A Survey of OFDMA and SC-FDMA in LTE System

Ankita Bhatia¹, Pooja Sharma²
¹ M.Tech Scholar, GGGI Dinarpur, INDIA
² Assistant Professor, GGGI Dinarpur, INDIA

ABSTRACT

The modern digital transmission systems offer better reliability in noise environment comparing to their analog counterparts. However, because of involvement of digital signals these systems are usually accompanied with a phenomenon known as inter symbol interference (ISI). In this phenomenon, the transmitted pulses are smeared out because of which the pulses corresponding to different symbols are not separable. The key reasons of ISI are multi-pathing and Doppler effect. In multi-pathing, the signal is received at same time through different paths of different delay which causes inter symbol interference. In addition, the wireless channel is usually dispersive. The result of data transmission over such a channel is that each received pulse is affected by adjacent pulse. This frequency-selective fading gives rise to ISI, where the received symbol over a given symbol period experiences interference from other symbols. As increasing signal power also increases the power of the ISI, this interference gives rise to an irreducible error floor that is independent of signal power. The irreducible error floor is difficult to analyze, as it depends on the ISI characteristics and the modulation format. The ISI characteristics further depend on the characteristics of the channel and the sequence of transmitted symbols.

Keywords-- LTE UPLINK, SC-FDMA, ISI.

I. INTRODUCTION

1.1 ISI

The modern digital transmission systems offer better reliability in noise environment comparing to their analog counterparts. However, because of involvement of digital signals these systems are usually accompanied with a phenomenon known as inter symbol interference (ISI). In this phenomenon, the transmitted pulses are smeared out because of which the pulses corresponding to different symbols are not separable [3], as can be seen in Figure 1. The key reasons of ISI are multi-pathing and Doppler effect. In multi-pathing, the signal is received at same time through different paths of different delay which causes inter symbol interference. In addition, the wireless channel is usually dispersive. The result of data transmission over such a channel is that each received pulse is affected by adjacent pulse. ISI usually arises in all pulse-modulation systems, including Frequency-shift keying (FSK), Phase-shift keying (PSK), and Quadrature amplitude modulation (QAM). Figure 1 shows the transmitted signal on the left and the received signal (affected by ISI) at the receiver shown on the right. The change in shape of the received signal is due to the pulse shaping at the transmitter end.

![Figure 1: InterSymbol Interference [3].](image)

The effect of ISI can be reduced using equalizers. These are based on equalization technique. There are also other processing techniques such as spread spectrum and multicarrier modulation that are used on the transmitter side to reduce the effects of ISI at the receiver end. Therefore, the research reported in this dissertation is focused on the equalization technique used in modern wireless communication systems such as SC-FDMA based long term evolution (LTE) systems.

1.2 BIT ERROR RATE AND SIGNAL TO NOISE RATIO

1.2.1 Bit Error Rate (BER)

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) 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, often expressed as a percentage. The bit error probability pe is the expectation value of the BER.

1.2.2 Signal to Noise Ratio (SNR)

Signal to noise ratios (Eb/No) are parameters that are more associated with radio links and radio communications systems. In terms of this, the bit error...
rate, BER, can also be defined in terms of the probability of error (POE). The determine this, three other variables are used. They are the error function (erf) the energy in one bit (Eb) and the noise power spectral density.

1.2.3 Additive White Noise Gaussian (AWGN)

The term thermal noise refers to unwanted electrical signals that are always present in electrical systems. The term additive means the noise is superimposed or added to the signal where it will limit the receiver ability to make correct symbol decisions and limit the rate of information. Thus, AWGN is the effect of thermal noise generated by thermal motion of electron in all dissipative electrical components i.e. resistors, wires and so on.

1.2.4 Rayleigh Fading

Since signal propagation takes place in the atmosphere and near the ground, apart from the effect of free path loss (Ls) the most notable effect of signal degradation is multipath propagation. The effect can cause fluctuations in the received signal's amplitude, phase and angle of arrival, giving rise to terminology multipath fading. Generally, there are two fading effects in mobile communications: large-scale and small-scale fading. Large-scale fading represents the average signal power attenuation or path loss due to shadowing effects when moving over large areas. On the other hand, small-scale fading refers to the dramatic changes in signal amplitude and phase that can be experienced as a result of small changes (as small as a half-wavelength) in the spatial separation between a receiver and transmitter.

1.3 SC_FDMA

LTE has recently come up as a solution to modern wireless communications systems. It is vastly and rapidly used because of its promising high speed and ability to handle multi-data at same time. This is why it is a subject of interest in research reported in this dissertation. The modulation used in the uplink of LTE is SC-FDMA, also often referred to as Fourier spread FDMA. The reason for favoring SC-FDMA in the uplink over orthogonal frequency division multiple access (OFDMA) is its reduced peak-to-average power ratio (PAPR) compared to OFDMA. The principal design of a SC-FDMA communication system is shown in Figure (2).
receiver, the carrier phase and frequency can be recovered using equalizers. This is very essential for modern communication systems such as LTE. Equalization is a processing technique used on any signal at the receiver to counter act the effects of ISI. As discussed above, the frequency-selective fading gives rise to ISI, where the received symbol over a given symbol period experiences interference from other symbols that have been delayed by multipath. As increasing signal power also increases the power of the ISI, this interference gives rise to an irreducible error floor that is independent of signal power. Improved SNR at the receiver end may be acquired when use duo binary signaling with training sequence.

