PERFORMANCE ANALYSIS OF 3GPP LTE

A THESIS SUBMITTED IN THE PARTIAL FULFILMENT OF THE REQUIREMENTS

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CERTIFICATE

This is to certify that the thesis entitled **"Performance Analysis of 3GPP LTE"** submitted by **ALI SUZAIN** and **MUKESH JOHNSON KUJUR** in partial fulfilment for the requirements for the award of Bachelor of Technology Degree in Electronics & Communication Engineering at National Institute of Technology, Rourkela 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

To meet the increasing demands on the mobile radio systems and data traffic, a successor of UMTS, which runs on an evolution of the existing infrastructure used by over 80 percent of mobile subscribers globally, has been worked on by 3GPP, called Long Term Evolution (LTE). This will permit more powerful and better spectral efficiency of the transmission. The major parts of LTE are Single Carrier Frequency Division Multiple Access (SC-FDMA) & Orthogonal Division Multiple Access (OFDMA). OFDMA is used in the LTE downlink as a multiple access method as it provides good bandwidth efficiency, immunity to multi-path and frequency selective fading, and less complex equalization at the receiver. SC-FDMA is introduced recently and it became handy candidate for uplink multiple access scheme in LTE system as it has the advantage of lower PAPR as compared to that of OFDMA.

In our thesis, we analysed the performance of SCFDMA and OFDMA of LTE using different modulation schemes (BPSK, QPSK, 16PSK and 64PSK) on the basis of BER by simulating the model of SCFDMA & OFDMA in MATLAB. We used Additive White Gaussian Noise (AWGN) channel and introduced frequency flat fading in the channel by using Rayleigh Fading model to evaluate the performance in presence of noise and fading. We also found PAPR for both the accessing methods using the same model developed for BPSK modulation.

Key words: OFDMA, SCFDMA, PAPR, cyclic prefix, BER, LTE

LIST OF ACRONYMS

3GPP	3rd Generation Partnership Project
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
FFT	Fast Fourier Transform
CCDF	Complementary Cumulative Density Function
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
LTE	Long Term Evolution
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PAPR	Peak to Average Power Ratio
QPSK	Quadrature Phase Shift Keying
SC-FDMA	Single Carrier-Frequency Division Multiple Access
SNR	Signal to Noise Ratio

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Designing an efficient wireless communication system is always a challenge. With increase in demand for high data rate this task has become even more challenging. To achieve this challenging goal 3GPP came in to existence. Recent standard introduced by 3GPP group which promises high-speed data, multimedia unicast and multimedia broadcast services is LTE. Single Carrier Frequency Division Multiple Access (SC- FDMA) & Orthogonal Division Multiple Access (OFDMA) are the major parts of the Long Term Evolution (LTE). OFDMA is used in the LTE downlink as a multiple access method as it provides good bandwidth efficiency, immunity to multi-path and frequency selective fading, and less complex equalization at the receiver. SC-FDMA is introduced recently and it became handy candidate for uplink multiple access scheme in LTE system as it has the advantage of lower PAPR as compared to that of OFDMA.

Our objective of this thesis is to analyse the performance of LTE by considering two multiple access techniques (SC-FDMA and OFDMA) with adaptive modulation techniques BPSK, QPSK, 16-PSK and 64-PSK. We have considered BER and PAPR parameters to evaluate the performance of LTE. We have considered these parameters because they are vital in communication systems and we have achieved our results by simulating the OFDMA and SC-FDMA models in MATLAB.

1.2 Thesis Outline

Chapter 1 gives an introduction about the thesis and outline of the thesis.

Chapter 2 contains an overview of different generations of mobile systems, introduction about LTE. It also describes in detail the two multiple access schemes (OFDMA & SC-FDMA) used in LTE.

Chapter 3 contains analysis models of both multiple access techniques i.e. SCFDMA and OFDMA. It also contains the description of performance parameters used for performance evaluation.

Chapter 4 contains simulation results.

Chapter 5 shows the set of conclusions of our thesis work based on result analysis.

CHAPTER 2

3GPP LONG TERM EVOLUTION (LTE) SYSTEM

2.1 Cellular Telecommunication Systems

Up to today there are four generations of cellular telecommunication systems generally known as 1G, 2G, 3G and 4G. Each generation has different systems with different specifications and capability. The table 2.1 below describes different generations with different systems and their specifications.

