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Research Article

Performance Analysis of OFDMA in LTE

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Abstract

The LTE employs OFDMA for downlink data transmission because Orthogonal Frequency Division Multiple Access (OFDMA) scheme offers high spectral efficiency and better resistance to fading environments. In OFDMA the data is modulated using multiple number of sub-carriers that are orthogonal to each other because of which the problems associated with other modulation schemes such as Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) are reduced .In this paper the performance of OFDMA system in LTE is taken into account, Then, the main technologies are explained, together with possible improvements, their associated challenges, and some approaches have been considered .We also investigate the performance of OFDMA in LTE physical layer by considering different modulation schemes (BPSK, QPSK, 16QAM and 64QAM) on the basis of PAPR, BER, power spectral density (PSD) and error probability .

Keywords: *OFDMA, LTE, BER, PAPR, PSD, BPSK, QPSK, 16QAM and 64 QAM*

1. Introduction

Wireless communication is enjoying a fast growth period in history which is coupled with technology improvements that permit its widespread deployment. That is the cellular concept developed by Bell Laboratories. Mobile communication offers a full duplex communication using a radio to connect portable device to a dedicated Base station, which is then connected to a switching network. The first generation of mobile communication, known as Advanced Mobile Phone System (AMPS), was deployed in 1983. The second generation (2G) of mobile communication is known as Global System for Mobile communication (GSM) which was deployed in the 1990s with 9.6 kbps data rate. The third Generation system (3G) standard deployed in 21st century improves the data handling capacity with data rate of 64 kbps to 2 Mbps. A collaborative group of standards organization and telecommunication companies called Third Generation Partnership Project (3GPP) was formed for enhanced versions to the 3G standard. The fourth generation (4G) of wireless cellular systems has been a topic of interest for quite a long time, probably since the formal definition of third generation (3G) systems. Motivated by the increasing demand for mobile broadband services with higher data rates and Quality of Service (QoS), 3GPP introduced the Long Term Evolution (LTE) which are intended to define both the radio access network (RAN) and the network core of the system, and are included in 3GPP Release 8. OFDMA is a novel application in cellular communication (S. Haykin *et al*, 2001; W. Stallings *et al*, 2007; T.S. Rappaport *et al* 1996; M. Salehi *et al* 2001).Performance analysis of LTE in OFDMA for downlink transmission is presented in this paper. A brief discussion of the basic properties and advantages is thereafter discussed in the later part of this paper. This paper has been divided into six sections, section I gives a brief introduction about the evolution of wireless communication, section 2 and 3 introduces basic idea about LTE and OFDMA, section 4 contains the channel environment required for OFDMA in LTE, section 5 discusses about the parameters taken in this paper, section 6 gives the simulation result and then the conclusion of the paper.

2. LTE

LTE stands for Long Term Evolution and it was started as a project in 2004 by telecommunication body known as the Third Generation Partnership Project (3GPP). LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System (UMTS), which in turn evolved from the Global System for Mobile Communications (GSM). The main goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. Same time its network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service.

For the Downlink, Orthogonal Frequency Division Multiple Access (OFDMA) is considered for transmitting

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Table1: Downlink OFDMA Modulation Parameters

Transmission BW(MHz)		1.25	2.5	5	10	15	20
Subframe duration		0.5ms					
Sub carrier spacing		15kHz					
Sampling frequency(MHz)		1.92	3.84	7.68	15.36	23.04	30.72
FFT size		128	256	512	1024	1536	2048
OFDM sym per slot(short/long CP)		7/6					
CP length(μsec/samples)	**Short**	(4.69/9)×6, (5.21/10)×1	(4.69/18)×6, (5.21/20)×1	(4.69/36)×6, (5.21/40)×1	(4.69/72)×6, (5.21/80)×1	(4.69/108)×6, (5.21/120)×1	(4.69/144)×6, (5.21/160)×1
	Long	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

from Base Station (BS) while Single Carrier Frequency Division Multiple Access (SC-FDMA) is for the Uplink. This work focuses on the Downlink access. 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 (Yapeng Wang *et al*, 2009).

In LTE, the frame duration of 10 ms is divided into subframes of 1 ms duration. Two slots of 0.5 ms duration each are formed out of a subframe. The Base Station schedules transmissions every 1 ms and resource blocks are formed from the subcarriers for allocation on the Downlink (Ayoola A.A *et al*, 2013).

