International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-5 Issue-5, June 2016

Physical Layer Comparison Between LTE, OFDM and WIMAX

M. Amr Mokhtar

Abstract— ***this paper presents simulation results along with underlying assumptions. In the first part, LTE uplink and performed link level simulations of Single Carrier Frequency Domain Equalization (SC-FDE) and SC-FDMA in comparison with OFDM, has been investigated. Two types of multipath channels, i.e. ITU Pedestrian A and ITU Vehicular A channels, have been used. In addition an Additive White Gaussian Noise (AWGN) channel is also used. Furthermore, the simulation of PAPR is performed for SC-FDMA and OFDMA systems. In the second part of this paper, the capacity of the MIMO system and performed a comparison with SISO, has been analyzed, and two significant 4G evolved technologies like LTE and WIMAX. They played an important role in the high speed communication systems with higher data rates, higher system capacity and robustness against bad channel conditions, thanks also to the two advanced technologies like MIMO (multi input multi output) and multicarrier aggregation for updating the LTE and WIMAX with higher bandwidth, higher data rates and better coverage.***

Keywords: OFDM, SC-FDE, SC-FDMA, AWGN, PAPR, MIMO, SISO, LTE, WiMax

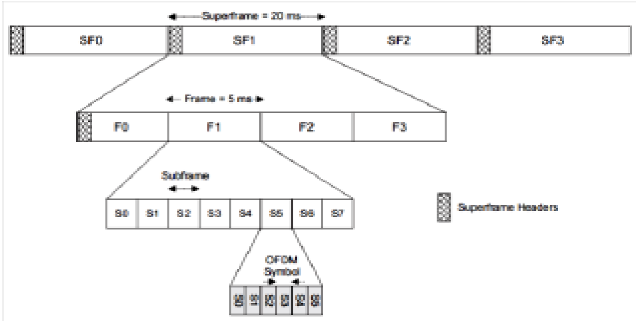
I.INTRODUCTION

Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WIMAX) technologies are the main competitors in the mobile communication domain, they provide with low latency and high mobility speeds reaches to 350 Km[1], also provide with high data rates to meet the users' need in internet services and to increase the system capacity. The Long Term Evolution (LTE) is an evolution of the third generation technology based on Wideband Code Division Multiple Access (WCDMA). LTE uses OFDM for downlink, i.e. from base station to the terminal. LTE developed to the advanced version which can deliver 1Gpbs [3] in downlink for fixed users with higher order of (MIMO) and carrier aggregation. Worldwide Interoperability for Microwave Access (WIMAX) technology, also known as the IEEE 802.16 standard, is based on WMAN (Wireless Metropolitan Area Network), WIMAX uses OFDMA (Orthogonal Frequency Division Multiple Access) as multiplexing technique in uplink and downlink directions. Other versions of WIMAX include IEEE 802.16-2004 and IEEE 802.16-2005[3]. IEEE 802.16-2004 is known as fixed WIMAX which has no mobility and is used for fixed communication [4]. Since fixed WIMAX has no mobility it does not support handovers. IEEE 802.16-2005 is known as mobile WIMAX which is an extension of fixed WIMAX [3], Introducing many new features to support enhanced Quality of Service (QoS) to provide high mobility [4]. WIMAX developed to the advanced version which can also Deliver 1Gpbs [6] in downlink for fixed users with higher order of MIMO and carrier aggregation.

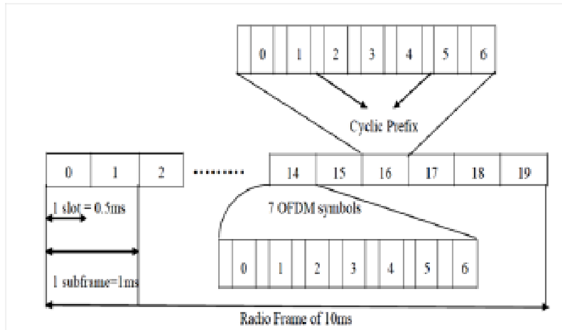
Manuscript published on 30 June 2016.
* Correspondence Author (s)
M. Amr Mokhtar, Associate Professor, Department of Electrical Engineering, Faculty of Engineering, Alexandria University, Alexandria, Egypt.

