OFDM SYSTEMS AND PAPR REDUCTION TECHNIQUES IN OFDM SYSTEMS

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Rourkela

CERTIFICATE

This is to certify that the thesis entitled **"OFDM Systems and PAPR Reduction Techniques in OFDM Systems"** submitted by **Abhishek Arun Dash** and **Vishal Gagrai** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in **Electronics & Communication Engineering** at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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ABSTRACT

Communication is one of the important aspects of life. With the advancement in age and its growing demands, there has been rapid growth in the field of communications. Signals, which were initially sent in the analog domain, are being sent more and more in the digital domain these days. For better transmission, even single – carrier waves are being replaced by multi – carriers. Multi – carrier systems like CDMA and OFDM are now – a – days being implemented commonly. In the OFDM system, orthogonally placed sub – carriers are used to carry the data from the transmitter end to the receiver end. Presence of guard band in this system deals with the problem of ISI and noise is minimized by larger number of sub – carriers. But the large Peak – to – Average Power Ratio of these signal have some undesirable effects on the system.

In this thesis we have focused on learning the basics of an OFDM System and have undertaken various methods to reduce the PAPR in the system so that this system can be used more commonly and effectively.

Keywords: OFDM, IDFT, ISI, ICI, PAPR, Cyclic Prefix, CCDF, Amplitude Clipping & Filtering, SLM, PTS.

CONTENTS

LIST OF ACRONYMS

AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CDF	Cumulative Distribution Function
CCDF	Complementary Cumulative Distribution Function
DFT	Discrete Fourier Transform
FFT	Fast Fourier Transform
ICI	Inter Carrier Interference
IDFT	Inverse Discrete Fourier Transform
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
OFDM	Orthogonal Frequency Division Multiplexing
PAPR	Peak – to – Average Power Ratio
QPSK	Quadrature Phase Shift Keying
SNR	Signal – to – Noise Ratio

LIST OF FIGURES

Chapter – 1

INTRODUCTION

INTRODUCTION

1.1 INTRODUCTION

Since the very genesis of man, communication has been one of the main aspects in human life .Previously various methods like sign languages were implemented for this purpose. As various civilizations started coming into existence, many innovative ideas came to the minds of the people – special birds and human messengers were employed to meet these challenges. As ages rolled by, post system developed and transportation vehicles like trains and ships were used to maintain link between people miles apart. But by the turn of the nineteenth century, a great leap in communication system was observed when wireless communication was introduced.

After the advent of wireless communication huge change has been observed in the lifestyle of people.

Wireless communication which was initially implemented analog domain for transfer has is now-a-days mostly done in digital domain. Instead of a single carrier in the system multiple sub-carriers are implemented to make the process easier.

1.2 ELECTRONIC COMMUNICATION SYSTEM

Electronics communication system has revolutionized the face of the world. Communication with someone a mere century back was only possible by physical mode. But now that can be done just by clicking a switch on the telephone pad or by just a click of the mouse. Even live television report, live games telecast could not be possible without wireless communication.

A simple communication system consists of a transmitter end which send the data and a receiver end at which the data is received. Usually there received data is not the same as the data sent. Because of the noise present in the medium the signal gets affected and distortion is observed in the signal. Various modulation techniques are under taken in order to ensure that the signal sent is safely available at the receiver end.