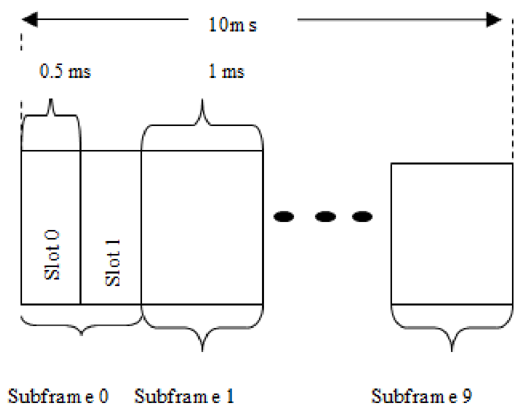

Figure 1: LTE frame structure

The total number of available subcarriers depends on the overall transmission bandwidth of the system. The LTE specifications define parameters for system bandwidths from 1.25 MHz to 20 MHz as shown in Table 2. A PRB is defined as consisting of 12 consecutive subcarriers for one slot (0.5 msec) in duration. A PRB is the smallest element of resource allocation assigned by the base station scheduler.

3. OFDMA

OFDMA is a type of frequency division multiplexing (FDM) in which available frequency band is divided into number of orthogonal frequency subcarriers. The data is first converted into parallel bit streams then it is modulated on each subcarrier using conventional modulation schemes. OFDMA allows low data rate from many users and has shorter and constant delay. It has flexibility in deployment across different frequency bands by need of little modification to air interface. The effect of multipath fading is reduced by using OFDMA because each user's data is modulated over several orthogonal frequencies rather than a fixed frequency for entire connection period. In addition, the OFDMA not only facilitate the capacity sharing in available bandwidth but it also increases the capacity for each user because of using several frequencies (Ayoola A.A *et al*, 2013).The difference between OFDM and OFDMA is that OFDMA has the ability to dynamically assign a subset of those subcarriers to individual users, making this the multi-user version of OFDM, using either Time Division Multiple Access (TDMA) (separate time frames) or Frequency Division Multiple Access (FDMA) (separate channels) for multiple users. OFDMA simultaneously supports multiple users by assigning them specific sub channels for intervals of time. Point-to-point systems are OFDM, and do not support OFDMA. Point-to-multipoint fixed and mobile systems use OFDMA (W. Stallings *et al*, 2007; T.S. Rappaport *et al*, 1996).

OFDMA technologies typically occupy nomadic, fixed and one-way transmission standards, ranging from TV transmission to Wi-Fi as well as fixed WiMAX and newer multicast wireless systems like Qualcomm's Forward Link Only (FLO). OFDMA, however, adds true mobility to the mix, forming the backbone of many of the emerging technologies including LTE and mobile WiMAX.

Due to high spectral efficiency and robust transmission in presence of multipath fading, the OFDMA has been selected as basic modulation scheme for downlink in LTE systems. To overcome the effect of multi path fading problem available in UMTS, LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) for the downlink - that is, from the base station to the terminal to transmit the data over many narrow band careers of 180 KHz each instead of spreading one signal over the complete 5MHz career (Laurent Boher *et al*, 2008). The LTE physical layer specifications are designed to deal with the bandwidths from 1.25MHz to 20MHz. The modulation parameters for different transmission bandwidth are shown in table 1

In downlink, the subcarriers are divided into resource blocks. This allows the system to split the subcarriers into small parts, without mixing the data across the total number of subcarriers for a given bandwidth. The resource block consists of 12 subcarriers for a single time slot of 0.5ms duration. The structure of PRB is given in figure 2

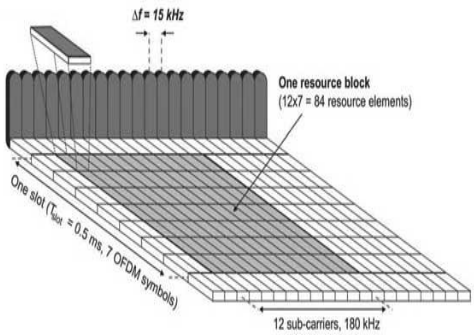

Figure 2: Downlink Resource Grid

Each user is allocated a number of so-called resource blocks in the time frequency grid. The more resource blocks a user gets, and the higher the modulation used in the resource elements, the higher the bit-rate. Which resource blocks and how many the user gets at a given point in time depend on advanced scheduling mechanisms in the frequency and time dimensions. The scheduling mechanisms in LTE are similar to those used in HSPA, and enable optimal performance for different services in different radio environments. There are different numbers of resource blocks for different signal bandwidths in LTE as shown in table 2