II.PHYSICAL LAYER COMPARISON BETWEEN LTE AND WIMAX

1) In Multiple Access Technology The uplink/downlink of the WIMAX is the orthogonal frequency division multiple access (OFDMA) [1] while in LTE the uplink is single carrier frequency division multiple access (SC-FDMA) for low peak to average power ratio and the downlink is OFDMA [2].
2) In Frame Structure LTE Uses the Generic Frame Structure (GFS) as shown in Figure.1 [5]. The GFS used by frequency division duplex (FDD) is 10ms in duration and has 10 subframes. Every subframe is 1ms in length and divided into two equal slots of 0.5ms. Every slot comprises 7 OFDM/SC-FDMA symbols in case of normal cyclic prefix (CP) 5us and 6 OFDM/SC-FDMA symbols in case of extended CP 16.67us[5].



For the mobile WIMAX the basic frame structure is shown in Figure.2 [1], a superframe is defined as a set of four consecutive and equally-sized radio frames. Each 20 ms superframe contains a Primary Superframe Header (P-SFH) and a Secondary Superframe Header (S-SFH). The number of subframes per frame varies depending on the CP size [1].



3) In Modulation Parameters the available spectrum OFDMA is divided into number of orthogonal subcarriers with the spacing of Δf between them (Δf=15 KHz and 10.94 KHz for LTE and WIMAX, respectively) [1], fixed numbers of subcarriers are grouped together to form a resource block (12 and 18 subcarriers in LTE and WIMAX, respectively) [1]. The resource block (RB) is defined in time for numbers of OFDM symbols (5-14 symbols) depending on the system configuration [1]. The resource blocks (RBs) are grouped in the frame 10ms in case of LTE [5] and 5ms in case of WIMAX [1].

Table.1 [1] brief summary between LTE and WIMAX

Aspect	Advanced LTE	WIMAX
Access Technology	DL:OFDMA UL:SC-FDMA	DL:OFDMA UL:OFDMA
Duplexing Modes	FDD,TDD	FDD,TDD
Channel Bandwidth (MHz)	1.25,5,10,15,20 up to 100 by carrier aggregation	1.25,5,10,15,20 up to 50 by carrier aggregation
FFT Size	256,512,1024,2048,2048	256,512,1024,2048,2048
Subcarrier Spacing (KHz)	15	10.94
Frame Duration (ms)	10	5
Cyclic Prefix Length	Normal CP:5.21us Extended CP:16.67us	1/8,1/16,1/32 (Tu) us
Peak Data Rates	DL:>1 Gbps (8*8) with aggregating components of release 8 UL:300 Mbps	DL:>350 Mbps (4*4) can be >1Gbps with aggregating carriers (8*8) In wimax2+ UL:>200 Mbps (2*4)
Mobility (Km/h)	350	350

III.SIMULATION OF LTE UPLINK IN COMPARISON WITH AN OFDM SYSTEM

A. *Link Level Simulation of SC-FDE*

1) SER for SC-FDE and OFDM using Minimum Mean Square Error (MMSE) as Equalization Scheme SER measurement of SC-FDE and OFDM have been calculated by using three types of channels, ITU Pedestrian A, ITU Vehicular A and AWGN channel. The equalization scheme used to obtain the SER curves is MMSE.

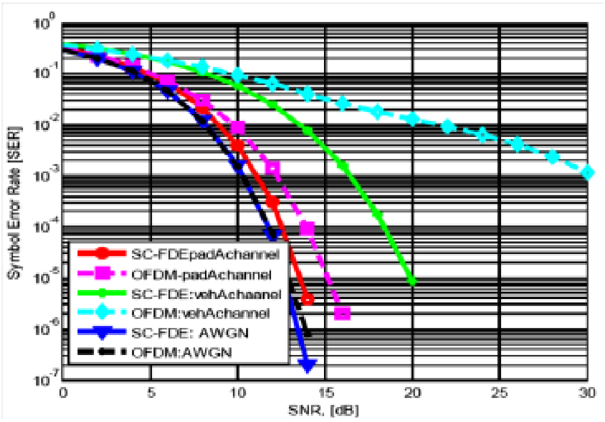


Figure. 3 Comparison of SC-FDE and OFDM using MMSE Equalization in Pedestrian A, Vehicular A and AWGN Channels