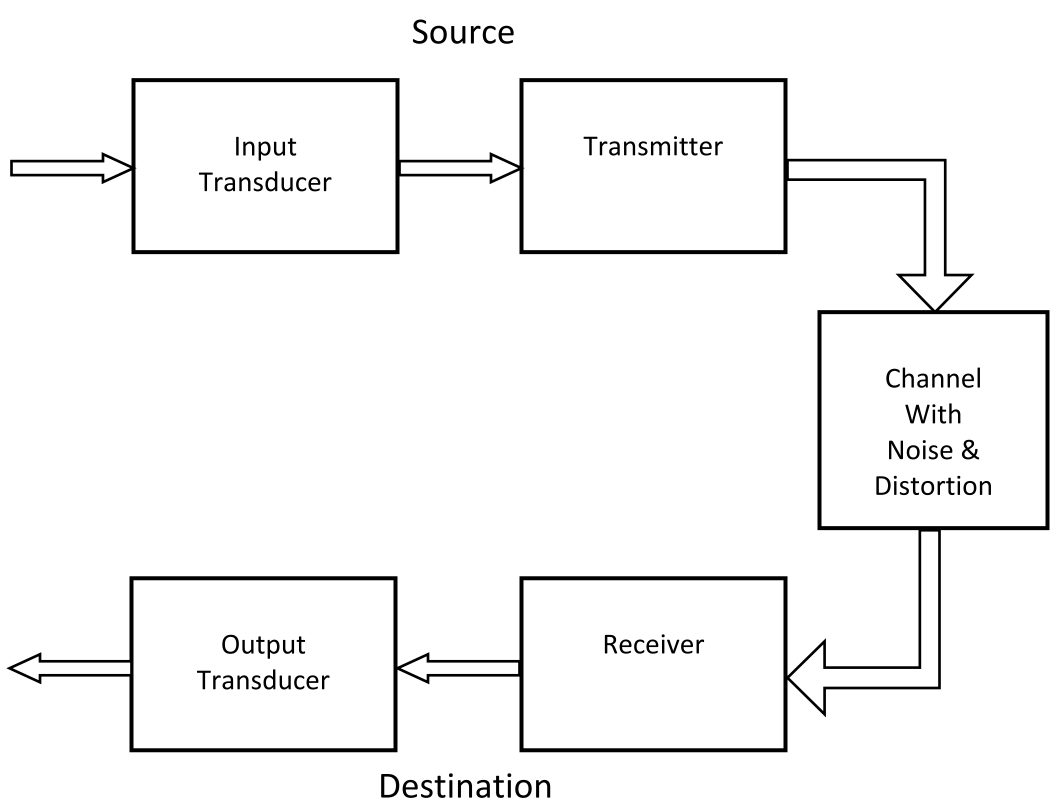


Fig 1.1 A block diagram representation of electronic communication system

Chapter – 2

BASICS

BASICS

2.1 INTRODUCTION

In this chapter we deal with the basic fundamentals and methods implemented in order to achieve a deeper knowledge on OFDM Systems. These basic terminologies, although not exclusively used for OFDM Systems, form a basic foundation for general Digital Communication Systems.

2.2 CONVOLUTION

Convolution is the process by which the output of a system can be determined. One of the signals is time reversed, shifted, multiplied with another signal and finally integrated to generate the output signal in this process. Mathematically, it is represented as

$$w(t) = v(t) \otimes h(t) = \int_{-\infty}^{+\infty} v(\tau)h(t-\tau)d\tau$$

Linear time invariant systems obey the above rules.

2.3 DISCRETE FOURIER TRANSFORM

In many occasions signals are available in a set of N sample values, taken at regularly spaced intervals, T_s over a time period of T_0. So it is desirable to have some approximate idea about the signal spectral content by interpreting its interval space and time period. For this, it is assumed that the signal is periodic (time period T_0.) and the Nyquist criterion is satisfied for sampling period. For simplicity, even number of samples are assumed and symmetrically placed across the origin. The location of sample values are $\pm T_s/2$, $\pm 3T_s/2$ etc.

If the waveform to be sampled is *m(t)*, we obtain *m(t)S(t)* after sampling, where S(t) is the sampling function. The amplitude of the spectrum of *m(t)S(t)* is given by:

$$M_n = \frac{1}{T}\int_{-T_0/2}^{T_0/2} m(t)e^{-j2\pi nt/T_0}dt$$

Similarly, the value of M_n can be computed for all *N* samples. The period of the highest frequency component should be $2T_s$.

2.4 MULTIPATH CHANNELS

The transmitted signal faces various obstacles and surfaces of reflection, as a result of which the received signals from the same source reach at different times. This gives rise to the formation of 'echoes' which affect the other incoming signals. Dielectric constants, permeability, conductivity and thickness are the main factors affecting the system.

Multipath channel propagation is devised in such a manner that there will be a minimized effect of the echoes in the system in an indoor environment. Measures are needed to be taken in order to minimize echo in order to avoid ISI.

Fig 2.1 Multipath Channel Propagation

Chapter – 3

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

3.1 INTRODUCTION

With the ever growing demand of this generation, need for high speed communication has become an utmost priority. Various multicarrier modulation techniques have evolved in order to meet these demands, few notable among them being Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). Orthogonal Frequency Division Multiplexing is a frequency – division multiplexing (FDM) scheme utilized as a digital multi – carrier modulation method. A large number of closely spaced orthogonal sub – carriers is used to carry data. The data is divided into several parallel streams of channels, one for each sub – carriers. Each sub – carrier is modulated with a conventional modulation scheme (such as QPSK) at a low symbol rate, maintaining total data rates similar to the conventional single carrier modulation schemes in the same bandwidth.

3.2 DEVELOPMENT OF OFDM SYSTEMS

The development of OFDM systems can be divided into three parts. This comprises of Frequency Division Multiplexing, Multicarrier Communication and Orthogonal Frequency Division Multiplexing.

3.2.1 Frequency Division Multiplexing

Frequency Division Multiplexing is a form of signal multiplexing which involves assigning non – overlapping frequency ranges or channels to different signals or to each 'user' of a medium. A gap or guard band is left between each of these channels to ensure that the signal of one channel does not overlap with the signal from an adjacent one. Due to lack of digital filters it was difficult to filter closely packed adjacent channels.

3.2.2 Multicarrier Communication

As it is ineffective to transfer a high rate data stream through a channel, the signal is split to give a number of signals over that frequency range. Each of these signals are individually modulated and transmitted over the channel. At the receiver end, these signals are fed to a de – multiplexer where it is demodulated and re – combined to obtain the original signal.

3.3 OFDM THEORY

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other.