Generation	Standard	Multiple Access	Frequency Band	Throughput
1	AMPS	Analog FDMA/FDD	824–849(MHz) 869–894(MHz)	-
2	GSM	TDMA/FDMA	890-960(MHz) 1710-1880(MHz)	9.6 Kbps
2.5	GPRS	TDMA/FDMA	890-960(MHz) 1710-1880(MHz)	171 Kbps
2.75	EDGE	TDMA/FDMA	890-960(MHz) 1710-1880(MHz)	384 Kbps
3	UMTS	WCDMA	1185-2025(MHz) 2110-2200(MHz)	2 Mbps
4	LTE	OFDMA/ SC-FDMA	1920-1980(MHz) 2110-2170(MHz)	100 Mbps

Table 2.1: Generations of Cellular Telecommunication Systems.

2.2 Overview 3GPP LTE System

The long term evolution (LTE) is a standard introduced by 3rd Generation Partnership Project (3GPP) as one of the recent steps in cellular 3G services. LTE provides many benefits like high-speed data, bandwidth efficiency, latency, multimedia unicast and multimedia broadcast services to cellular networks.

In order to achieve these benefits LTE employs new accessing technologies like OFDMA and SC-FDMA. To provide benefits like high data rate, bandwidth efficiency and immunity to the multi-path fading OFDMA is used for downlink transmission while SC-FDMA is used for uplink transmission in order to save power.

The LTE increases the system capacity and widens the spectrum from existing technology up to 20MHz. It can be deployed in any bandwidth combination because of its flexible usage of spectrum (1.4 MHz to 20 MHz). It uses Frequency Division Duplex (FDD) and Time Division Duplex (TDD) to suit all types of spectrum resources.

2.3 LTE Performance Demands

To meet the desired performance of the system LTE demands many specifications. Below is summarization of some of these demands (specifications).

Data Rate: For 20 MHz spectrum, peak data rate is 50 Mbps for uplink and 100 Mbps for downlink.

Bandwidth: In 3GPP technology family, there were considered both the wideband (WCDMA with 5MHz) and the narrowband (GSM with 200 kHz). Therefore the new system is now required to facilitate frequency allocation flexibility with 1.25/2.5, 5, 10, 15 and 20 MHz allocations.

Peak Spectral Efficiency: The peak spectral efficiency requirement for downlink is 5 bps/Hz or higher, and for uplink is 2.5 bps/Hz or higher.

Latency: The LTE control-plane latency (transition time to active state) is less than 100 ms (for idle to active), and is less than 50 ms (for dormant to active). The user-plane latency is less than 10 ms from UE (user end) to server.

Security & Mobility: Security and mobility in 3GPP technology is used at good level with the earlier systems starting from GSM and it is sustained at that level and higher.

2.4 Orthogonal Frequency Division Multiple Access (OFDMA)

OFDMA is a multiple access technique which uses Orthogonal Frequency Division multiplexing (OFDM) for each user. In this technique each user is allotted separate channel and available frequency band of that channel is divided into number of orthogonal frequency subcarriers. The high speed serial data from each user is first converted into low speed parallel bit streams with increased symbol duration then it is modulated on each subcarrier using conventional modulation schemes. OFDMA allows achieving high data rate for each user. With little modification to air interface it can be deployed across different frequency bands. OFDMA reduce the effect of multipath fading because data from each user is modulated over several orthogonal frequencies rather than a fixed frequency for entire connection period. In addition, the OFDMA is bandwidth efficient as orthogonal frequency carriers with small spacing is used. All these advantage make it to be used in the downlink transmission of LTE.

2.4.1 Working principle of OFDMA

In OFDMA transmitter, the high speed serial data from each user is first converted in to low speed parallel data streams. This increases the symbol duration which reduce the Intersymbol Interference (ISI) at the receiver. Then the parallel data streams are passed through modulator, where adaptive modulation schemes such as (BPSK, QPSK, 16-QAM, 64-QAM) is applied. These modulated data streams are then mapped to orthogonal subcarriers by dividing the available spectrum into number of orthogonal frequency subcarriers. This makes the time domain data stream from user a frequency domain data stream or signal as at different frequency different low speed data stream will be present. The IFFT stage converts these complex data streams into time domain and generates OFDM symbols. A guard band or cyclic prefix (CP) is inserted between OFDMA symbols in order to cancel the ISI at the receiver. The CP is inserted by taking some part from end of the OFDM symbol and putting it at the start of the symbol as shown in figure 2.1. The duration of these CP should be greater than the channel impulse response or delay spread. After appending CP the data streams are converted to a serial data stream to be transmitted in the channel.