Simulation results show that in case of AWGN channel, SC-FDE and OFDM have similar SER performance. However, in case of Pedestrian A and Vehicular A channel, SC-FDE outperforms the OFDM. As it is known, OFDM needs additional channel coding to achieve this performance due to its sensitive nature to carrier frequency. The comparative summary obtained from Figure 3 is described in Table .2 and Table .3.

Table .2 Comparison between SC-FDE and OFDM in Various Channels Using MMSE Equalization

	Channels	SNR (indB)	SER
SC-FDE	AWGN	10	0.001566
	Pedestrian A	10	0.004029
	Vehicular A	10	0.0577
OFDM	AWGN	10	0.001566
	Pedestrian A	10	0.008625
	Vehicular A	10	0.09313

Table .3 clearly shows that SC-FDE significantly reduces SER as compared to OFDM in Vehicular A and Pedestrian A Channel.

Table .3 Comparison between SCFDE and OFDM in Vehicular A Channel using MMSE Equalization

	Channel	SNR (indB)	SER
SC-FDE	Vehicular A	16	0.001578
		20	8.594e-006
OFDM	Vehicular A	16	0.02622
		20	0.013

Table .3 illustrates an important result, as SNR increases, the SC-FDE sharply reduces the Symbol error rate as compared to OFDM in case of vehicular channel.

2) SER for SC-FDE and OFDM using Zero Forcing Calculation of SER is performed using Zero Forcing as equalization scheme for the comparison of SC-FDE and OFDM in AWGN, ITU Pedestrian A and ITU Vehicular A channel.

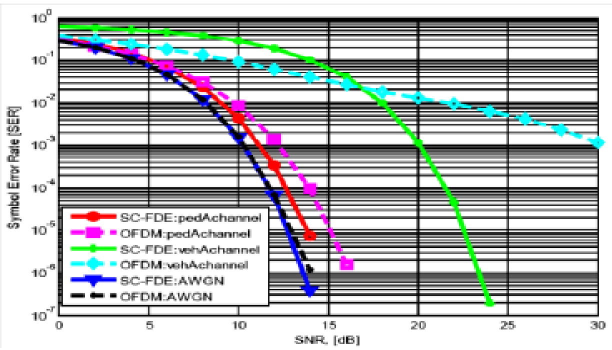


Figure .4 Comparison of SC-FDE and OFDM using Zero Forcing Equalization

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-5 Issue-5, June 2016

Simulation results show that SC-FDE outperforms the OFDM in case of multipath channels i.e. ITU Pedestrian A and ITU Vehicular A channel. It is seen that in case of Vehicular A channel, OFDM has a continuous reduction of SER and it significantly minimizes the SER up to certain values of SNR as compared to SC-FDE. However, SC-FDE outperforms OFDM for higher values of SNR. The comparative summary of the results obtained from the simulation are shown in Figure 3.4 and described in Table .4 and .5

Table .4 Comparison of SCFDE and OFDM in various Channels using Zero Forcing

	Channels	SNR (indB)	SER
SC-FDE	AWGN	10	0.001578
	Pedestrian A	10	0.004428
	Vehicular A	10	0.2797
OFDM	AWGN	10	0.001578
	Pedestrian A	10	0.008546
	Vehicular A	10	0.0932

Table .4 shows that SCFDE has better performance in case of AWGN and Pedestrian channel while OFDM is better in case of vehicular channel.

Table.5 Performance of SCFDE and OFDM using Zero Forcing in Vehicular A Channel

	Channel	SNR (indB)	SER
SC-FDE	Vehicular A	14	0.1004
		18	0.009742
		22	4.492e-005
OFDM	Vehicular A	14	0.04008
		18	0.01804
		22	0.009223

Table.5 shows that OFDM gives better performance for smaller values of SNR but for higher values, the SC-FDE significantly reduces SER as compared to OFDM system which continuously reduces the error as the value of SNR is increased.