Table 2: Available Downlink Bandwidth is divided into Physical Resource Block

Bandwidth(MHz)	1.25	2.5	5.0	10.0	15.0	20.0
Sub carrier Bandwidth(KHz)	15					
Physical resource block (PRB) bandwidth (kHz)	180					
Number of available PRBs	0	12	25	50	75	100

4. Design Analysis

The details of OFDMA transmitter and receiver structure are presented in the block diagram below. We note that the OFDM systems basically involve the blocks shown in figure 3.

In Serial to Parallel Conversion of OFDM system, each channel can be broken into various sub-carriers. The use of sub-carriers makes optimal use out of the frequency spectrum but also requires additional processing by the transmitter and receiver. This additional processing is necessary to convert a serial bitstream into several parallel bitstream to be divided among the individual carriers. In the downlink of OFDMA systems, the high bit-rate data stream passes through modulator, where adaptive modulation schemes such as BPSK, QPSK, 16-QAM, 64-QAM is applied. Modulated data is converted from serial to parallel and mapped to different subcarriers.

IFFT of the mapped data is carried out to convert the data into their corresponding time domain and the output signal are converted back to serial data called OFDM symbols. The IFFT block is followed by adding the cyclic extension (cyclic prefix, CP).

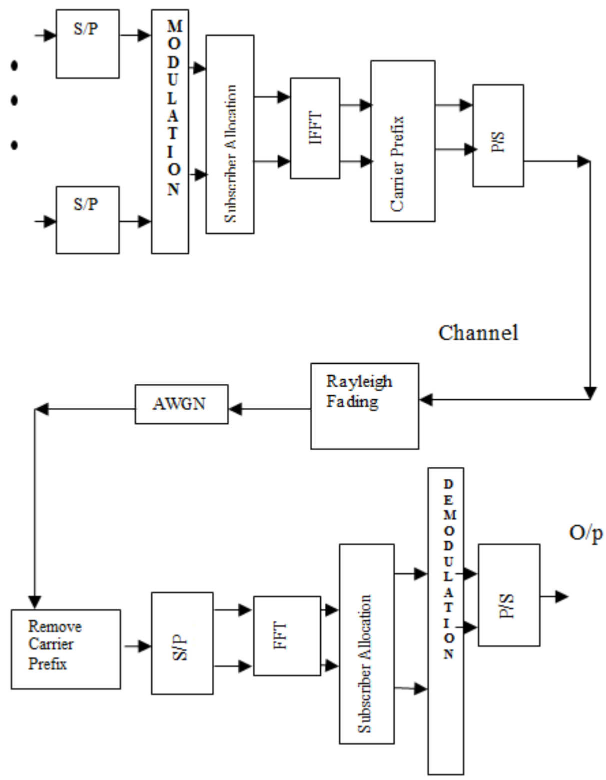

Figure 3: The Block Diagram of Transmitter and Receiver in OFDMA-LTE

Cyclic Prefix Insertion: Since, wireless communications systems are susceptible to multi-path channel reflections; a cyclic prefix is added to reduce ISI. A cyclic prefix is a repetition of the first section of a symbol that is appended to the end of the symbol. In addition, it is important because it enables multi-path representations of the original signal to fade so that they do not interfere with the subsequent symbol (Erik Dahlman *et al*, 2011).

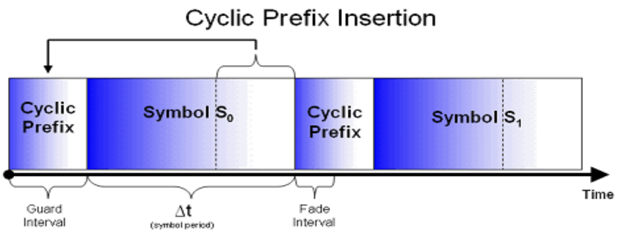

Figure 4: OFDM symbol with cyclic prefix

The motivation for adding the cyclic extension is to avoid inter-symbol interference (ISI). When the transmitter adds a cyclic extension longer than the channel impulse response, the effect of the previous symbol can be avoided by removing the cyclic extension at the receiver.

