Performance Analysis of LTE Physical Layer Based on 3GPP-Release-8

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ABSTRACT

Long Term Evolution is the last step towards the 4th generation of cellular networks. This revolution is necessitated by the unceasing increase in demand for high speed connection on LTE networks. This paper mainly focuses on performance evaluation of LTE physical layer to study and analysis the effect of transmitting and receiving data over noisy channels and how to resist loss in data by this simulation model for the downlink and uplink direction using matlab simulink based on 3GPP release 8 specifications to build up a simulation model for transmission voice over LTE networks, using the proposed simulation model in this paper to analysis the problems appeared in wireless air interface. Where, LTE is the latest high speed mobile broadband technology that is gaining widespread attention due to its high data rates and improved Quality of Service.

Keywords: *Long term Evolution (LTE); Physical Layer (PHY); 3rd Generation Partnership Project (3GPP);Single Carrier Frequency Division Multiple Access (SC-FDMA);Orthogonal Frequency Division Multiple Access (OFDMA); and Bit Error Rate (BER).*

1. INTRODUCTION

Wireless systems are more prone to security hazards than the wired ones. On the other hand, the adaptability of any wireless network technology is mainly dependent on the security features it provides. When the data rate of the wireless network technology is as high as in LTE, BER becomes one of the most important issues [1]. The trend of 4G is (i) Convergence services, (ii) Broadband services, (iii) Interactive All-IP with home networking, and (iv) flexibility and personalized service [2].

1.1 LTE Overview

Universal Mobile Telecommunications System (UMTS) networks worldwide are being upgraded to High Speed Packet Access (HSPA) in order to increase data rate and capacity for packet data. HSPA refers to the combination of High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA). While HSDPA was introduced as a 3GPP release 5 feature, HSUPA is an important feature of 3GPP release 6.However, even with the introduction of HSPA, evolution of UMTS has not reached its end. HSPA+ will bring significant enhancements in 3GPPrelease 7 and 8.Objective is to enhance performance of HSPA based radio networks in terms of spectrum efficiency, peak data rate and latency, and exploit the full potential of WCDMA based 5 MHz operation. Important features of HSPA+ are downlink MIMO (Multiple Input Multiple Output), higher order modulation for uplink and downlink, improvements of layer2 protocols, and continuous packet connectivity. In order to ensure the competitiveness of UMTS for the next 10 years and beyond, concepts for UMTS Long Term Evolution (LTE) have been introduced in 3GPP release 8. Objective is a high-data-rate, low-latency and packet-optimized radio access technology. LTE is also referred to as EUTRA (Evolved UMTS Terrestrial Radio Access) or E-UTRAN (Evolved UMTS Terrestrial Radio Access Network) [1].

1.2 LTE Specifications

The LTE PHY employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE PHY uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA is power inefficient, because of the high peak-to-average-power ratio (PAPR), but since the downlink is part of the base station (e-Node-B in 3GPP terminology) it does not matter that much. In the uplink, where the transmission starts from the mobile devices that use batteries, LTE uses SCFDMA, which brings a reduced peak-to-average-power ratio (PAPR). It saves power without degrading system flexibility or performance ensuring a better mobility since the higher power efficiency is important for mobile devices [3].

SCFDMA is an alternative solution to OFDMA. The performance of OFDMA can be better than SCFDMA but it is less power efficient. The LTE PHY is designed to meet the following goals: (i) Support scalable bandwidths of 1.25, 2.5, 5.0, 10.0 and 20.0 MHz; (ii) Antenna configurations Downlink: 4x2, 2x2, 1x2, 1x1 , Uplink: 1x2, 1x1; (iii) Optimized for low speeds (<15 km/hr); High performance at speeds up to 120 km/hr; and Maintain link at speeds up to 350 km/hr [4];(iv) High capacity support 200 users for active mode and 400 user for idle mode at 5MHz band width[5]; and(v) Very low latency where 100ms from idle to active and 50 ms from active to idle[6], However LTE system does not support macro-diversity or soft-handoff [7].

This paper addresses the 3GPP outlines and analyzes the performance of multiplexing techniques used in LTE release 8 explaining the spectrum scope of transmitted and received signals and the cumulative BER due to transmitting over a noisy channel. The system was simulated over an AWGN; Rayleigh; and Rician channels with a variable modulation scheme index.