It is observed from Figure 3.3 and 3.4 that MMSE gives better performance as compared to zero forcing.

3) Comparison of SC-FDE and OFDM with/without CP
The comparison of SCFDE and OFDM is performed in Vehicular channel with and without CP. The equalization scheme used in this simulation is MMSE.

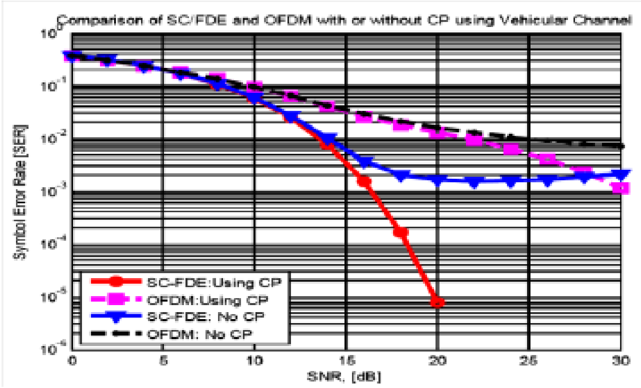


Figure.5 Comparison of SC/FDE and OFDM with or without CP using Vehicular Channel

Figure.5 shows that the use of CP reduces the SER as compared to the system having no CP. In addition, it is clearly shown that SC-FDE system gives low SER as compared to OFDM. Table.6 summarizes the comparison obtained from simulation.

Table.6 Comparison of SC-FDE and OFDM With and Without CP

	Channel	With CP		Without CP		Equalization
		SNR (indB)	SER	SNR (indB)	SER	
SC- FDE	Vehicular A	16	0.00155	16	0.00377	MMSE
		18	0.0001684	18	0.00203	
		20	7.813e-006	20	0.00167	
OFDM	Vehicular A	16	0.02626	16	0.02895	
		18	0.01823	18	0.02083	
		20	0.01292	20	0.01611	

B. *Link Level Simulation of SCFDMA*

The simulation flow for SCFDMA is shown in Figure.6. Two types of subcarrier mapping schemes for SCFDMA have been investigated and their performance in terms of SER and SNR has been compared. The types of subcarrier mapping schemes are Interleaved FDMA (IFDMA) and Localized FDMA (LFDMA). Parameters used in simulation are given in Table.7.

Table.7 Simulation Parameters of SC-FDMA

Parameters	Assumptions
System Bandwidth	5 MHz
FFT Size	512
Block Size	16 symbols
CP Length	20 samples
Range of SNR	0 to 30 dB
Modulation	QPSK
Number of iteration	10^4
Channel	AWGN, Pedestrian A and Vehicular A.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Equalization	MMSE
Confidence Interval	32

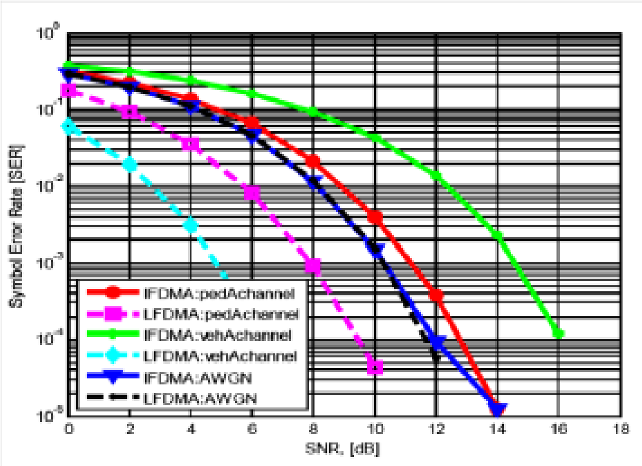


Figure.6 Comparison of SER with Various Subcarrier Mapping Schemes

Figure.6 presents the performance of SC-FDMA system using subcarrier mapping schemes IFDMA and LFDMA for various channels. It is clear from the simulation that LFDMA outperforms the IFDMA in all channel conditions and gives better performance.