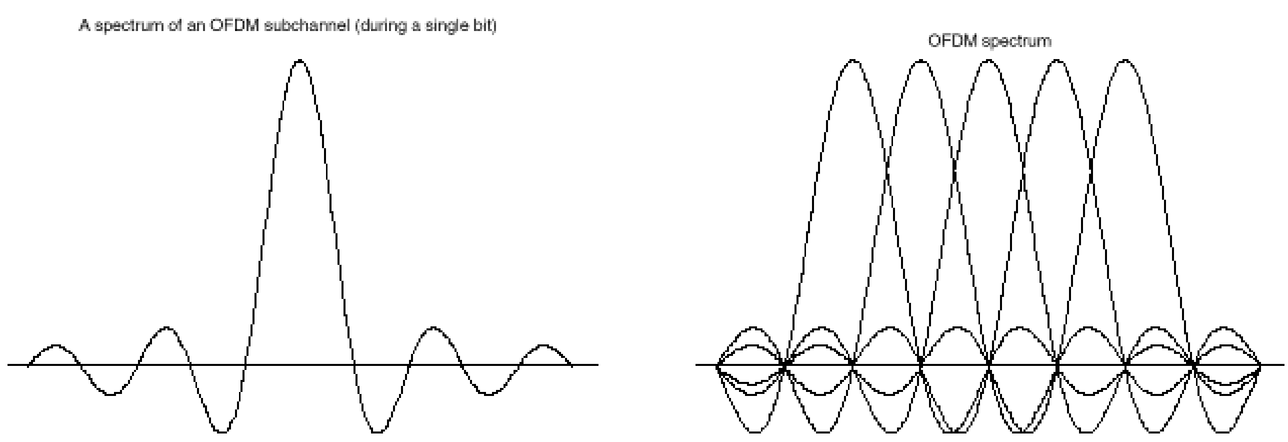


Fig 3.1 OFDM Spectrum

3.3.1 Orthogonality

Two periodic signals are orthogonal when the integral of their product over one period is equal to zero.

For the case of continuous time:

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)dt = 0,$$

For the case of discrete time:

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right)\cos\left(\frac{2\pi km}{N}\right) dt = 0,$$

where $m \neq n$ in both cases.

3.3.2 Sub – Carriers

Each sub – carrier in an OFDM system is a sinusoid with a frequency that is an integer multiple of a fundamental frequency. Each sub – carrier is like a Fourier series component of the composite signal, an OFDM symbol.

The sub – carriers waveform can be expressed as –

$$s(t) = \cos(2\pi f_c t + \theta_k)$$
$$= a_n \cos(2\pi n f_0 t) + b_n \sin(2\pi n f_0 t)$$
$$= \sqrt{a_n^2 + b_n^2}\cos(2\pi n f_0 t + \varphi_n),$$

Where $\varphi_n = \tan^{-1}(\frac{b_n}{a_n})$

The sum of the sub – carriers is then the baseband OFDM signal:

$$s_B(t) = \sum_{n=0}^{N-1}\{a_n \cos(2\pi n f_0 t) - b_n \sin(2\pi n f_0 t)\}$$

3.3.3 Inter – Symbol Interference

Inter – symbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI is usually caused by multipath propagation or the inherent non – linear frequency response of a channel causing successive symbols to 'blur' together. The presence of ISI in the system introduces error in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI and thereby deliver the digital data to its destination with the smallest error rate possible.

3.3.4 Inter – Carrier Interference

Presence of Doppler shifts and frequency and phase offsets in an OFDM system causes loss in orthogonality of the sub – carriers. As a result, interference is observed between sub – carriers. This phenomenon is known as inter – carrier interference (ICI) .

3.3.5 Cyclic Prefix

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation [1].

The cyclic prefix has to two important benefits –

- ♦ The cyclic prefix acts as a guard interval. It eliminates the inter – symbol interference from the previous symbol.
- ♦ It acts as a repetition of the end of the symbol thus allowing the linear convolution of a frequency – selective multipath channel to be modeled as circular

convolution which in turn maybe transformed to the frequency domain using a discrete fourier transform. This approach allows for simple frequency – domain processing such as channel estimation and equalization.

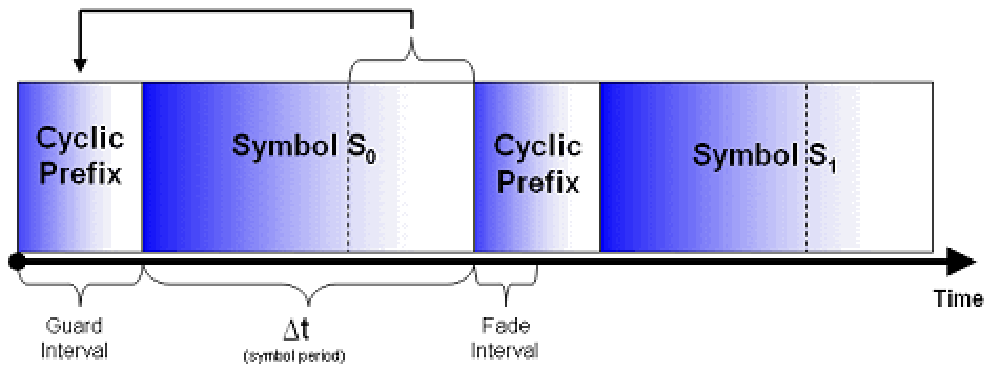


Fig. 3.2 Cyclic Prefix

3.3.6 Inverse Discrete Fourier Transform

By working with OFDM in frequency domain the modulated QPSK data symbols are fed onto the orthogonal sub-carriers. But transfer of signal over a channel is only possible in its time-domain. For which we implement IDFT which converts the OFDM signal in from frequency domain to time domain.