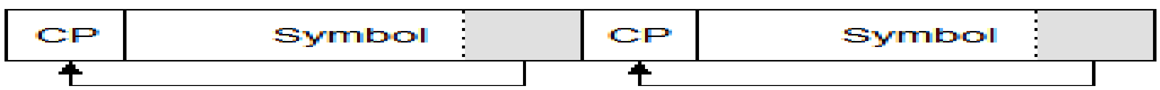

Figure 2.1: Inserting Cyclic prefix (CP)

At the receiver, the inverse processes of the transmitter occur. The serial data is converted to parallel data streams, CP is removed from each symbol and FFT stage converts the OFDM symbols in to frequency domain followed by subcarrier de-mapping and demodulation. Finally parallel data streams are converted to high speed serial data stream.

2.5 Single carrier Frequency Division Multiple Access (SC-FDMA)

SC-FDMA is a multiple access method. Its structure is same as OFDMA with an addition of Fast Fourier Transform (FFT) block. The parallel data streams are first passed through FFT block then are modulated on subcarriers because of this the SC-FDMA is also called DFT-precoded OFDM. The main difference between OFDMA and SC-FDMA is, in OFDMA, each data symbol is carried on a separate subcarrier while, in SC-FDMA, multiple subcarriers carry each data symbol due to mapping of the symbols' frequency domain samples to subcarriers. As SC-FDMA is derived from OFDMA it has same basic advantages as OFDMA but the spreading of each data symbol over multiple subcarriers gives it the profound advantage of lower PAPR value as compare to that of OFDMA. Hence PAPR is a useful parameter for uplink it is used in uplink transmission of LTE system.

2.5.1 Working principle of SC-FDMA

In SC-FDMA transmitter, after modulating parallel low speed data streams, the transmitter groups the modulated symbols into a block of N symbols. An N-point FFT block transforms these symbols in time domain into frequency domain. The frequency domain samples are then mapped to a subset of M subcarriers where M is typically greater than N. Similar to OFDMA, an IFFT block is used to generate the time-domain samples of these subcarriers, which is followed by appending cyclic prefix and parallel to serial conversion.

At the receiver just the opposite processes take place. Serial to parallel conversion, removing CP, taking FFT to convert to frequency domain, sub-carrier demapping followed by IFFT and demodulation.

CHAPTER 3

SYSTEM MODEL

3.1 OFDMA System Model

Figure 3.1 shows the block diagram of the model we used to simulate OFDMA system. We wrote a MATLAB program to simulate the model shown.

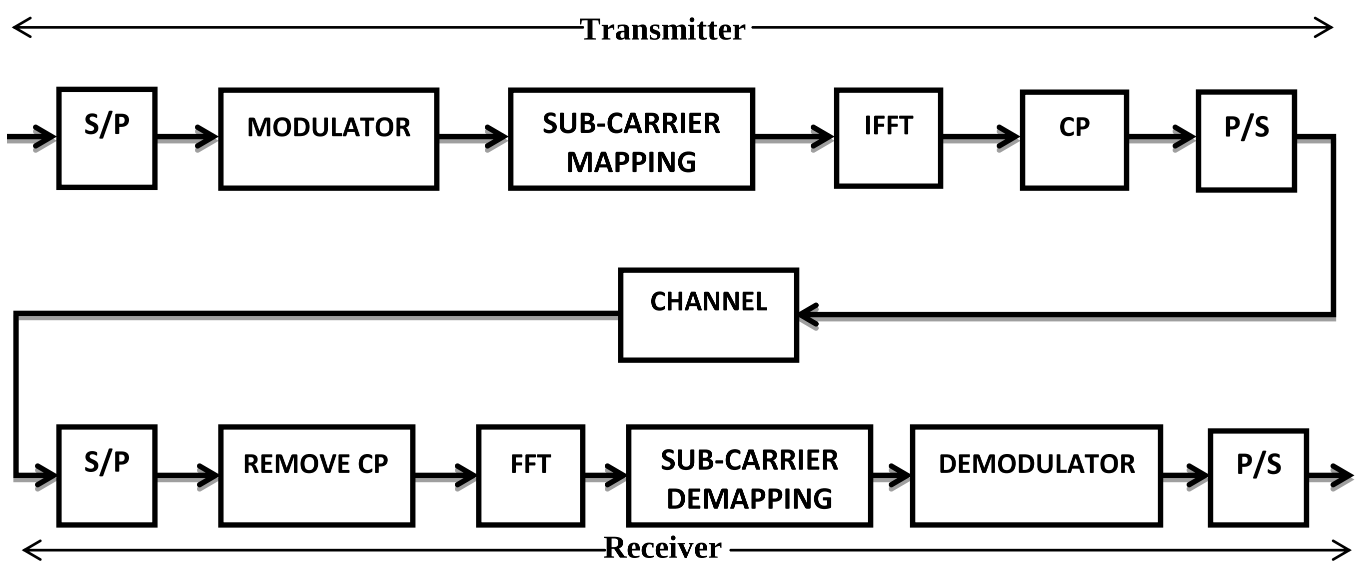

Figure 3.1: Block diagram of the OFDMA system model

Following are the steps or algorithm we followed while writing the program to simulate the model.