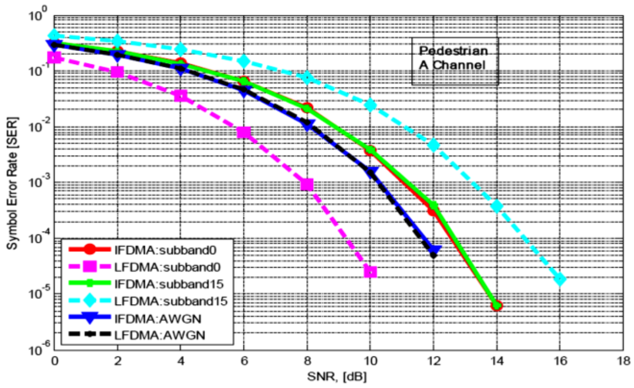


Figure.7 SER Performance of SC-FDMA System Using Various Subcarrier Mapping Schemes

Figure.7 presents the SER performance of SC-FDMA system in AWGN and Pedestrian A channel using two subcarrier mapping schemes. In case of AWGN channel, it is seen that IFDMA and LFDMA have similar performance whereas for Pedestrian A channel the two subcarrier schemes have different SER performance. In addition, it is clearly shown that the performance of IFDMA system does not depend on location of subband and gives approximately similar SER curves for subband 0 and subband 15. This is due to the inherent characteristic of frequency diversity of the IFDMA scheme. As for LFDMA, the performance of SC-FDMA is better in case of subband 0 and worst in case of subband 15. This is because of channel gain which is higher than average at subband 0 and below to average at subband 15.

C. Peak -to- Average Power Ratio

Peak to average power ratio is defined as “the ratio of peak signal power to the average signal power”.

$$PAPR = \frac{PeakSiganalPower}{AverageSignalPower} \qquad (1)$$

Mathematically, PAPR can be written as

$$PAPR = \frac{\max_{0\le t\le NT}[x(t)]^2}{\frac{1}{NT}\int_0^{NT}[x(t)]^2 dt} \qquad (2)$$

Where

$$x(t) = e_c^{jw}.t\sum_{n=0}^{N-1}\tilde{x}_n p(t-nT)a_n \qquad (3)$$

$\tilde{x}_n$: n =0, 1, …, N-1 are the time domain symbols that come after the IDFT.

W_c= Carrier Frequency

$\tilde{T} = \tilde{x}_n$symbol duration, and

P(t) = Baseband Pulse.

For pulse shaping we used Raised Cosine (RC) and Square Root Raised Cosine (RRC) filters because they make the receiver robust against timing synchronization errors. The parameters used for the calculation of PAPR are illustrated in Table .8. For the calculation of PAPR we use Complementary Cumulative Distribution Function (CCDF). The CCDF is defined as the probability for which PAPR is greater than any PAPR value i.e. PAPR0.
CCDF: Pr (PAPR >PAPR0)

Table .8 Parameters used in the simulation of PAPR calculation for SCFDMA

Parameters	**Assumptions**
System Bandwidth	10 MHz
Number of Subcarriers (N)	512
Number of Symbols (M) Spreading Factor for IFDMA (Q)	128 Q= N/M=4
Spreading Factorfor LFDMA	2
Roll of Factor Over Sampling Factor	0.25 4
Number of iteration	10^4
Subcarrier Mapping Schemes	IFDMA, DFDMA, LFDMA
Confidence Interval	32

D. PAPR-SCFDMA Calculation Using QPSK

The PAPR calculation using various subcarrier mapping schemes for SCFDMA system is shown in Figure 3.10. The modulation scheme used for the calculation of PAPR is QPSK.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

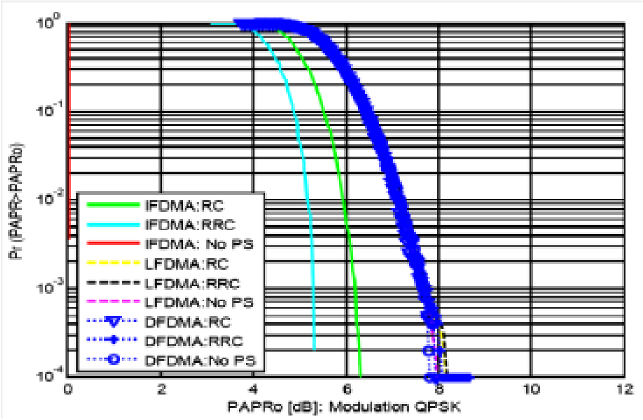


Figure .8 Comparison of CCDF of PAPR for DFDMA, IFDMA and LFDMA using QPSK

Figure .8 shows that IFDMA gives lowest PAPR values as compared to other subcarrier mapping schemes (DFDMA and LFDMA).