IDFT being a linear transformation can be easily applied to the system and DFT can be applied at the receiver end to regain the original data in frequency domain at the receiver end. Since the basis of Fourier transform is orthogonal in nature we can implement to get the time domain equivalent of the OFDM signal from its frequency components.

Usually, in practice instead of DFT and IDFT we implement Fast Fourier Transformation for an N-input signal system because of the lower hardware complexity of the system.

3.4 MODULATION & DEMODULATION IN OFDM SYSTEMS

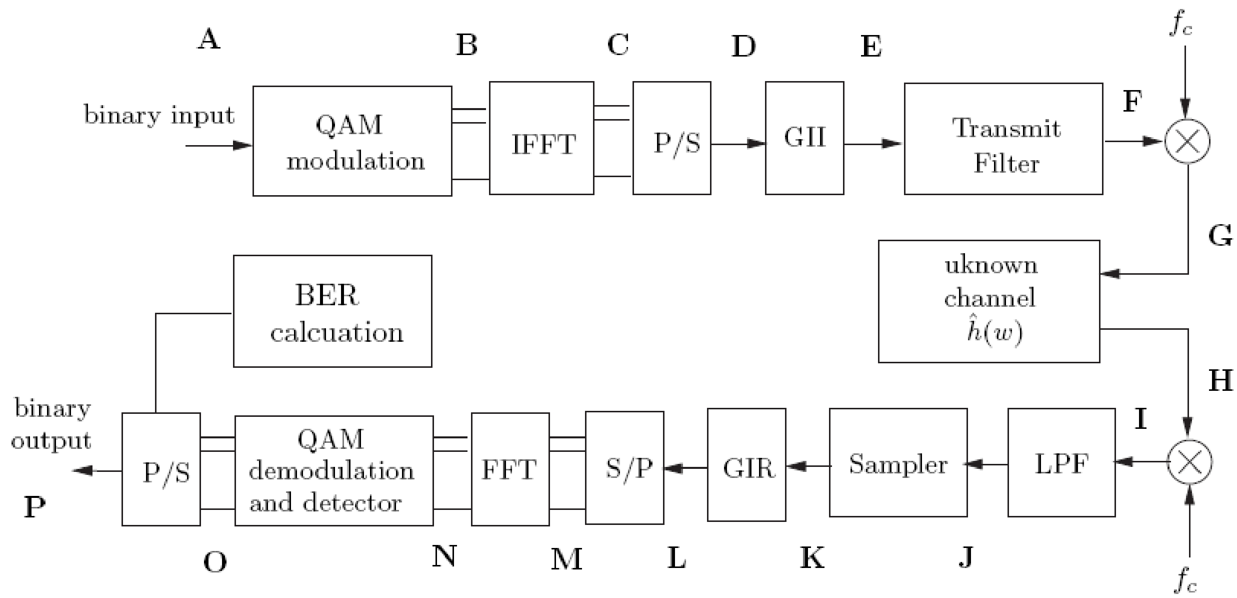


Fig. 3.3 OFDM Block Diagram

3.4.1 Modulation

Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. In an OFDM system, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique (QPSK). After this, IFFT is performed on the modulated signal which is further processed by passing through a parallel – to – serial converter. In order to avoid ISI we provide a cyclic prefix to the signal.

3.4.2 Communication Channel

This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

3.4.3 Demodulation

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed. FFT of the signal is done after it is made to pass through a serial – to – parallel converter. A demodulator is used, to get back the original signal.

The bit error rate and the signal – to – noise ratio is calculated by taking into consideration the un – modulated signal data and the data at the receiving end.

3.5 ADVANTAGES & DISADVANTAGES OF AN OFDM SYSTEM

Advantages

- Due to increase in symbol duration, there is a reduction in delay spread. Addition of guard band almost removes the ISI and ICI in the system.
- Conversion of the channel into many narrowly spaced orthogonal sub – carriers render it immune to frequency selective fading.
- As it is evident from the spectral pattern of an OFDM system, orthogonally placing the sub – carriers lead to high spectral efficiency.
- Can be efficiently implemented using IFFT.

Disadvantages

- These systems are highly sensitive to Doppler shifts which affect the carrier frequency offsets, resulting in ICI.
- Presence of a large number of sub – carriers with varying amplitude results in a high Peak – to – Average Power Ratio (PAPR) of the system, which in turn hampers the efficiency of the RF amplifier.

Chapter – 4

PEAK – TO – AVERAGE POWER RATIO: AN OVERVIEW

PEAK – TO – AVERAGE POWER RATIO: AN OVERVIEW

4.1 INTRODUCTION

OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non – linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system. A large PAPR increases the complexity of the analog – to – digital and digital – to – analog converter and reduces the efficiency of the radio – frequency (RF) power amplifier [3,6]. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value [3].

