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Implementation of Downlink Physical Channels and Channel estimation for Long-Term Evolution (LTE)

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ABSTRACT
In this paper, we have implemented Long-Term Evolution (LTE) Downlink Physical Channels using Single Input Single Output (SISO) channel based on standard parameters for 4G in MATLAB. We also estimated the Downlink Physical Channels. For this purpose we increased the number of reference signals for improving resolution of channel estimation. This work showed the difference between Zero Forcing (ZF) Equalizer and Minimum Mean Square Error (MMSE) Equalizer. The Bit Error Rate (BER) vs. Signal-to-Noise Ratio (SNR) curve for the Known Channel, Estimated Channel and Modified Estimated Channel are also showed in this paper.
Keywords: Bit Error Rate (BER), Long-Term Evolution (LTE), Minimum Mean Square Error (MMSE), Orthogonal Frequency Division Multiplexing (OFDM), Single Input Single Output (SISO), Signal-to-Noise Ratio (SNR)

I. INTRODUCTION

Latest version of mobile communication is 4G or 4th generation. It developed in 2010 and gives higher data rate which is up to 200 Mbps. LTE and WIMAX technologies are used here. 4G can provide a 10 times increase in data transfer over 3G. The transfer data at speed of more than 100 Mbps can be achieved through OFDM [1], but it can also eliminate interference that impairs high speed signals. In 4G LTE technology is used. It is a standard for wireless communication of high speed data rate. It is a faster network technology. LTE is a wireless broadband technology and it is designed for access internet via cell phone and organized devices [2]. It gives more coverage by providing higher data rate. Long Term Evolution supports browsing Web sites, Voice over Internet Protocol (VoIP) and other IP-based services well.

This paper discusses about overall OFDM process, introduces the LTE Frame Structure where we discuss about the time duration of frame, subframe, slot, cyclic prefix, Resource Block, Resource Element (RE), Downlink Physical Channels, LTE Downlink Process and presents the results of our simulation.

II. OVERALL OFDM PROCESS

OFDM [3] is a technology of 4G system. It is a multi-carrier modulation where a single data stream is transmitted over a number of lower rate subcarriers. It is one of the applications of parallel data transmission scheme which reduce the influence of multipath fading. OFDM increases the robustness frequency selective fading and narrow band interface. The overall OFDM Process is described in fig. 1.

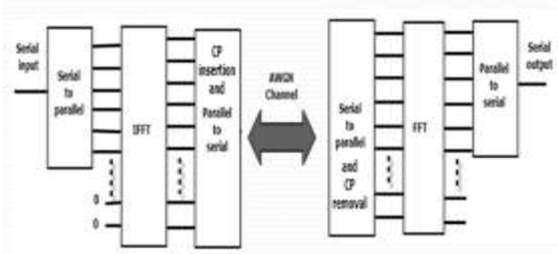

Fig. 1. Overall OFDM process

III. LTE FRAME STRUCTURE

In the LTE standard, we use OFDM technology and OFDM frame structure. In Fig. 2, total frame duration is about 10ms.There are 10 subframes of equal length in a frame and the resulting duration for subframe is 1ms. Each subframe is composed of 2 time slots each of duration of 0.5ms. Each slot consists of six or seven OFDM symbols in case of normal and extended cyclic prefix respectively. LTE Resource element is the smallest unit of resource assignment and it consisting of one subcarrier during one OFDM symbol.

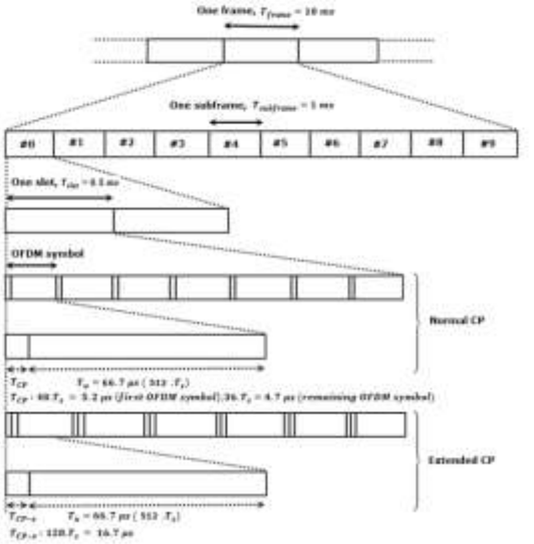

Fig. 2. LTE Frame Structure [3]

IV. LTE DOWNLINK PHYSICAL LAYER PARAMETERS

Table I shows LTE downlink physical layer parameters.