E. PAPR-SCFDMA Calculation Using 16-QAM

The PAPR calculation using various subcarrier mapping schemes for SC-FDMA system is shown in Figure .11. The modulation scheme used for the calculation of PAPR is 16-QAM.

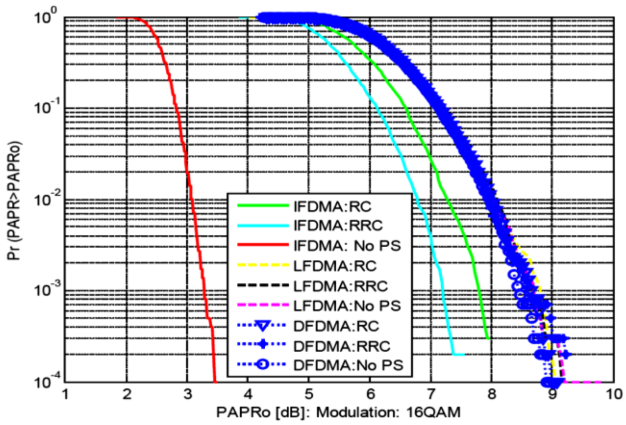


Figure.9 Comparison of CCDF of PAPR for IFDMA, DFDMA and LFDMA using 16-QAM

Figure.9 show that IFDMA has lowest value of PAPR at 3.2dB which is 0dB in case of QPSK as modulation technique. We can also observe from the figure that we get higher values of PAPR by using 16-QAM which is undesirable because they cause nonlinear distortions at the transmitter.

F. PAPR Calculation for OFDMA

It is known theoretically that OFDMA gives higher PAPR values as compared to SCFDMA due to its multicarrier nature. In addition, there is no pulse shaping filter used in OFDMA. The simulation model for the calculation of PAPR for OFDMA system is shown in Figure.10.

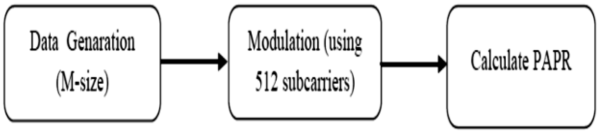


Figure .10 Simulation Model of PAPR Calculations for OFDMA

The simulation parameters used in the simulation are described in Table.9.

Table .9 Parameters Used in the Simulation of PAPR-Calculation for OFDMA

Parameters	Assumptions
System Bandwidth	5 MHz
Number of Subcarriers (N)	512
Number of Symbols (M)	128
Over Sampling Rate	4
Number of Iterations	10^4
Confidence Interval	32

Figure.11 shows the PAPR calculation of OFDMA system using QPSK and 16-QAM modulation techniques. The graph shows that the PAPR value of OFDMA system is much higher than SC-FDMA system. We can also observe that the behavior of CCDF (Complementary Cumulative Distribution Function) is quite similar in case of QPSK and 16-QAM.

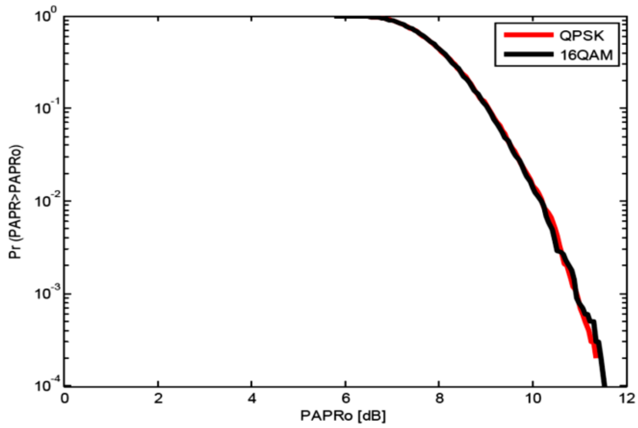


Figure.11 Comparison of CCDF of PAPR for OFDMA using QPSK and 16-QAM

G. Capacity of MIMO System

MIMO system consists of multiple transmit and receive antennas interconnected with multiple transmission paths. MIMO increases the capacity of system by utilizing multiple antennas both at transmitter and receiver without increasing the bandwidth.