1.3 LTE Advantages

LTE has also some power-saving mechanisms to turn off the transmitter whenever there is no data to transmit or receive. It uses Discontinued Reception (DRX) and Discontinued Transmission (DTX). The DRX supports an on/off cycle for the user device's radio. When it's on, the radio can transmit and receive data, but when it is off, it does not communicate with other devices or hardware. It is even possible to turn the radio off in the middle of a call when there are longer breaks and no data is transmitted. This approach leads also to power savings [8].

1.4 LTE Limitations

Although LTE was labeled as 4G but after the International Telecommunication Union Radio communication Sector (ITU-R) decided the specifications of 4G, LTE did not meet all requirements. These 4G specifications, also known as IMT-Advanced (International Mobile Telecommunications Advanced) require: (i) maximum data rates up to 100 Mbitps for mobile access, (ii) maximum data rates up to 1 Gbitps for fixed access, (iii) all-IP architecture, and (iv) scalable channel bandwidth. LTE doesn't meet the requirement of supporting peak data rates of 1 Gbitps in fixed connectivity [9].

1.5 LTE Utilizations Today

LTE designed to provide up to 10x the speeds of 3G networks for mobile devices such as smart phones, tablets, notebooks, and wireless hotspots. .and also provides IP-based voice, data and multimedia streaming at speeds of at least 100 Mbit per second and up to as fast as 1 GBit per second in LTE Advanced [10].

1.6 LTE-Advanced

LTE-Advanced aims to fulfill all the requirements of IMT-Advanced, which makes LTE-Advanced a real 4G telecommunication network. It is planned that LTE-Advanced will support higher transfer rates up to 1 Gbitps in downlink. LTE-Advanced also targets faster switching between power states and higher bandwidth. Other main goals are compatibility with first release LTE equipment, a scalable system bandwidth with higher frequencies than 20MHz, possibly up to 100 MHz and a hybrid OFDMA and SCFDMA solution to combine the advantages of both, OFDMA with its performance and SC-FDMA with its power efficiency [11].

2. 3GPP STANDARDIZATION

The standards-developing body that specifies the 3G UTRA and GSM systems, 3GPP TSGRAN is the technical specification group that has developed WCDMA, its evolution HSPA, as well as LTE, and is in the forefront of the technology. TSGRAN consists of five working groups (WGs):RAN WG1 dealing with the physical layer specifications; RAN WG2 dealing with the layer 2 and layer 3 radio interface specifications; RAN WG3 dealing with the fixed RAN interfaces, for example interfaces between nodes in the RAN, but also the interface between the RAN and the core network; RAN WG4 dealing with the radio frequency (RF) and radio resource management (RRM) performance requirements; and RAN WG5 dealing with the terminal conformance testing.

Work in 3GPP is carried out with relevant ITU recommendations in mind and the result of the work is also submitted to ITU. The organizational partners are obliged to identify regional requirements that may lead to options in the standard. Examples are regional frequency bands and special protection requirements local to a region. The specifications are developed with global roaming and circulation of terminals in mind. This implies that many regional requirements in essence will be global requirements for all terminals, since a roaming terminal has to meet the strictest of all regional requirements. Regional options in the specifications are thus more common for base stations than for terminals. As shown in Fig.1 Releases of 3GPP specifications for UTRA [12].

A parallel partnership project called 3GPP2 was formed in 1999. It also develops 3G specifications, but for cdma2000; which is the 3G technology developed from the 2G CDMA-based IS-95 standards; as shown in Table.1 3GPP2 Evolution [13].

IJCSI International Journal of Computer Science Issues, Vol. 11, Issue 4, No 2, July 2014
ISSN (Print): 1694-0814 | ISSN (Online): 1694-0784
www.IJCSI.org

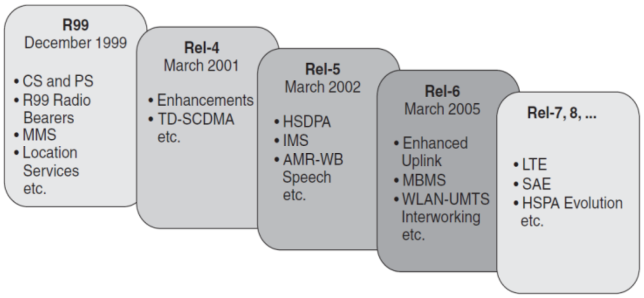

Fig. 1 Releases of 3GPP specifications for UTRA [12]