Parallel to Serial Conversion: once the cyclic prefix has been added to the sub-carrier channels, they must be transmitted as one signal. Thus, the parallel to serial conversion stage is the process of summing all sub-carriers and combining them into one signal. As a result, all sub-carriers are generated perfectly simultaneously.

Rayleigh fading: This is a reasonable statistical fading model for multipath situation in the absences of LOS component (Sai Krishna Borra *et al*, 2013).

AWGN Channel: Practically there are some losses in the system as compared to theoretical values; therefore we use the Additive White Gaussian Noise (AWGN) channel, which is commonly used to simulate the background noise of the channel (Sai Krishna Borra *et al*, 2013).

At receiver, the CP is removed first and then subcarriers are converted from parallel to serial sequence. The FFT stage further converts the OFDM symbols in to frequency domain followed by equalizer and demodulation as shown in figure

We use following adaptive modulation schemes to analyse the Peak to Average Power Ratio (PAPR), Bit Error Rate (BER), Signal to Noise Ratio (SNR), Error Probability (P_e) and Power Spectral Density (PSD) for OFDMA (M. Salehi *et al*, 2001)

- Binary Phase Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- 16-Quadrature Amplitude Modulation (16-QAM)
- 64-Quadrature Amplitude Modulation (64-QAM)

Advantages of OFDMA

- The primary advantage of OFDMA over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters.
- Channel equalization is simplified because OFDMA may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal.
- The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter symbol interference (ISI).
- This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

Disadvantages of OFDMA

- High peak-to-average ratio
- Sensitive to frequency offset, hence to Doppler-shift as well.

5. Performance Calculation

Using various mathematical Parameters of multiple access technique, the performance analysis of OFDMA is observed in this section

A. PAPR (Peak to Average Power Ratio): Power saving in transmission is an extensive issue for the multiple access techniques used in LTE, therefore is considered an important transmission factor PAPR for OFDMA. The PAPR is calculated by representing a CCDF (Complementary Cumulative Distribution Function) of PAPR. The CCDF of PAPR is the probability that the PAPR is higher than a certain PAPR value PAPR0 (Pr {PAPR>PAPR0}). It is an important measure that is widely used for the complete description of the power characteristics of signals (H.G. Myung *et al*, 2006).

B. BER: The bit error rate is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure.

BER = Error Bits / Number of Transmitted Bits

C. SNR: The SNR is the ratio of bit energy (Eb) to the noise power spectral density (N0) and it is expressed in dB.

$$SNR = E_b / N_0$$

D.BER vs. SNR Process: For any modulation scheme, the BER is expressed in terms of SNR. BER is measured by comparing the transmitted signal with received signal, and compute the error counts over total number of bits transmitted.

E. Probability of error (P_e): The probability of error or error probability (Pe) is the rate of errors occurs in the received signal. For coherent detection, the symbol error probability of M-ary PSK and M-ary QAM in the AWGN channel is determined by following expression;

$$\mathrm{P_e} \cong 2\left(1-\frac{1}{\sqrt{\mathrm{M}}}\right)\mathrm{erfc}\left[\sqrt{\frac{3\mathrm{E_{av}}}{2(\mathrm{M}-1)\mathrm{N_o}}}\right]$$

Where,
N_0 = Noise density in AWGN
E_{av} = Average value of transmitted symbol energy in M-ary QAM

F. Power Spectral density (PSD): In regard to communication, PSD for any signal is very helpful since, the integral of the PSD over a given frequency band computes the average power in the signal over that frequency band. PSD gives you the strength of a signal over a period of time. it is nothing but different ways of computing the sum of FFT of a signal. The PSD of a signal x(t)is given by

$$P = \lim_{T=\infty} \frac{1}{2T} \int_{-T}^{T} x(t)^2 dt$$

G. Adaptive modulation and coding (AMC): It is a term used in wireless communications to denote the matching of the modulation, coding and other signal and protocol parameters to the conditions on the radio link. Adaptive modulation systems improve rate of transmission, and/or bit error rates, by exploiting the channel information that is present at the transmitter. Especially over fading channels which model wireless propagation environments, adaptive modulation systems exhibit great performance enhancements compared to systems that do not exploit channel knowledge at the transmitter (Essam Sourour *et al*, 2011).