- First we generated binary stream of data.
- We converted this stream of data in to number of parallel streams of data.
- We modulated these streams of data using different modulation schemes.(we used BPSK, QPSK, 16-PSK and 64-PSK modulation)
- Then these modulated streams of data are mapped to different sub-carriers.
- Then we took the IFFT of these mapped streams of data.

- CP was appended by taking some portion from end of each symbol and adding it at the beginning of the symbol.
- Then the resultant parallel streams were converted to long serial data stream.
- Then we created an AWGN channel by using a built in function in MATLAB in which the noise level is described by SNR per sample, which is one input parameter to the function.
- We passed serial data stream through this channel (function).
- For Rayleigh fading channel simulation we introduced fading using a built in function in MATLAB for Rayleigh frequency flat fading.
- Corrupted data from channel were then converted to parallel data streams.
- From each symbol CP were removed.
- Then FFT of the streams were taken.
- Data streams were de-mapped from the subcarriers.
- Demodulations of data streams were done.
- Finally parallel data streams were converted to serial data stream.

3.2 SC-FDMA System Model

Figure 3.2 shows the block diagram of the model we used to simulate SC-FDMA system. The model is same as that of OFDMA except an FFT block is inserted before sub-carrier mapping at the transmitter while an IFFT block is placed after sub-carrier demapping at the receiver. The steps for creating the program to simulate the model are same as that of OFDMA except we took FFT before sub-carrier mapping and IFFT after sub-carrier demapping.