Table 1: 3GPP2 Evolution

Evolution	*Year*	*Specifications*
CDMA2000 1X	1999	1 times Radio Transmission Technology
CDMA2000 1xEV-DO	2000	Evolution-Data Only
EV-DO Rev. A	2004	VoIP
EV-DO Rev. B	2006	Multi-carrier
EV-DO Rev. C	2007	Ultra Mobile Broadband

3. LTE MULTIPLEXING TECHNIQUES

Multiplexing is the method of sharing a bandwidth with other independent data channels [14]. The main two multiplexing techniques are OFDMA for down link and SC-FDMA for the uplink, as we discuss below.

3.1 OFDMA Multiplexing Technique

During the past 15 years, Division Multiplexing (OFDM) has been gaining year after year a well-deserved reputation, demonstrating its high data rate and robustness to wireless environments capabilities. In the multipath environment, broadband communications will suffer from frequency selective fading [15].OFDM has shown many interesting properties for wireless data transmission such as spectral efficiency, low complex transceivers and robustness over time dispersive channels. Also, OFDM has been chosen to be the downlink multiple access schemes in LTE [16].

3.1.1 OFDM Fundamentals

The OFDM technique differs from traditional FDM in the following interrelated ways: Multiple carriers (called sub-carriers) carry the information stream. The sub-carriers are orthogonal to each other; and a guard time may be added to each symbol to combat the channel delay spread. These concepts are illustrated in the time-frequency representation of OFDM presented in Fig.2 [17].

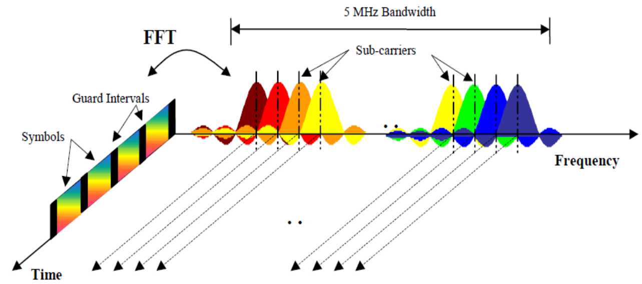

Fig. 2 Frequency-Time Representation of an OFDM Signal [16]

3.1.2 OFDMA block diagram

OFDM has been adopted as the downlink transmission scheme for the 3GPP Long-Term Evolution (LTE) and is also used for several other radio technologies, e.g. WiMAX and the DVB broadcast technologies. As shown in Fig.3 the general block diagram of Transmitter-Receiver for OFDMA [17].

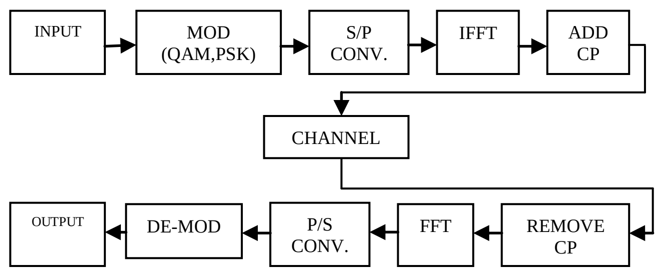

Fig. 3 Transmitter-Receiver block diagram for OFDMA [17].

3.1.3 OFDM Advantages and Disadvantages

The major advantage of OFDM is its robustness against multi path propagation. Thus, it is suitable to be implemented in wireless environments. The introduction of cyclic prefix made OFDM system resistance to time dispersion. OFDM symbol rate is low since a data stream is divided into several parallel streams before transmission. This make the fading is slow enough for the channel to be considered as constant during one OFDM symbol interval. Cyclic prefix is a crucial feature of OFDM used to combat the inter-symbol interference (ISI) and inter-channel-interference (ICI) introduced by the multipath channel through which the signal is propagated. As shown blew in table.2 the main advantages and disadvantages of OFDM systems [16].

