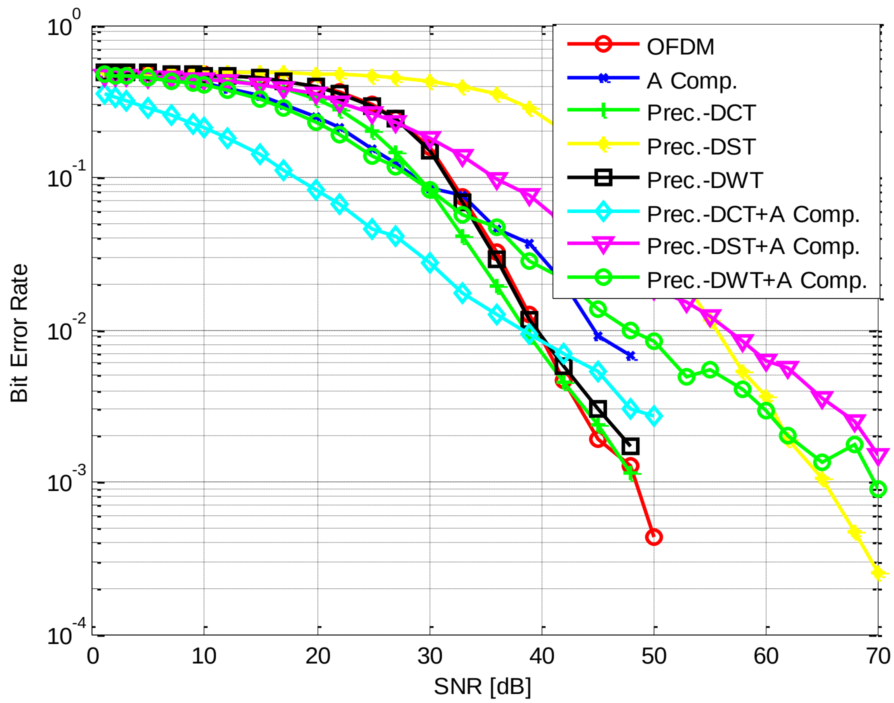


Figure 5.17(b): SNR vs. BER analysis of OFDM with Hybrid A-law Companding with Precoding Techniques

With these one can see that PAPR factor is reduced with some good level but at the same time BER is increases which is not required for efficient OFDM system. Both parameters should be decreased for reliable system

➢ **With μ-law Companding**

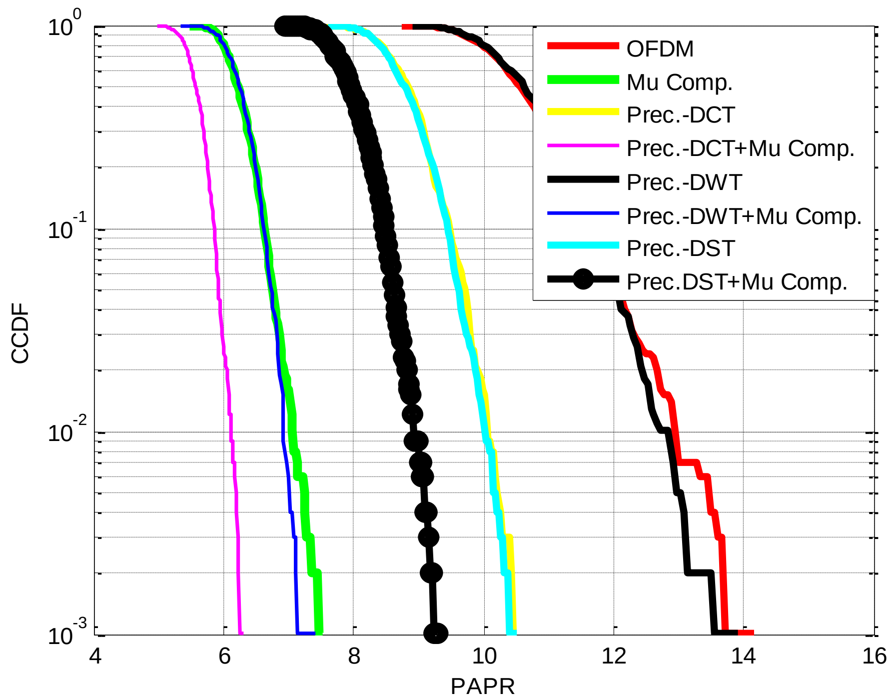


Figure 5.17(c): PAPR vs. CCDF analysis of OFDM with Hybrid Mu-law Companding with Precoding Techniques

Here the analysis for Hybrid Precoding scheme with μ-law Companding is done. For Hybrid DCT, DST, DWT with μ-law Companding PAPR are 6.2dB, 8.8dB, 6.5dB individually. Same procedure is accomplished for BER. BER for Hybrid DCT, DST, DWT with μ-law Companding are 70dB, 70dB and 70dB around.