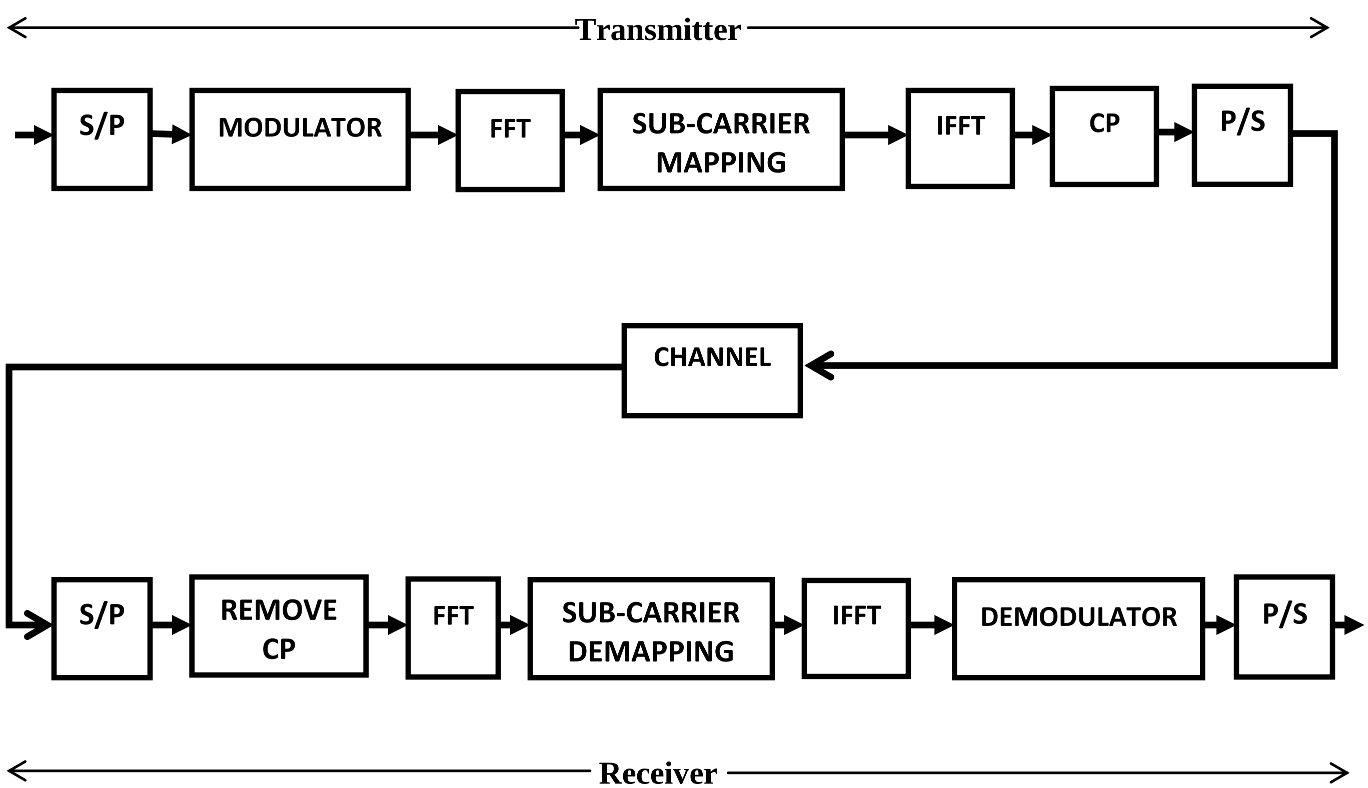

Figure 3.2: Block diagram of the SC-FDMA system model

3.3 Parameters used for Simulation

Table 3.1 shows the parameters we used for simulation

PARAMETERS	**ASSUMPTION**
Number of Sub-carriers	64
CP Length	7
Range of SNR in dB	0 to 35
Modulation	BPSK, QPSK, 16-PSK, 64-PSK
Data Block Size	16
Channel	AWGN Channel
System Bandwidth	5 MHz
FFT and IFFT size	64
Fading	Rayleigh (frequency flat) fading

Table 3.1: Parameters used for simulation

3.4 Bit Error Rate (BER)

The BER is ratio of number of error bits and total number of bits transmitted. It is given by the following formulae.

BER = Number of Error Bits / Total Number of Transmitted Bits

To plot BER performance first we simulated the developed model, calculated BER for different Signal to Noise Ratio (SNR) values using the above formulae and then we plotted these values against corresponding SNR values. The procedure was repeated for different modulation techniques.

3.5 Peak to Average Power Ratio

We calculated PAPR for both OFDMA and SC-FDMA system using the following formula.

PAPR = Peak power of transmitted signal / Average power of transmitted signal

where peak and average power of transmitted signal was calculated by

*Peak power of transmitted signal = Maximum (xt * conjugate of xt)*

*Average power of transmitted signal = Mean (xt * conjugate of xt)*

where *xt* represent *transmitted signal.*

We calculated PAPR only for BPSK modulation scheme.

To plot PAPR we used Complementary Cumulative Distribution Function (CCDF) of calculated PAPR values. The CCDF of PAPR is the probability that the PAPR is higher than a certain PAPR value PAPR0 (Pr {PAPR>PAPR0}).

CHAPTER 4

SIMULATION RESULTS

4.1 BER vs SNR of OFDMA and SC-FDMA

The BER vs SNR of OFDMA and SC-FDMA for AWGN channel are shown in figure 4.1 and figure 4.2 respectively.