Table 2: Main advantages and disadvantages of OFDM systems

Advantages	***Disadvantages***
N narrowband transmissions are done, this way is easily to accomplish that Ts (of each channel) is larger than T (of the channel), this means the transmission is not affected by the channel	High synchronism accuracy
High transmission bitrates	Multipath propagation must be avoided in other orthogonallity not be affected
Chance to cancel any cannel if is affected by fading	Large peak-to-mean power ratio due to the superposition of all subcarrier signals

3.2 SC-FDMA multiplexing technique

SC-FDMA has been adopted by the 3GPPfor uplink transmission in technology standardized for the LTE cellular systems. 3GPP publishes standards for cellular systems that build on GSM, the second generation cellular system that has been adopted by hundreds of operating companies and used by billions of people throughout the world. GSM uses TDMA for radio transmission in 200 kHz bands. The third generation successor to GSM is referred to as Universal Terrestrial Radio Access (UTRA) and relies on wideband code division multiple accesses (W-CDMA) for radio transmission in 5 MHz bands. The letter G in GSM stands for “global” and the U in UTRA stands for “universal”. LTE technology is referred to as E-UTRA (evolved UTRA), perhaps because 3GPP could not find an adjective more comprehensive than universal. It is anticipated that LTE technology will be ready for deployment in 2010. LTE anticipates transmissions in spectrum bands with widths ranging from 1.4 to 20 MHz This choice of transmission technologies places the complex, power-hungry operations of frequency domain equalization (in SC-FDMA) and linear power amplification (OFDM) at the base station, rather than in portable terminals [18].

3.2.1 SC-FDMA block diagram

SC-FDMA delivers performance similar to OFDM with essentially the same overall complexity, even for long channel delay. As shown in Fig.4 SC-FDMA transceiver block diagram [19].

3.2.2 SC-FDMA vs. OFDMA

SC-FDMA has advantage over OFDMA as shown blow in Table.3 [15, 19].

Table 3: SC-FDMA advantage over OFDMA

OFDMA	***SC-FDMA***
Large peak-to-mean power ratio	Lower peak-to-mean power ratio
Multipath propagation must be avoided in other orthogonallity not be affected	Robustness to spectral null
High synchronism accuracy	Less sensitivity to carrier frequency offset

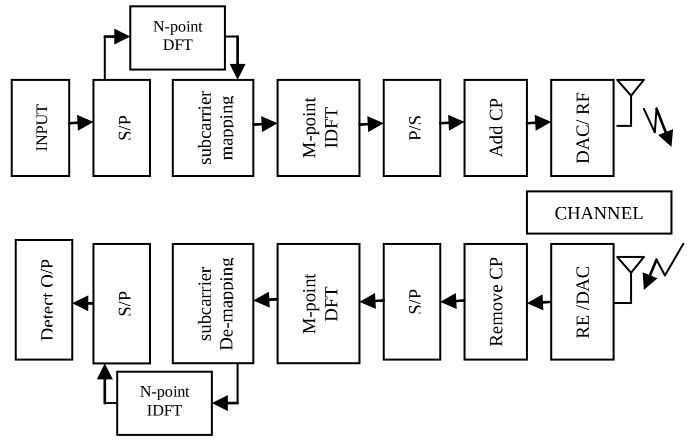

Fig. 4 Transmitter-Receiver block diagram for SC-FDMA[19].

4. SIMULATION ENVIRONMENT

The main focus of this study is to measure the performance of LTE uplink and downlink physical layer based on Release 8. First and foremost, studies made on issues related to LTE and the fundamental of LTE need to understand. Next, the related simulator need to find to running the simulation and the suitable simulator use to obtain the result is MATLAB. The purpose of choosing MATLAB simulator is because it is widely used in data analysis. Furthermore, the result can be obtained by running a program and setting the parameter in the simulator and the comparison of OFDM performance can be measured and analyzed with different modulation techniques and different channel models. Simulink is a graphical extension to MATLAB for the modeling and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Many elements of block diagrams are available (such as transfer functions, summing junctions, etc.), as well as virtual input devices and output devices. Simulink is integrated with MATLAB and data can be easily transferred between the programs [20].

5. WORKING PRINCIPLE

Simulink model consists of transmitter and receiver side. Transmitter section first block is Data source, its Contains random integer input and integer to binary bit converter, this integer is converted into binary bits then its gives input as a IQ Mapper, this IQ Mapper block contains binary bit into integer converter, QAM modulation, Math function ,here IQ-mapper performs modulation for given inputs then its followed to OFDM Modulation its converts given input as 24 subcarrier then follows perform FFT and Add cyclic prefix after its goes to receiver section its perform operation of transmitter side. After that each block output are taken from use of Go to tag then it’s give to input of error rate calculation use of from tag. Similarly between transmitter and receiver use different channel model and analyze the performance. As shown in Table.4 the system parameters of the Down Link and system parameters of the UP Link Table.5.