There are a number of techniques to deal with the problem of PAPR. Some of them are ‘amplitude clipping’, ‘clipping and filtering’, ‘coding’, ‘partial transmit sequence (PTS)’, ‘selected mapping (SLM)’ and ‘interleaving’. These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on [3].

4.2 PEAK – TO – AVERAGE POWER RATIO

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal.

The major disadvantages of a high PAPR are-

1. Increased complexity in the analog to digital and digital to analog converter.

2. Reduction is efficiency of RF amplifiers.

4.3 PAPR OF A MULTICARRIER SIGNAL

Let the data block of length N be represented by a vector $\boldsymbol{X} = [X_0, X_1, \dots, X_{N-1}]^T$. Duration of any symbol X_k in the set $\boldsymbol{X}$ is T and represents one of the sub – carriers $\{ f_n,\ n = 0, 1, \dots, N-1\}$ set. As the N sub – carriers chosen to transmit the signal are orthogonal to each other, so we can have $f_n = n\Delta f$, where $n\Delta f = 1/NT$ and NT is the duration of the OFDM data block $\boldsymbol{X}$. The complex data block for the OFDM signal to be transmitted is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n . e^{j2\pi n\Delta f t}, \qquad 0 \le t \le NT,$$

The PAPR of the transmitted signal is defined as

$$PAPR = \frac{\max\limits_{0 \le t < NT} |x(t)|^2}{1/NT \int_0^{NT} |x(t)|^2 dt}$$

Reducing the *max*|*x(t)*| is the principle goal of PARP reduction techniques. Since, discrete- time signals are dealt with in most systems, many PAPR techniques are implemented to deal with amplitudes of various samples of *x(t)*. Due to symbol spaced output in the first equation we find some of the peaks missing which can be compensated by oversampling the equation by some factor to give the true PAPR value.

4.4 CUMULATIVE DISTRIBUTION FUNCTION

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

By implementing the Central Limit Theorem for a multi – carrier signal with a large number of sub-carriers, the real and imaginary part of the time – domain signals have a mean of zero and a variance of 0.5 and follow a Gaussian distribution. So Rayleigh distribution is followed for the amplitude of the multi – carrier signal, where as a central chi-square distribution with two degrees of freedom is followed for the power distribution of the system.

The CDF of the amplitude of a signal sample is given by

$$F(z) = 1 - \exp(z)$$

The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques. This is given by

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

Chapter – 5

PAPR REDUCTION TECHNIQUES

PAPR REDUCTION TECHNIQUES

5.1 INTRODUCTION

PAPR reduction techniques vary according to the needs of the system and are dependent on various factors. PAPR reduction capacity, increase in power in transmit signal, loss in data rate, complexity of computation and increase in the bit-error rate at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system. [3].

The PAPR reduction techniques on which we would work upon and compare in our later stages are as follows:

- **AMPLITUDE CLIPPING AND FILTERING**
  A threshold value of the amplitude is set in this process and any sub-carrier having amplitude more than that value is clipped or that sub-carrier is filtered to bring out a lower PAPR value.

- **SELECTED MAPPING**
  In this a set of sufficiently different data blocks representing the information same as the original data blocks are selected. Selection of data blocks with low PAPR value makes it suitable for transmission.

- **PARTIAL TRANSMIT SEQUENCE**
  Transmitting only part of data of varying sub-carrier which covers all the information to be sent in the signal as a whole is called Partial Transmit Sequence Technique.

5.2 AMPLITUDE CLIPPING AND FILTERING

Amplitude clipping is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal. Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed [3].

$$B(x) = \begin{cases} x, & |x| \leq A \\ Ae^{j\emptyset(x)}, & |x| > A \end{cases}$$

where,

B(x)	=	the amplitude value after clipping.
x	=	the initial signal value.
A	=	the threshold set by the user for clipping the signal.

The problem in this case is that due to amplitude clipping distortion is observed in the system which can be viewed as another source of noise. This distortion falls in both in – band and out – of – band. Filtering cannot be implemented to reduce the in – band distortion and an error performance degradation is observed here. On the other hand spectral efficiency is hampered by out – of – band radiation. Out – of – band radiation can be reduced by filtering after clipping but this may result in some peak re – growth. A repeated filtering and clipping operation can be implemented to solve this problem. The desired amplitude level is only achieved after several iteration of this process.

5.2 SELECTED MAPPING

The main objective of this technique is to generate a set of data blocks at the transmitter end which represent the original information and then to choose the most favorable block among them for transmission. Let us consider an OFDM system with N orthogonal sub – carriers. A data block is a vector $X = (x_n)_N$ composed of N complex symbols x_n, each of them representing modulation symbol transmitted over a sub – carrier. X is multiplied element by element with U vector $B_u = (b_{u,n})_N$ composed of N complex numbers $b_{u,n}$, $u \in \{0,1,\dots,U-1\}$, defined so that $|b_{u,n}| = 1$, where |.| denotes the modulus operator. Each resulting vector $X_u = (x_{u,n})_N$, where $x_{u,n} = b_{u,n}.x_n$, produces after IDFT, a corresponding OFDM signal $s_u(t)$ given by

$$s_u(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x_{u,n}\, e^{j2\pi n\Delta f t}, \qquad 0 \le t \le T,$$

where T is the OFDM signal duration and $\Delta f = 1/T$ is the sub – carrier spacing[5,6].