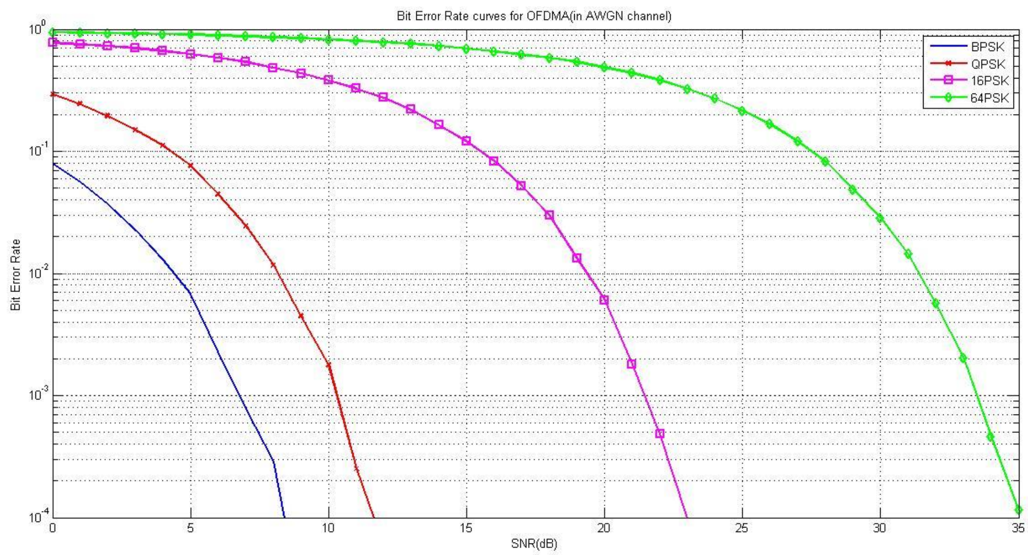

Figure 4.1: BER vs SNR for OFDMA in AWGN channel

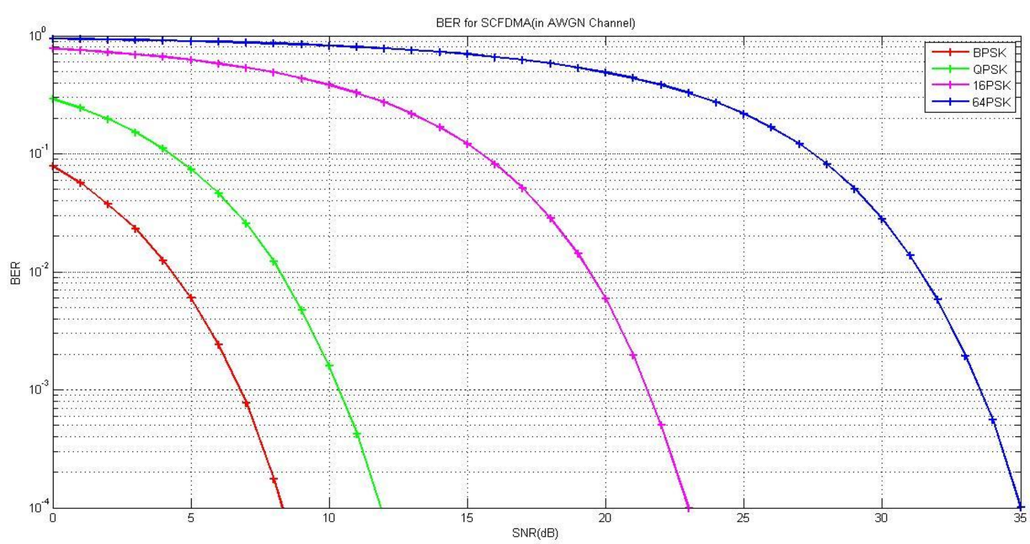

Figure 4.2: BER vs SNR for SC-FDMA in AWGN channel

The BER vs SNR of OFDMA and SC-FDMA for Rayleigh (frequency flat) fading channel are shown in figure 4.3 and figure 4.4 respectively.