Table 4: System parameter - DL

FFT Size	1024
Modulation Scheme	QAM, 16QAM&64 QAM
Channel Models	AWGN SNR = 60 dB
Simulation Time	0.4s

The result shows at 0.4s, AWGN channel transmit 376 bits with zero packet loss and zero bit loss for SNR = 60 dB and transmitted signal power = 0.01 Watt. Below result shows the scatter plot of QAM, 16QAM & 64QAM and spectrum scope.

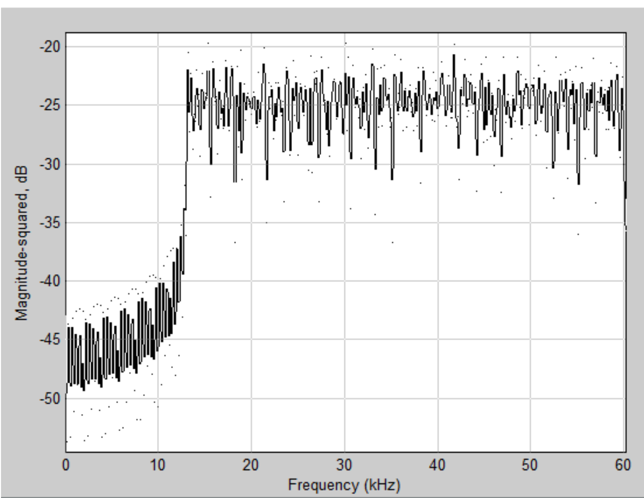

Fig. 5 Spectrum Scope of Transmitted data_ QAM _AWGN

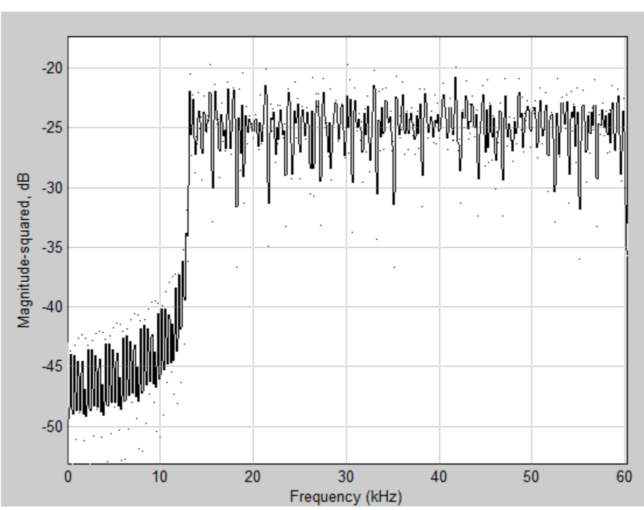

Fig. 6 Spectrum Scope of Received data_ QAM _AWGN

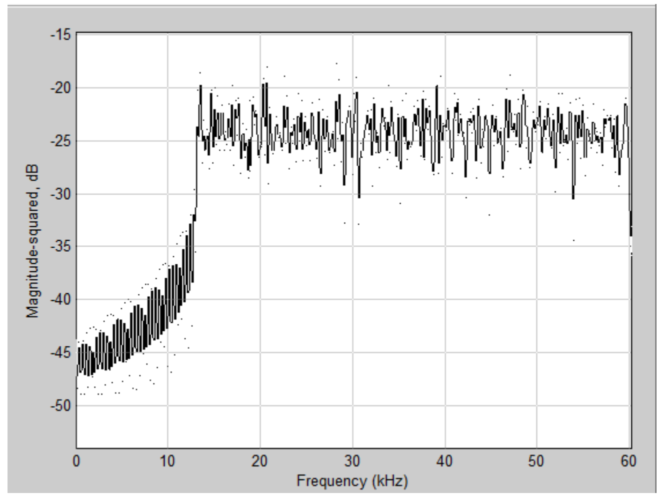

Fig. 7 Spectrum Scope of Transmitted data_ 16QAM _AWGN