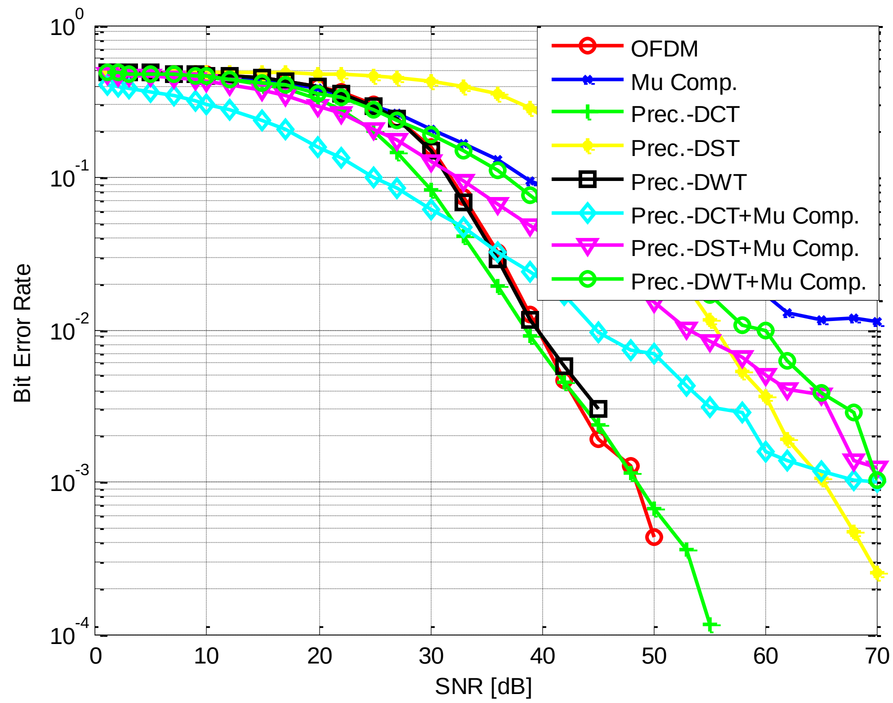


Figure 5.17(d): SNR vs. BER analysis of OFDM with Hybrid Mu-law Companding with Precoding Techniques

CHAPTER 6 CONCLUSION

OFDM is very much attractive scheme for multicarrier transmission as it is known as MCM and has better spectral efficiency, simple deployment of receiver section and high speed data transmission up to 100mbps over a communication channel. Every scheme has pros and cons so its main disadvantage is a very high PAPR. In this project different techniques are elaborated to overcome this problem but as in some techniques we get reduced PAPR then at the same time high BER is there which is not a useful for conventional system.

Clipping scheme is the most straightforward approach to lessen the PAPR however huge number of iterations is required to restrict out-of-band radiation and to accomplish wanted PAPR level. Clipping technique is easiest for implementation but tradeoff between PAPR and BER is there. For clipping alone PAPR is 2dB but at the same time 49dB BER is there. To maintain the balance between the PAPR and BER with clipping Transforms are used . Among DCT, DWT transforms both are having low PAPR values when used with the reduction technique clipping i.e. 2dB and 3dB respectively but BER for this combination is 49dB for both the transforms which is not acceptable. Further Precoding techniques with the combination of Clipping technique is used which is known s hybrid system and DWT is the best among DCT and DST which give PAPR 7.2dB and BER is 12dB in a hybrid system. Next SLM is done for this same analysis and natural Hadamard transform is good when combined with SLM technique as it gives the PAPR and BER values 8.7dB and 10dB respectively. For Hybrid precoding system with SLM again tradeoff is there between PAPR and BER. To reduce the complexity in SLM next analysis is done with companding. With the combination of A-law companding with different transforms (DCT, DST, DWT) DWT give the best .is the best value of PAPR i.e. 6.2 but worst value of BER i.e. 52dB. With Mu-law same thing is happened there. DWT is also best here but in PAPR only. Next comes for Hybrid Precoding with A-law DST give the best PAPR value of 10.2dB but worst value of BER of 70dB and for Mu-law same thing is happened in this case also DCT is having best PAPR but poor BER value.

In future filteration, tone rejection, block coding, interleaving reduction techniques can be used with different precoding as well as transforms to counterbalance between BER and PAPR.

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