II. PREVIOUS WORK

As the main objective of this study is the comprehensive analysis of LTE performance, so the related literature review is presented below.

Z. Wang et. al.[20] (2004) presented the carrier aggregation which supports the inter-band aggregation contiguous component carriers, intra-band aggregation non-contiguous component carriers and inter-band aggregation. Authors also presented the enhancement of LTE spectrum flexibility through carrier aggregation, further extension of multi-antenna transmission and provision of improvements in the area of inter-cell interference coordination in heterogeneous network deployments. Authors concluded that carrier aggregation (CA) provides a powerful means to boost the peak user throughput in LTE Release 10 and to meet the IMT-Advanced requirements set by the ITU-R.

Sánchez et. al. [14] (2007) discussed the features of LTE such as MIMO, channel coding, and scheduling. Performance analysis in this research is limited to downlink SISO and 2x2 MIMO scenarios. This research mainly focuses on outlining the impact of different features of LTE on performance. However, at the time of this publication, some characteristics of LTE were under development, e.g., channel coding and rate matching, 4x4 MIMO.

Weinstein et. al. [33] described an open LTE uplink link level simulator. Authors presented the basic structure of the simulator, as well as results for AWGN channels showing BER and throughput performance. The shown AWGN performance results confirmed the ability of the simulator to work according to the 3G-3GPP 36-series standards.

Astély et. al. [5] (2009) give an overview of LTE characteristics and study different features such as physical layer specifications, multi antenna transmission, and intra-cell interference coordination. According to authors, LTE spectral efficiency for uplink and downlink is evaluated under specific conditions.

Larmo et. al. [1] (2009) presented a comprehensive description of the link layer protocols and the interaction between protocol layers. Authors compared the same with other UTRAN protocols and found that LTE provides less delay and overhead. Authors, also mentioned that the interaction between protocol layers is more efficient. For example, the MAC and RLC layers are interact with each other with two layer ARQ functionalities, and scheduling in MAC and segmentation in RLC are interworking properly. As a result of appropriate layer interactions, the LTE protocol header has low overhead. Furthermore, UE advanced sleep mode and handover techniques are described and outlined.

Ghosh et. al. [2] (2010) provided an overview of Release 8, followed by LTE-Advanced requirements and technologies such as carrier aggregation, evolved MIMO schemes for uplink and downlink. This article also provides peak spectral efficiency and radio access performance for uplink and downlink of LTE-Advanced.

Sánchez et. al. [13] (2010) mentioned that the performance study is limited to downlink transmission by using a MAC layer simulator. The main focus of this study is on evaluating the channel estimation method performance in Wiener low complexity (Wlc). Different estimation error impacts are investigated such as SNR estimation error, Doppler frequency estimation error, and PDP estimation error. Simulation results mentioned by authors are based on 10 MHz system bandwidth, one transmit and two receive antenna (SIMO). LTE downlink performance is evaluated based on the EVA channel and Wlc channel estimation method; however, high code rate and multi antenna schemes are not considered in performance analysis. This simulation is based on EVA channel and shows 5Mbps, 13 Mbps, and 31 Mbps of throughput for QPSK 1/3, 16 QAM ½ and 64QAM ¾ respectively.

Juan J. Sánchez et. al. [12] (2011) analyzed the performance of the LTE cellular technology in simulation environment. The analysis has focused on the main features involved in the downlink, like the user multiplexing, adaptive modulation and coding, and support for multiple antennas. Adaptive modulation and coding feature has been validated as an efficient and reliable transmission technique to maximize the spectral efficiency while fulfilling the BER requirements. Simulation results showed a maximum LTE capacity around 60 Mbps (for 20 MHz system bandwidth).

Fahad Shamshad et. al. (2012) [7] presented an overview of the generic frame structure of physical layer of LTE for both uplink and downlink together with advance techniques which are new to cellular systems such as OFDM, OFDMA and MIMO along with their advantages over traditional techniques. It also summarizes the modulation parameters used in the uplink and downlink of 3GPP LTE. Author concluded that LTE is designed to meet high speed data and multimedia unicast and broadcast services.

Gerardo Gómez et. al. (2013) [8] presented a simulator for MIMO-OFDM-based wireless systems. The simulator includes the main functionalities carried out at the physical and MAC layers of a wireless MIMO-OFDM system. This simulator has been used to evaluate the
performance of the 3GPP LTE technology. Performance results are provided for the different MIMO-OFDM techniques included in LTE under realistic assumptions such as user mobility or bandwidth limited feedback channel. It has been proved that spatial multiplexing techniques provide the best spectral efficiency for high SNR although very low terminal speeds (up to 20 Km/hr) are supported to fulfill the reliability requirements. On the other hand, SFBC is shown to be the most robust technique in high mobility scenarios as the maximum admissible user speed is around 80–90 Km/hr.

III. CONCLUSION

This survey paper provides a overview of LTE system and its specifications. It also presents a review of recent technologies and research focused on implementation of LTE physical layer. From the review, it is investigated that all the work presented by different authors are based on simulation environment From the review, it is found that Release 8/9, allows smooth upgrade and migration of LTE networks towards LTE-Advanced. Further work is in progress by 3GPP to implement upcoming LTE-Advanced standards. In proposed work therefore, focused on doing comprehensive analysis of the LTE physical layer and implementation of LTE SC-FDMA uplink for the wireless channels.

REFERENCES