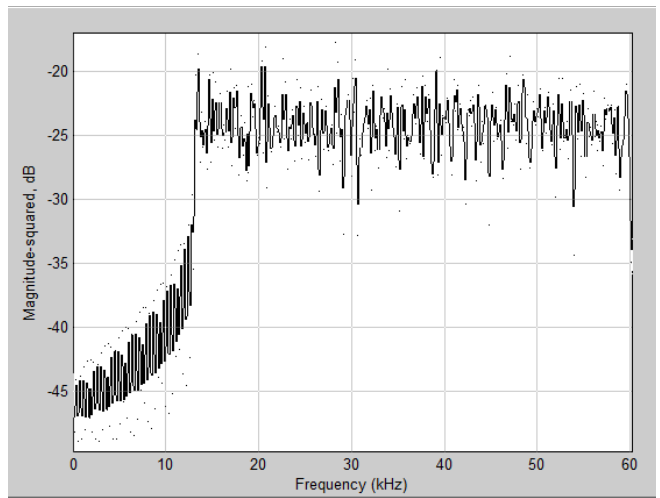

Fig. 8 Spectrum Scope of Received data_ 16QAM _AWGN

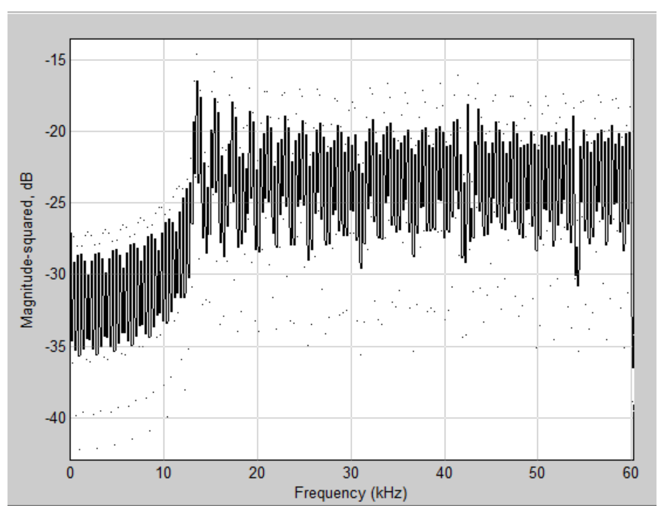

Fig. 9 Spectrum Scope of Transmitted data_ 64QAM _AWGN

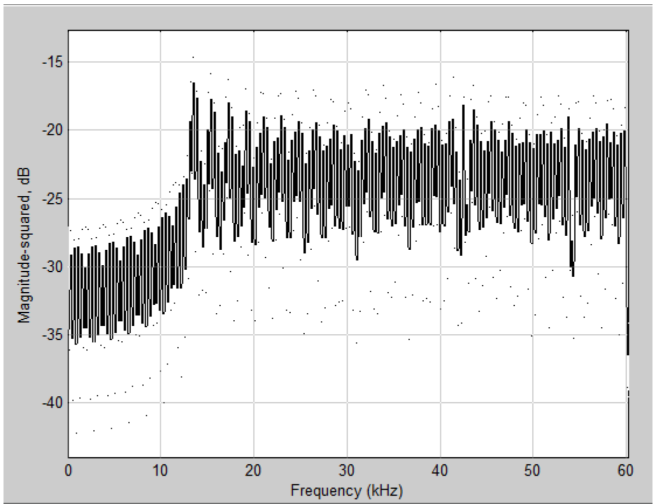

Fig. 10 Spectrum Scope of Received data_ 64QAM _AWGN

Table 5: System parameter - UL

FFT Size	1024
Modulation Scheme	16QAM 64 QAM
Channel Models	AWGN SNR = 60 dB
Simulation Time	0.4s

The result shows at 0.4s, AWGN channel transmit 376 bits with zero packet loss and zero bit loss for SNR = 60 dB and transmitted signal power = 0.01 Watt. Below result shows the scatter plot of QAM, 16QAM& 64QAM and spectrum scope.