Among the modified data blocks, the one with the lowest PAPR is selected for transmission. The amount of PAPR reduction for SLM depends on the number of phase sequences U and the design of the phase sequences.

5.3 PARTIAL TRANSMIT SEQUENCE

In the PTS technique, input data block **X** is partitioned in *M* disjoint sub – blocks $\boldsymbol{X}_m = [X_{m,0}, X_{m,1}, \dots, X_{m,N-1}]^T, m = 1, 2, \dots, M,$ such that $\sum_{m=1}^{M} \boldsymbol{X}_m = \boldsymbol{X}$ and the sub – blocks are combined to minimize the PAPR in the time domain. The L times oversampled time domain signal of $\boldsymbol{X}_m, m = 1, 2, \dots, M,$ is obtained by taking the IDFT of length *NL* on $\boldsymbol{X}_m$ concatenated with *(L – 1)N* zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{j\emptyset_m}, m = 1, 2, \dots, M,$ are introduced to combine the PTSs. The set of phase factors is denoted a vector $\boldsymbol{b} = [b_1, b_2, \dots, b_M]^T$. The time domain signal after combining is given by

$$\boldsymbol{x}'(\boldsymbol{b}) = \sum_{\boldsymbol{m}=\boldsymbol{1}}^{\boldsymbol{M}} \boldsymbol{b}_{\boldsymbol{m}} . \boldsymbol{x}_{\boldsymbol{m}}$$

where $\boldsymbol{x}'(\boldsymbol{b}) = [\boldsymbol{x}'_{\boldsymbol{0}}(\boldsymbol{b}), \boldsymbol{x}'_{\boldsymbol{1}}(\boldsymbol{b}), \dots, \boldsymbol{x}'_{\boldsymbol{NL-1}}(\boldsymbol{b})]^{\boldsymbol{T}}$**.** The objective is to find the set of phase factors that minimizes the PAPR. Minimization of PAPR is related to the minimization of $\max_{0 \le k \le \le NL-1} |x'_k(b)|$.

Chapter – 6

SIMULATIONS & RESULTS

SIMULATIONS & RESULTS

6.1 SIMULATION 1

AIM: To find the Bit Error Rate (BER) of an OFDM System and plot it against Signal – to – Noise Ratio (SNR).

BLOCK DIAGRAM:

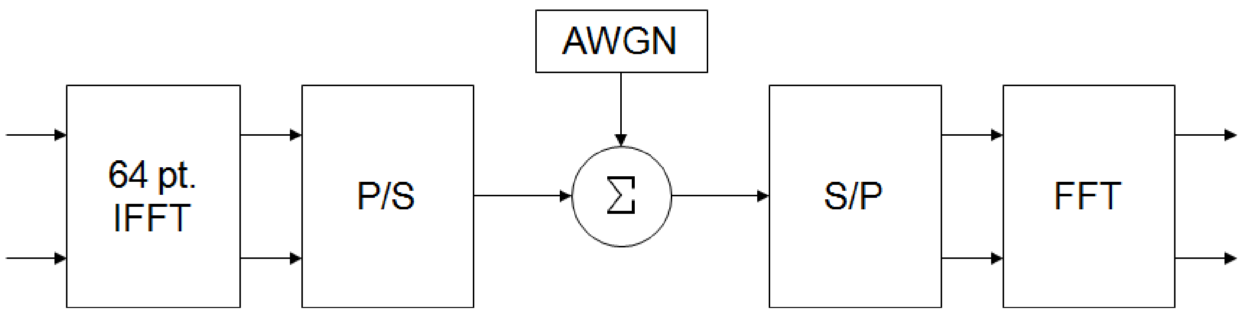


Fig. 6.1 Simulation Model of an OFDM System

RESULT:

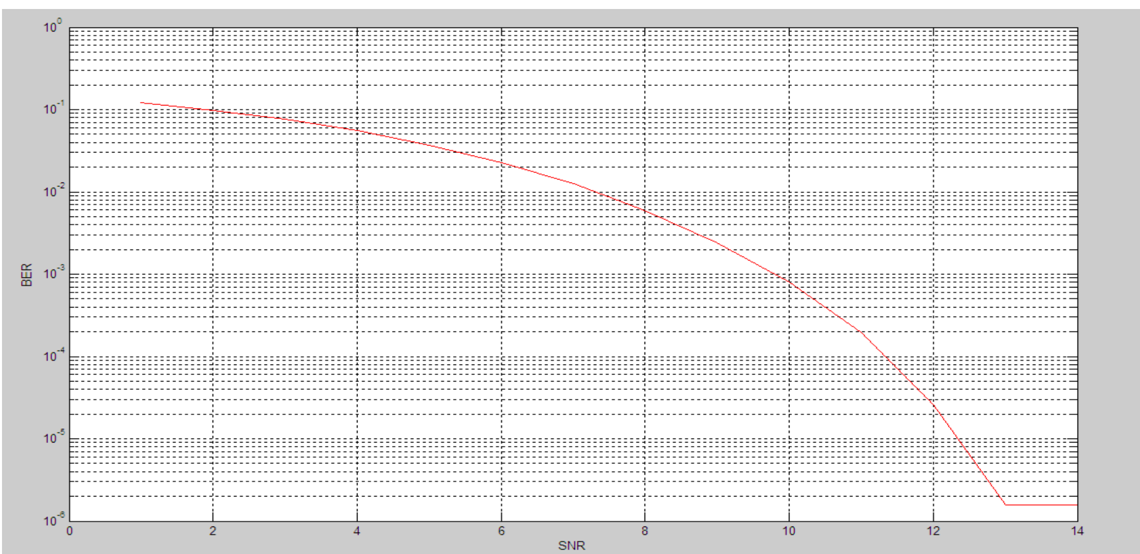


Fig. 6.2 BER vs. SNR Plot of an OFDM System

6.2 SIMULATION 2

<u>AIM</u>: To calculate the PAPR of an OFDM Signal before and after ***Amplitude Clipping*** and then to compare the results.

<u>RESULT</u>:

Number of Subcarriers	Peak (mean)	Threshold (mean)	PAPR before Amplitude Clipping (in dB) (mean)	PAPR after Amplitude Clipping (in dB) (mean)	Difference in PAPR (in dB) (mean)
64	0.3872	0.3572	6.6004	5.9441	0.6562
128	0.2909	0.2609	7.2343	6.3315	0.9029
256	0.2170	0.1870	7.8743	6.6434	1.2309
512	0.1626	0.1326	8.3099	6.5916	1.7183

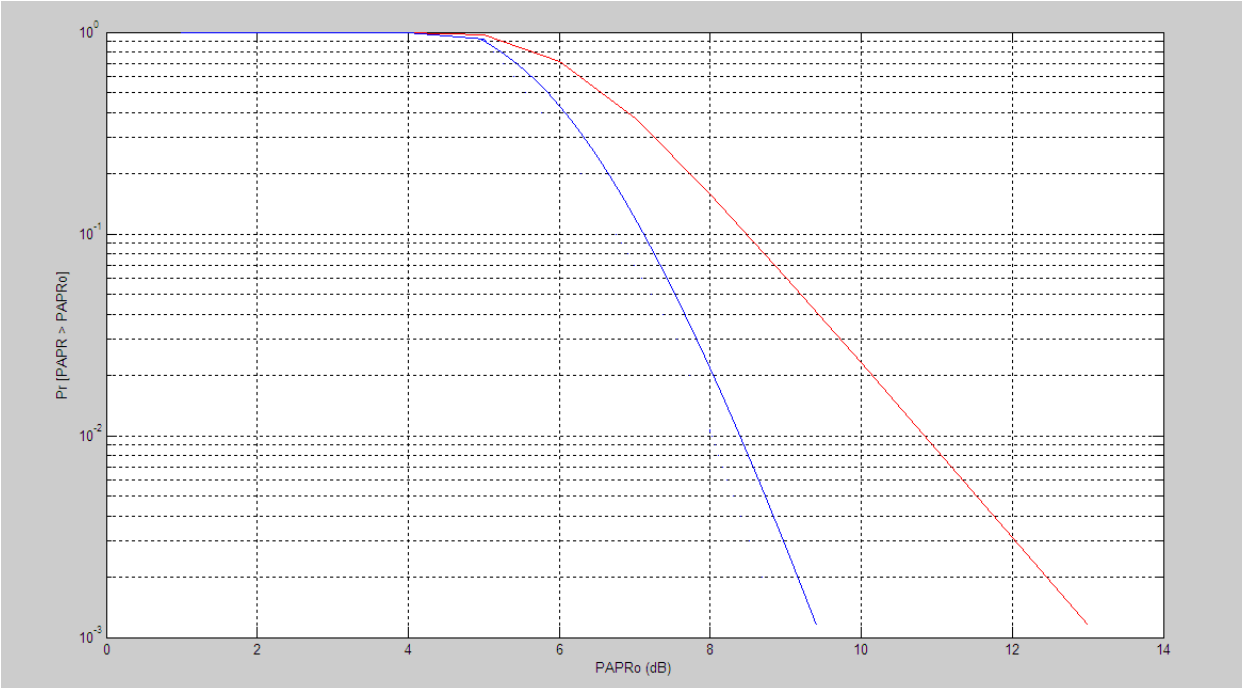
** The number of iterations in all the cases is taken as 100.*

Table 6.1 Comparison of PAPR of an OFDM Signal before and after Amplitude Clipping

6.3 SIMULATION 3

AIM: To plot the CCDF for ***Amplitude Clipping and Filtering***.