V. DOWNLINK PHYSICAL CHANNELS

Downlink physical channels [4] carry information from the MAC layers and higher layers. Physical Broadcast Channel (PBCH) [5] is used to broadcast the Master Information Block (MIB) which consists of a limited number of the most frequently transmitted parameters essential for initial access to the cell. Physical Downlink Shared Channel (PDSCH) [4] is the main data carrying channel which is allocated by user expectations and also used to transfer system information, paging messages and application data. PDSCH broadcasts the System Information Blocks (SIBs) which are multiplexed with unicast data transmission. PDSCH uses QPSK, 16 QAM and 64 QAM according to the value of Channel Quality Indicator (CQI). When the CQI value is higher, user uses 64 QAM modulation or higher data rate. When the value of CQI is smaller, user uses lower data rate. Physical Multicast Channel (PMCH) is used to carry Multimedia Broadcast and Multicast services (MBMS). Physical Downlink Control Channel (PDCCH) [4] is used to transfer Downlink control information (DCI) message which carries the resource assignment of User equipment (UE). Physical Control Format Indicator Channel (PCFICH) [4] carries the control frame indicator (CFI) which calculates the no. of OFDM symbols used for control channel transmission. Physical Hybrid ARQ Indicator Channel (PHICH) [4] is specially used to carry the HARQ ACK or NAK for the physical uplink shared channel (PUSCH) received by the network.

Table I. LTE Downlink Physical Layer Parameters [4]

Channel Bandwidth (MHz)	1.25	2.5	5	10	15	20
Frame Duration (ms)	10					
Subframe Duration (ms)	1					
Sub-carrier Spacing (kHz)	15					
Sampling Frequency (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
FFT size	128	256	512	1024	1536	2048
No. of Sub-carriers	75	150	300	600	900	1200
No. of Resource Blocks	6	12	25	50	75	100
OFDM symbols/Slot	7/6 (normal CP/ extended CP)					
CP length (normal CP) µs	5.2 (first symbol) / 4.7 (remain symbols)					
CP length (extended CP) µs	16.7					
No. of CP length for first symbol (normal CP)	10	20	40	80	120	160
No. of CP length for remain symbols (normal CP)	9	18	36	72	108	144
No. of CP length for extended CP	32	64	128	256	384	512

VI. REFERENCE SIGNALS AND SYNCHRONIZATION SIGNALS

Downlink Reference Signal means which signal direction is from Base station to mobile Station. These are added within the first and fifth OFDM symbols of each slot to perform for channel estimation. UE will interpolate total reference symbols for channel estimation.

The synchronization signals are needed to get synchronized to the eNodeB. Primary Synchronization Signal (PSS) [4] allows the UE to get the slot boundary timing independent of the type of CP length. Secondary Synchronization Signal (SSS) [4] allows the UE to determine the cyclic prefix length.

VII. OVERALL LTE DOWNLINK PROCESS

Overall LTE Downlink Process is shown in Fig. 3. Cyclic Redundancy Check (CRC) generator is used for error detection and error correction. Turbo encoder [6] consists of two encoders separated by internal interleaver. There are three output streams for turbo encoder (Systematic bit stream, Parity 1 bit stream and Parity 2 bit stream). The basic function of rate matcher is to match the number of input bits and the number of transmitted bits. Rate dematcher inverts operation of rate matcher. Scrambler transposes or inverts input bits. Descrambler inverts operation of scrambler. Modulator is performed various modulation. QPSK (Quadrature Phase Shift Keying), 16QAM (Quadrature Amplitude Modulation), 64QAM modulation schemes are used in LTE. Demodulator inverts operation of modulation.

Resource element mapper [6] is produced by creating number of indices to the 2D grid matrix where various information types are placed. For resource element mapper, we used a software which is “LTE Visualisation Tool”. From this software, OFDM symbols are divided into 11 groups where each group has the same RE mapping. Resource element demapper inverts the operation of resource element mapper.

The Fast Fourier Transform (FFT) transforms a time domain signal into frequency spectrum. The Inverse Fast Fourier Transform (IFFT) performs the reverse process of FFT, transforming a spectrum into a time domain signal. An IFFT converts a number of complex data points into the time domain signal of the same number of points. The cyclic prefix is added by copying part of the symbol at the end and attaching it to the beginning of the symbol, used to "signal" a break in the transmission or as guard interval and the OFDM symbol seems to be periodic. Cyclic-prefix removal is the reverse process of Cyclic-prefix Insertion.

Wireless channels are defined by the different paths of propagation between transmitter and receiver. Different propagation channels have different path gain, path delay, Doppler [6]. There are many channel models. These are: Low-Mobility Flat-Fading channels, High-Mobility Flat-Fading channels, Low-Mobility Frequency-Selective channels, High-Mobility Frequency-Selective channels.