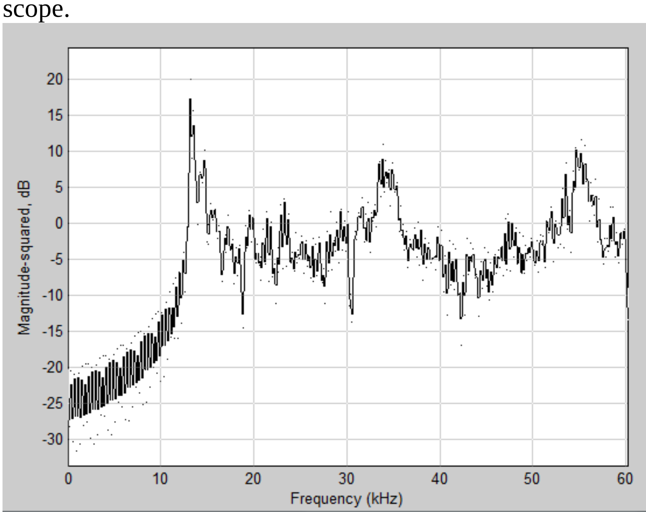

Fig. 11 Spectrum Scope of Transmitted data_ QAM _AWGN

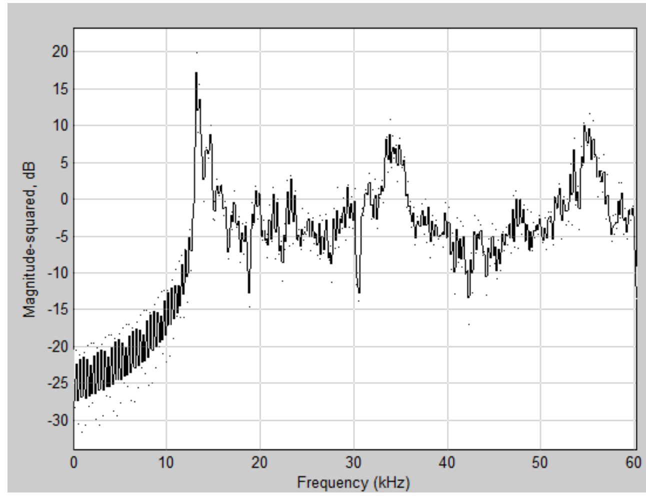

Fig. 12 Spectrum Scope of Received data_ QAM _AWGN

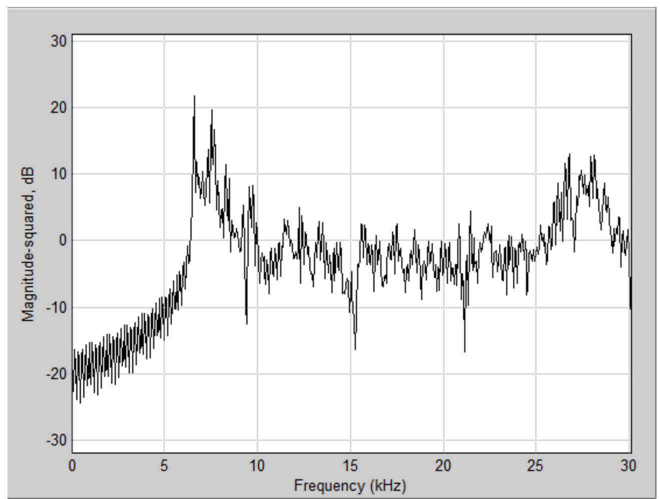

Fig. 13 Spectrum Scope of Transmitted data_ 16QAM _AWGN

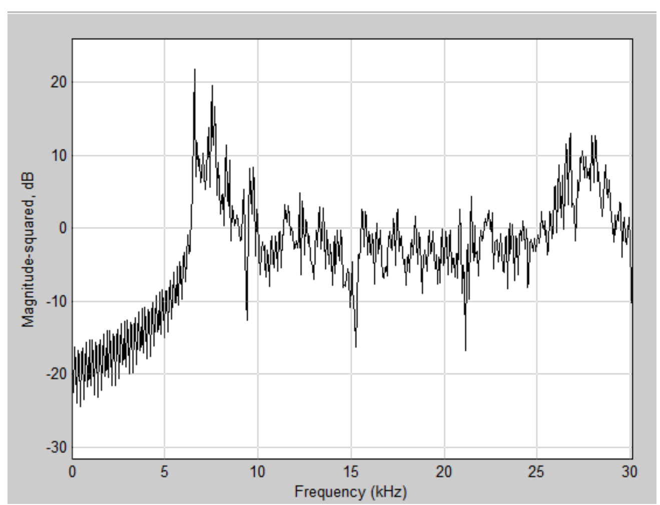

Fig. 14 Spectrum Scope of Received data_ 16QAM _AWGN

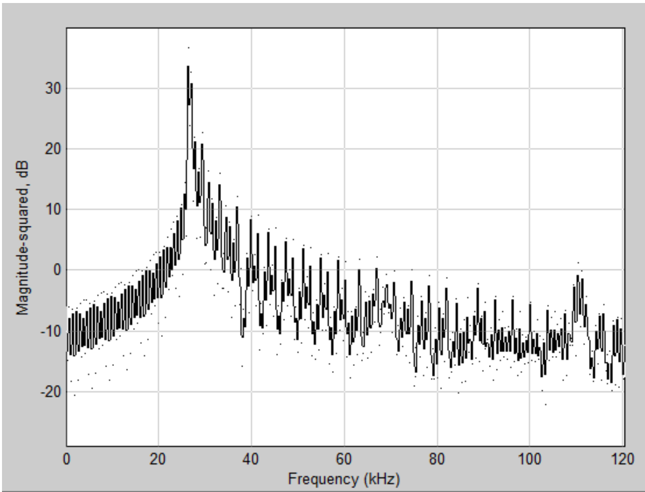

Fig. 15 Spectrum Scope of Transmitted data_ 64QAM _AWGN

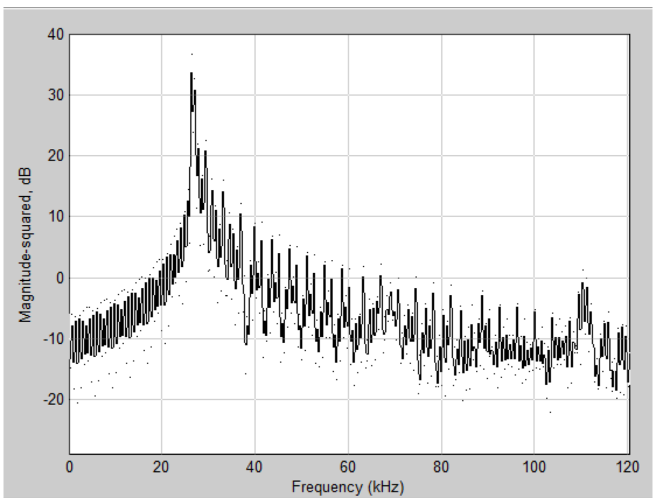

Fig. 16 Spectrum Scope of Received data_ 64QAM _AWGN

By changing the channel models for the above Simulink models and different modulations are used. While changing channel model, total number of bits are not changed.

If Rayleigh and Rician channel considered its non-line of sight so there is present bit loss and packet loss. Table shows the Simulink result for AWGN, Rayleigh, and Rician channel with different modulation for channel properties: SNR = 60 dB and maximum Doppler shift = 35 HZ.

5. CONCLUSION

This paper presents the performance of LTE physical layer, As a comparative study using a simulation model for the downlink and uplink direction using matlab simulink based on 3GPP release 8 specifications we found that The packet loss and bit loss is zero for a line of sight simulated channel (i.e. AWGN). By using Non line of sight channel like