6. Simulation Result

The simulation was carried out using MATLAB and the following results are obtained:

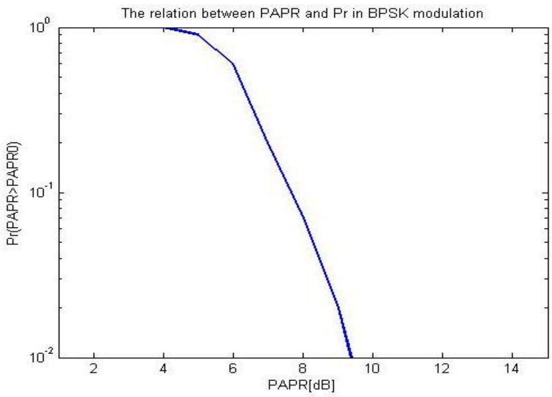

Figure 5: Graph showing the relation between PAPR and P_r in BPSK Modulation

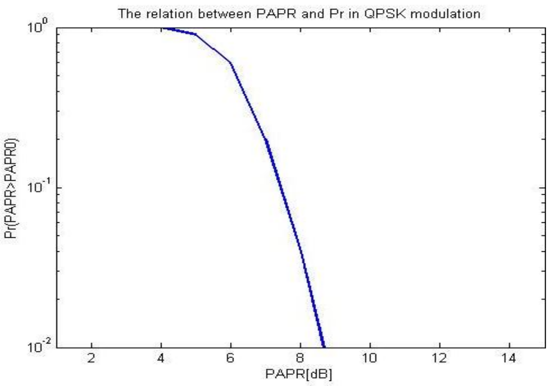

Figure 6: Graph showing the relation between PAPR and P_r in QPSK Modulation

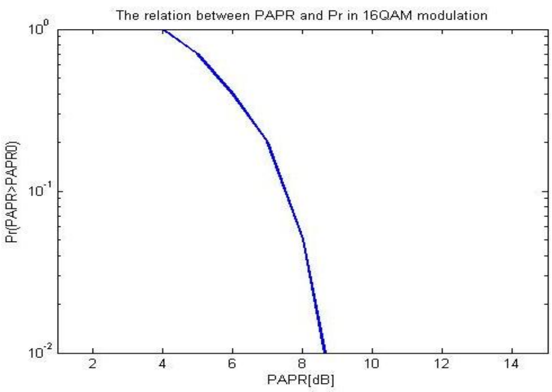

Figure 7: Graph showing the relation between PAPR and P_r in 16 QAM Modulations

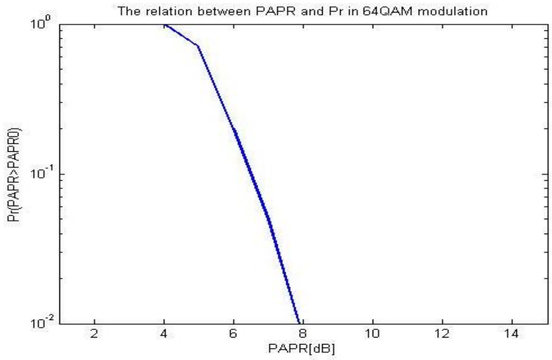

Figure 8: Graph showing the relation between PAPR and P_r in 64 QAM

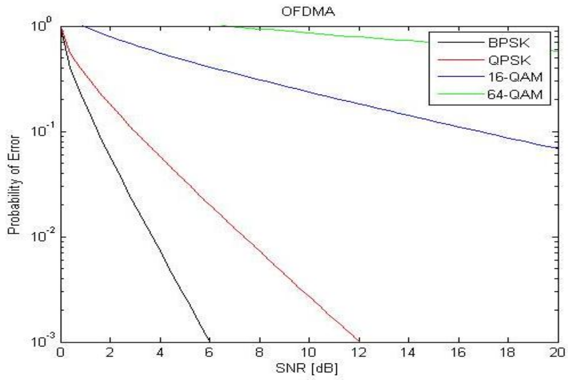

Figure 9: The relation between SNR and P_e for different modulation type

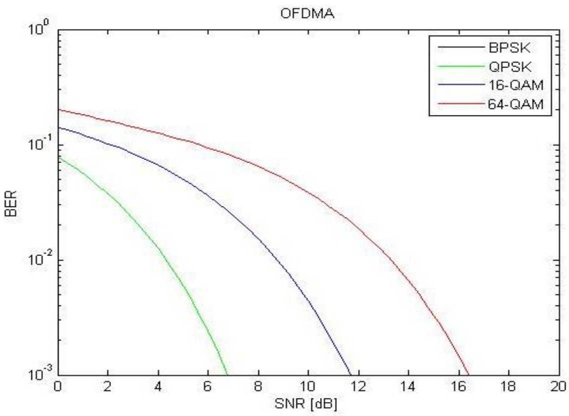

Figure 10: The relation between SNR and BER for different modulation types

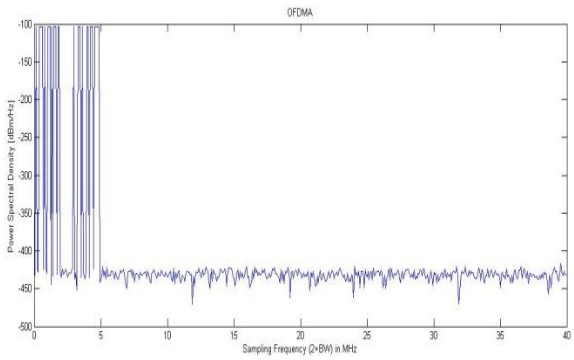

Figure 11: The relation between Sampling rate (2×Bandwidth) and PSD

Figure (5, 6, 7 and 8) shows that for OFDMA the PAPR decreases for higher order modulation (64-QAM).Therefore high order modulation is more effective to reduce the problem of high PAPR in OFDMA. From the relation between BER vs. P_e in figure 9, the BPSK modulation has less value of SNR as compared to other modulations. The 64-QAM has higher SNR values in OFDMA.

In OFDMA the graph between BER vs. SNR (Figure 10) shows that the BPSK and QPSK have same SNR values, but a sudden change occurs in 16-QAM and 64-QAM. The 64-QAM has highest value of SNR, which shows that 64-QAM is more efficient in terms of BER and Figure 11 show the relation between the sampling frequency (Fs) and power spectral density (PSD).

Conclusion

The following conclusions are made from the simulation results:

- Higher order modulation schemes have an impact on the PAPR of OFDMA. The PAPR decreases for higher order modulation scheme. Since Higher PAPR requires expensive and inefficient power amplifiers, we need to adopt higher order modulation scheme i.e. 16-QAM and 64-QAM for downlink in order to have less PAPR at user end.