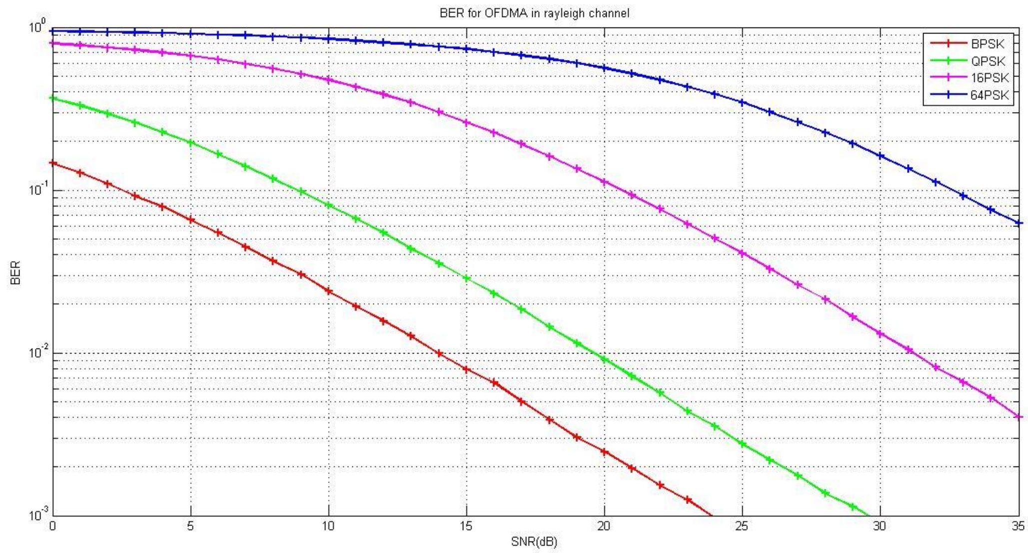

Figure 4.3: BER vs SNR for OFDMA in Rayleigh (frequency flat) fading channel

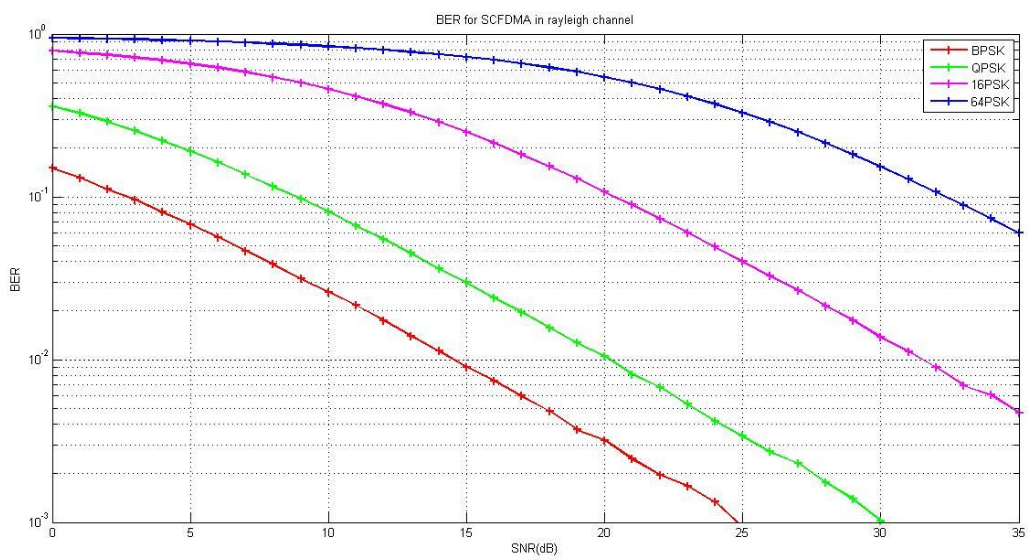

Figure 4.4: BER vs SNR for SC-FDMA in Rayleigh (frequency flat) fading channel

The BER vs SNR of both OFDMA and SC-FDMA in AWGN channel are shown in figure 4.5.

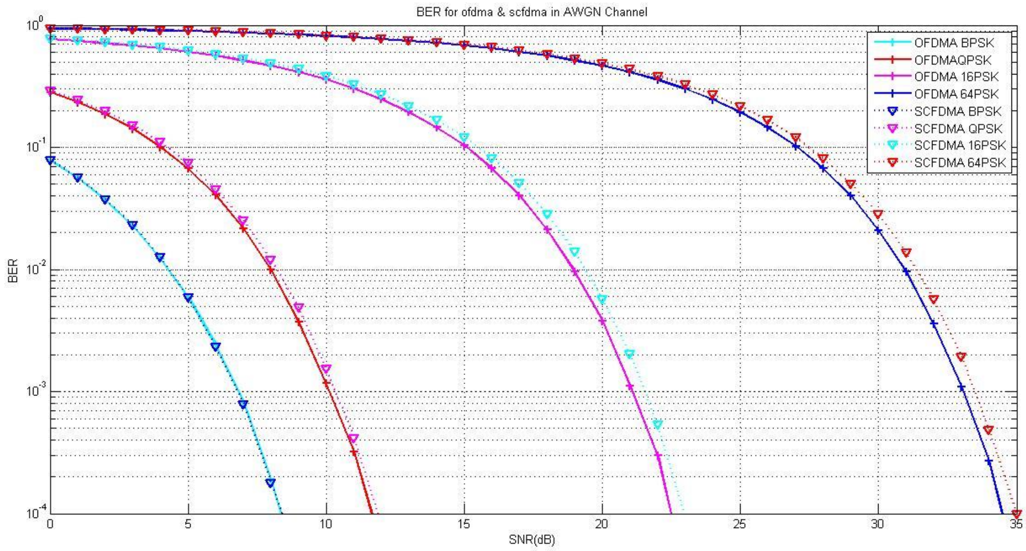

Figure 4.5: BER vs SNR for both OFDMA and SC-FDMA in AWGN channel

The BER vs SNR of both OFDMA and SC-FDMA in Rayleigh (frequency flat) fading channel are shown in figure 4.6