$$Capacity\ of\ MIMO = \sum_{i=1}^{r} \log_2\left(1 + \frac{\rho}{M}\lambda_i\right) \qquad (4)$$

Where,

r = rank of matrix
λ= Positive eigenvalues of HH^H (as H^H is the conjugate of H)
ρ= SNR
Capacity of SISO= $\log_2(1+\rho h^2)$

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

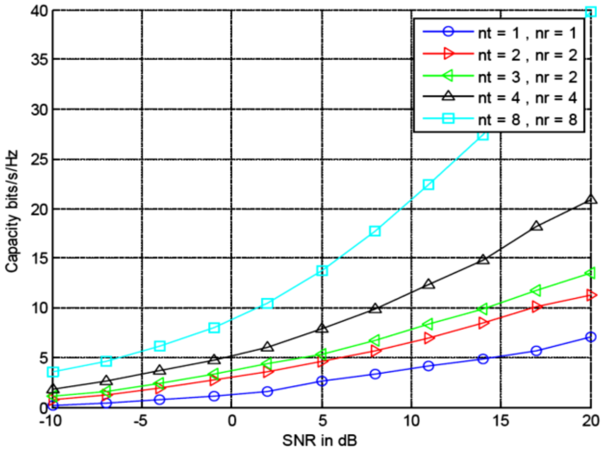


Figure.12 Comparison of MIMO and SISO system in terms of Capacity

Figure.12 shows the comparison between MIMO and SISO systems in terms of capacity. The graph depicts that the capacity of system can be increased by increasing the number of antennas at transmitter and receiver. The graph also show that 8x8 MIMO system has larger capacity whereas SISO system as lowest capacity.

Table.10 summarizes simulation results obtained from Figure .12.

- **For SNR= 5dB**

Table .10 Comparison between MIMO and SISO System with SNR=5 dB

Antenna Configuration	Capacity (bits/s/Hz)
SISO	2.589
MIMO (2x2)	4.589
MIMO (3x2)	5.325
MIMO (4x4)	7.907
MIMO (8x8)	13.7

- **For SNR= 14dB**

Table .11 Comparison between MIMO and SISO System with SNR=14 dB

Antenna Configuration	Capacity (bits/s/Hz)
SISO	4.89
MIMO (2x2)	8.485
MIMO (3x2)	9.941
MIMO (4x4)	14.83 `
MIMO (8x8)	27.48

IV.SIMULATION LTE, WIMAX.

Figure.13 is for LTE physical layer performance with different modulation techniques such as QPSK, 16QAM and 64QAM, for bit error rate 10^{-3} the most power efficiency is given by QPSK at SNR ≈16 db.

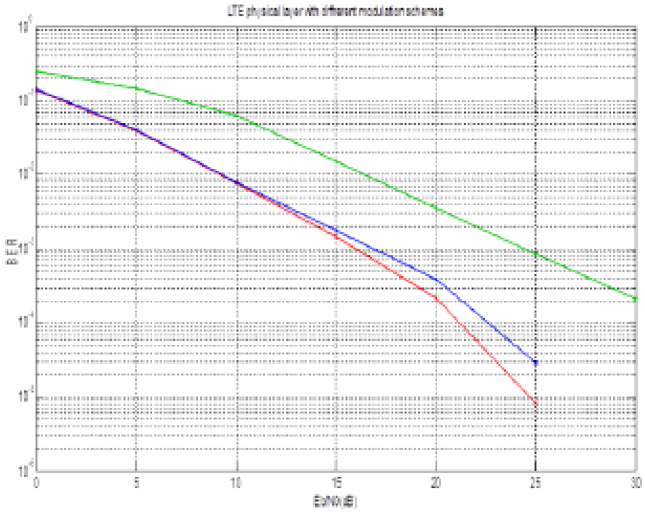


Figure .13 LTE physical layer performance with different modulation techniques

In Figure.14 is for WIMAX physical layer performance with different modulation techniques such as QPSK, 16QAM and 64QAM, for bit error rate10^{-2} the most power efficiency is given by QPSK at SNR ≈8 db.