- For a fix value of SNR, the BER increases for high order modulation (16-QAM and 64-QAM) in OFDMA 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 and SNR.
- We also conclude from our results that, the error probability increases as order of modulation scheme increases.

Therefore the selection of modulation schemes in adaptive modulation is a key feature based on these results.

References

S. Haykin (2001), Communication system, *John Wiley & Sons*, New Jersey.

W. Stallings(2007), Data and computer communications, *prentice hall*.

T.S. Rappaport (1996), Wireless communications: principles and practice, *Prentice Hall* PTR New Jersey

J.G. Proakis and M. Salehi(2001), Digital communications, *McGraw-hill* New York.

Yapeng Wang, Xu Yang, Athen Ma, and Laurie Cuthbert(2009),Intelligent Resource Optimization Using Semi-Smart Antennas in LTE OFDMA Systems, *Proceedings of ICCTA.*

Ayoola Akinloye Akinniranye and Samson Adenle Oyetunji(2013), Resource Optimisation for 3rd Generation Partnership Project (3GPP) Long Term Evolution OFDMA Downlink Interface Air, *Scientific Research, Wireless Engineering and Technology*, vol 4, 188-197

Laurent Boher, Rodolphe Legouable, and Rodrigue Rabineau(2008), Performance Analysis of Iterative Receiver in 3GPP/L TE DL MIMO OFDMA System, ISSSTA, *IEEE 10th International Symposium on Spread Spectrum Techniques and Applications*.

H.G. Myung, J. Lim, and D.J. Goodman(2006), Peak-to-average power ratio of single carrier FDMA signals with pulse shaping, Proc. of PIMRC06.

Sai Krishna Borra; Suman Krishna Chaparala(2013), Performance Evaluation of OFDM System with Rayleigh, Rician and AWGN Channels, *International Journal of Emerging Technology and Advanced Engineering*, Volume 3, Issue 3.

Erik Dahlman, Stefan Pariwall, and Johan Skiild, (2011),4G LTE/LTE Advanced for Mobile Broadband, *Academic Press of Elsevier*, Oxford, USA.

Mofreh EI- Gendy and Essam Sourour(2011), A Study of Access Methods Effect on the Performance of Two-Tier LTE Femtocell Networks, *28th National Radio Science Conference (NRSC).*