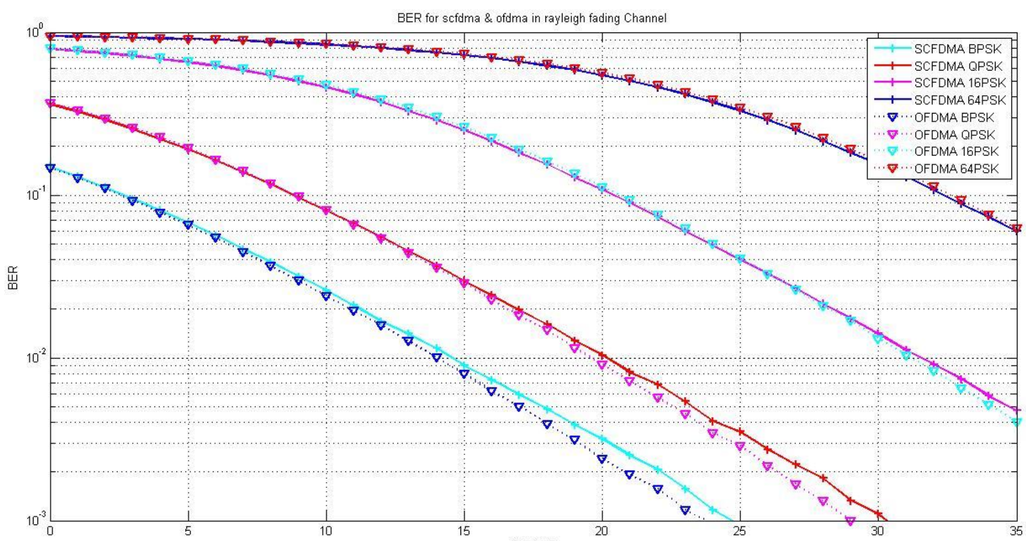

Figure 4.6: BER vs SNR for both OFDMA and SC-FDMA in Rayleigh fading channel

4.2 PAPR of OFDMA and SC-FDMA for BPSK

The PAPR of OFDMA and SC-FDMA for BPSK modulation is shown in figure 4.7

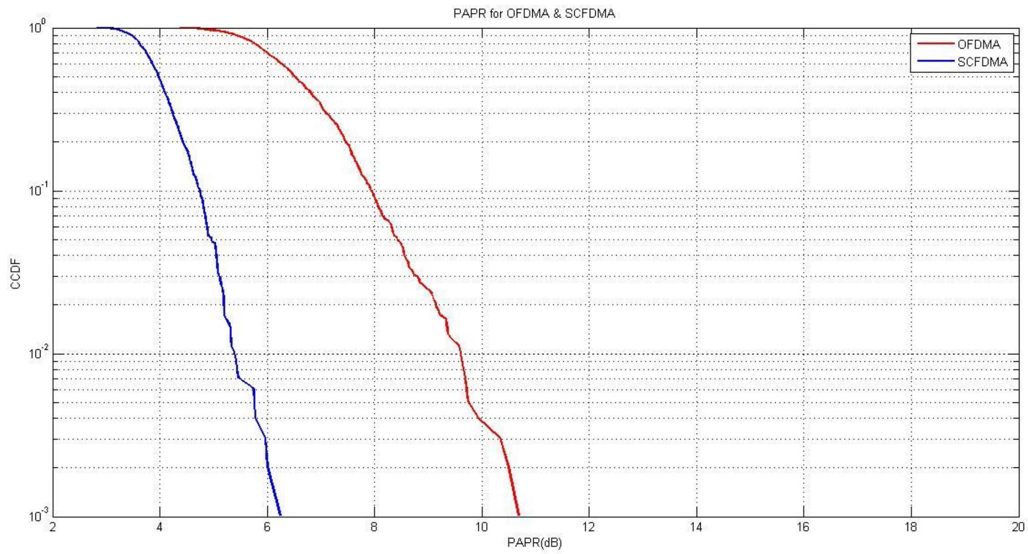

Figure 4.7: PAPR of OFDMA and SC-FDMA for BPSK

CHAPTER 5

CONCLUSION

5 Conclusion

BER is the key parameter for indicating the system performance of any data link. In our project we analysed that for different values of SNR, the BER increases for high order modulation in both the multiple access techniques (OFDMA and SC-FDMA) used in LTE system. On the other hand, the lower order modulation schemes (BPSK and QPSK) experience less BER at receiver thus lower order modulations improve the system performance in terms of BER. The BER increases for high order modulation in both the techniques used in LTE system because of the fact that higher order modulation techniques use more bits per symbol. Hence it is easily affected by the noise. If we consider the bandwidth efficiency of these modulation schemes, the higher order modulation accommodates more data within a given bandwidth and is more bandwidth efficient as compare to lower order modulation. Thus there exists a trade-off between BER and bandwidth efficiency among these modulation schemes used in LTE. BER Performance of SC-FDMA and OFDMA are better in AWGN Channel as compared to that of Rayleigh Fading Channel as less distortion is introduced in the signal in AWGN channel. The BER performance of OFDMA is little bit better as compare for SC-FDMA for both the channels and all the modulation schemes. This is because in SC-FDMA symbols are spread over multiple sub-carriers.

As in SC-FDMA individual symbols are spread over multiple sub-carriers average power distributed on all frequencies is greater than OFDMA. This even reduce the peak transmits power requirements of SC-FDM as compare to OFDMA. Thus SC-FDM has low PAPR and is more power efficient.

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