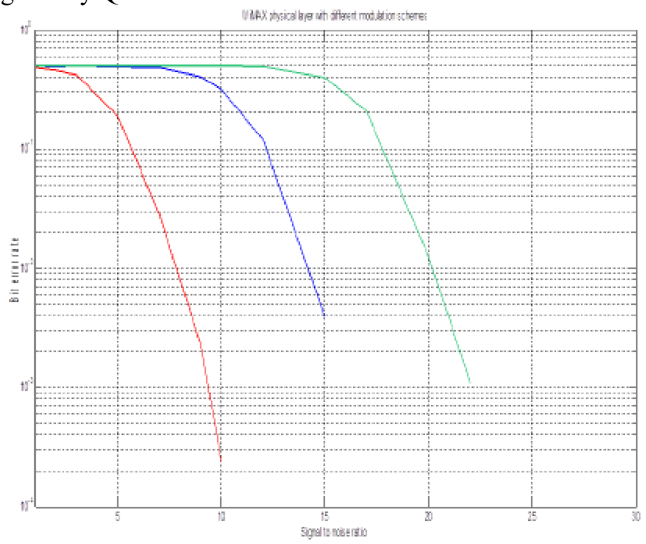


Figure. .14 WIMAX physical layer performance with different modulation techniques

V.CONCLUSION

It is concluded from the simulations that SC-FDE has low SER as compared to OFDM in all channel conditions. Also, the use of LFDMA as a subcarrier mapping scheme in SC-FDMA gives better SER performance when compared to IFDMA in all channel conditions (ITU Pedestrian A, ITU Vehicular A, AWGN). IFDMA gives lowest PAPR as compared to LFDMA and DFDMA subcarrier mapping schemes. The use of QPSK further reduces the PAPR as compared to 16-QAM. It is also concluded that OFDMA gives high PAPR values as compared to SC-FDMA due to the use of multiple subcarriers. The two technologies are in competition and have evolved tremendously and are qualified for 4G interface.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

These technologies have enabled the telecommunication industry to reach download speed from 100Mb/s up to 1 GB/s and exceeds allowing real time and higher speed for multimedia communication also higher bandwidth can reach up to 100MHz in LTE and 50MHz in WIMAX allowing more users per cell and higher speeds improving the overall system capacity. All the benefits mentioned above of the LTE and WIMAX as a result of applying two significant technologies and they are MIMO and carrier aggregation. MIMO for providing higher data rates with good spectral efficiency and power efficiency. Carrier aggregation enables aggregating the distributed spectrum band to make a large frequency resource to increase the total bandwidth and throughput.

REFERENCES

1. Sassan Ahmadi, Mobile WIMAX. A systems approach to understanding IEEE 802.16m radio access technology, Academic press Elsevier, and 2011.
2. Eric Dahlman, Stefan Parkvall and Johan Skold, 4G LTE-Advanced for Mobile Broadband, Academic press Elsevier, 2011.
3. Zakhia Abichar and J.Morris Chang, WIMAX VS. LTE: who will lead the broadband mobile internet?, IEEE computer society, 2010.
4. Jeffrey G. Andrews, Arunabha Ghosh and Rias Muhamed, Fundamentals of WIMAX Understanding Broadband Wireless Networking, prentice hall series, February 2007.
5. Eric Dahlam, Stefan Parkvall, Johan Skold, 3G Evolution - HSPA and LTE for Mobile Broadband. Elsevier Ltd.2008.2ndEd.
6. Berge Ayvazian, WIMAX advanced to harmonized with TD-LTE, white paper, Heavy reading website, November 2013

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)