Rayleigh and Rician there is some packet loss and bit loss. Comparing between Rayleigh channel and Rician channel for modulation schemes QAM; 16-QAM; and 64-QAM number of bits loss in Rician channels is larger than Rayleigh channel's, but packet loss in Rayleigh channel is less than Rician channels. Whatever channel model or modulation scheme, the number of bit loss and number of packet loss primarily depends on the probability of the zero's in the original transmitted data whenever the probability approached from 1 the BER will decrease and when the probability approached from 0 the BER will increase. Also when the simulation time increase, the total number of bits increase then the BER increases.

Table 6: BER in AWGN, Rayleigh and Rician channels in up/down link in QAM modulation scheme

Channel	*Total no. of bits*	*Bit loss*	*Packet loss*
AWGN	376	0	0
Rayleigh	376	4	0.0106
Rician	376	2	0.0053

Table 7: BER in AWGN, Rayleigh and Rician channels in up/down link in 16- QAM modulation scheme

Channel	*Total no. of bits*	*Bit loss*	*Packet loss*
AWGN	752	0	0
Rayleigh	752	378	0.5026
Rician	752	380	0.5053

Table 8: BER in AWGN, Rayleigh and Rician channels in up/down link in 64- QAM modulation scheme

Channel	*Total no. of bits*	*Bit loss*	*Packet loss*
AWGN	1128	0	0
Rayleigh	1128	747	0.6622
Rician	1128	749	0.6640

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