RESULT:



Unmodified OFDM signal

OFDM Signal after Amplitude Clipping

Fig. 6.3 CCDF of an OFDM Signal with and without Amplitude Clipping & Filtering

6.4 SIMULATION 4

AIM: To calculate the PAPR of an OFDM Signal before and after ***Selected Mapping*** and then to compare the results.

RESULT:

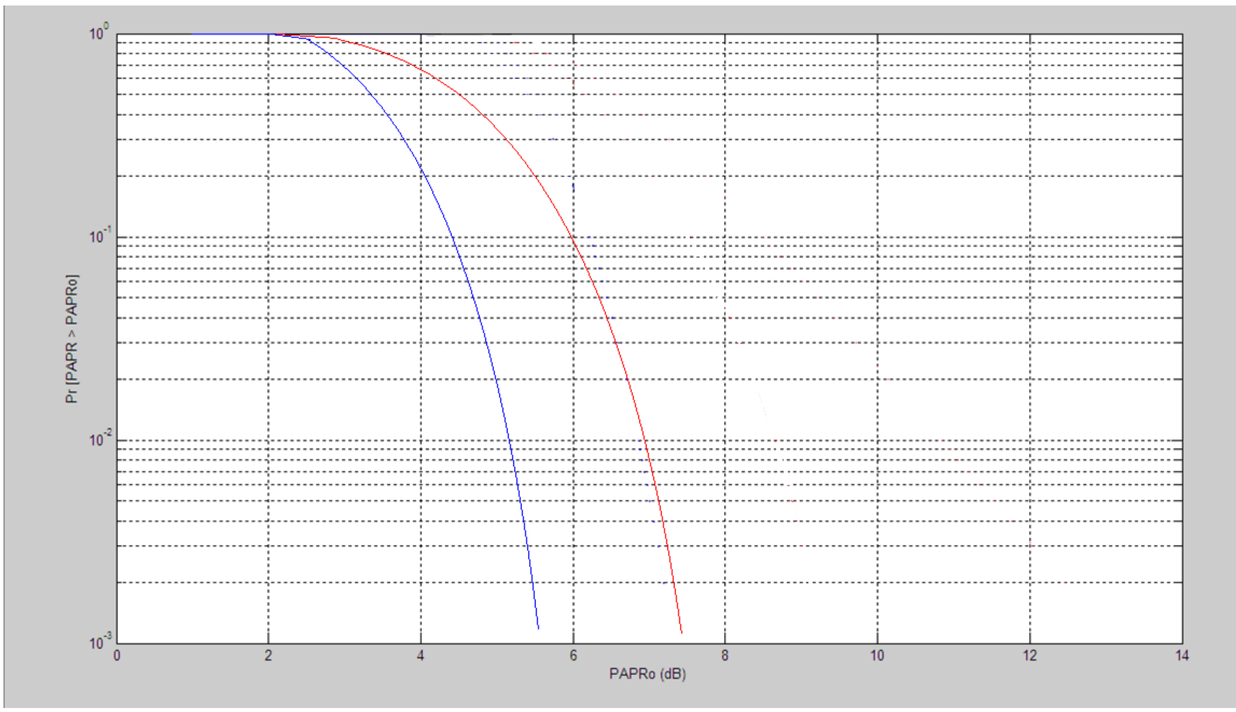
Number of Subcarriers	PAPR before Selected Mapping (in dB)	PAPR after Selected Mapping For 10 different Phase Factors (in dB)				Least PAPR (in dB)	Difference in PAPR (in dB)
128	8.2528	6.8266	6.6511	5.7972	6.4042	**5.7972**	**2.4556**
256	9.2308	7.1376	7.0148	7.2264	6.0147	**6.0147**	**3.2161**
512	9.8086	6.1223	7.0299	6.8038	7.1006	**6.1223**	**3.6863**

Table 6.2 Comparison of PAPR of an OFDM Signal before and after Selected Mapping

6.5 SIMULATION 5

AIM: To compare the performances of Selected Mapping and Partial Transmit Sequence Techniques.

RESULT:



SLM, U = 16

PTS, V = 16

Fig. 6.4 Performance Curves of SLM and PTS Techniques

Chapter – 7

CONCLUSION

CONCLUSION

OFDM is a very attractive technique for multicarrier transmission and has become one of the standard choices for high – speed data transmission over a communication channel. It has various advantages; but also has one major drawback: it has a very high PAPR.

In this project, the different properties of an OFDM System are analyzed and the advantages and disadvantages of this system are understood. The bit – error – rate is also plotted against the signal – to – noise ratio to understand the performance of the OFDM system.

We have also aimed at investigating some of the techniques which are in common use to reduce the high PAPR of the system. Among the three techniques that we took up for study, we found out that Amplitude Clipping and Filtering results in Data Loss, whereas, Selected Mapping (SLM) and Partial Transmit Sequence (PTS) do not affect the data. From the comparison curve of the SLM and PTS techniques, we could infer that PTS is more effective in PAPR reduction.

However, no specific PAPR reduction technique is the best solution for the OFDM system. Various parameters like loss in data rate, transmit signal power increase, BER increase, computational complexity increase should be taken into consideration before choosing the appropriate PAPR technique.

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