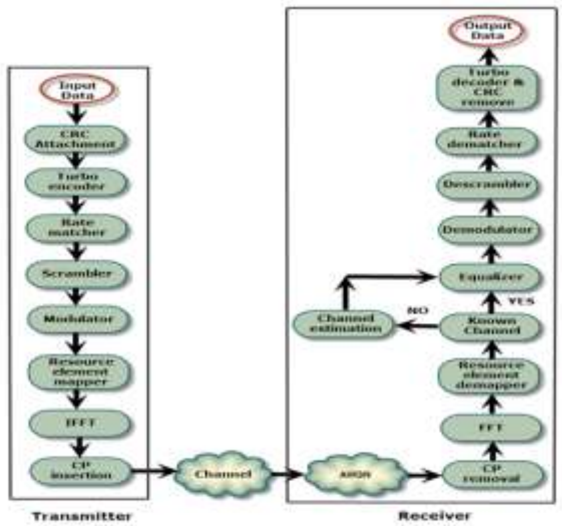

Fig. 3. Overall LTE Downlink Process

AWGN is additive because it is added to any noise, white because it has uniform power across the frequency band and Gaussian because it has normal distribution in time domain. AWGN channel processes MIMO fading channel output and makes same size output with added noise.

Turbo decoder decodes the encoded symbols from the Turbo encoder. After performing Turbo decoding, CRC bits are removed from each OFDM symbol. CRC bits are checked for error detection. If no errors are found, the loop is stopped and Turbo decoding is early terminated. If errors are found in CRC bits, loop is continued until no errors are found or loop reaches maximum iteration. Finally we get output data.

Equalizer calculates the gain of all received resource elements at each OFDM symbol [6]. There are many different methods for equalization which are Zero Forcing (ZF) equalizer and Minimum Mean Square Error (MMSE) equalizer. After finding the gain of equalizer, the output of equalizer is the multiplication of received data and the gain of equalizer.

VIII. CHANNEL ESTIMATION

If the channel is known in receiver side, this channel is called as known channel or ideal channel. From MIMO fading channel, we get overall channel path gain of each OFDM symbol. For known channel, we take a mean value from total channel path gain of each OFDM symbol and assign this value at impulse response sample locations and take FFT of impulse response. The output of FFT is ideal channel and this process is known as ideal channel estimation. For unknown transmission channel, channel estimation is performed by calculating known reference signals. The receiver can estimate the channel response of each OFDM symbol using known reference signals. At first known reference signals of receive data are divided by known reference signals of transmitted data and we can know the channel response of reference signals. After that channel estimation is performed by averaging or interpolation the channel response of reference signals and we get overall channels. We use interpolation for channel estimation.

A modified channel estimation process is proposed that uses increased number of reference signals. For increasing the number of reference signal, each DTX signal is replaced by RS in 1st OFDM symbol in each subframe. Since we know channel gains at more frequency points, we get better resolution of channel estimation.

IX. SIMULATION RESULTS

The LTE Downlink process has been implemented in MATLAB. We used some simulation parameters. Table II shows the simulation parameters.

Table II. Simulation parameters

Parameters	**Values**
Bandwidth	5 MHz
Modulation Scheme	16QAM
Coding Rate	1/3
No. of Bits	3,60,000
Channel Model	High-Mobility Frequency-Selective channel

A. Different types of BER vs. SNR curve for using ZF equalizer and MMSE equalizer

Using ZF equalizer and MMSE equalizer, we take three types of BER vs. SNR curve for three different conditions. Conditions are: for known channel, for channel estimation, for modified channel estimation.

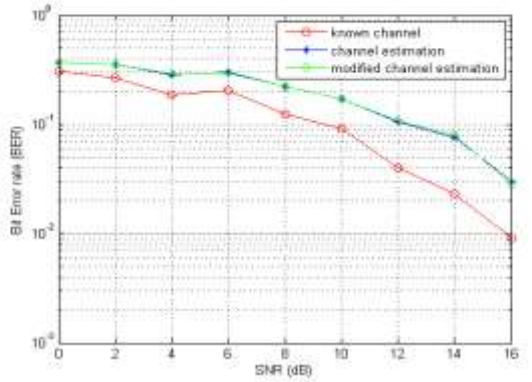

Fig. 4. Different types of BER vs. SNR curve for using ZF equalizer

From Fig. 4-5, if we increase the number of input bits, every curve will become smoother. This figure contains three outputs: red color for known channel, blue color for channel estimation and green color for modified channel estimation. In this figure, we can't realize any variation between channel estimation and modified channel estimation. If we will increase the BW, we can see the difference between channel estimation and modified channel estimation. BER of known channel are smaller than others because channel responses of others are estimated by interpolation.

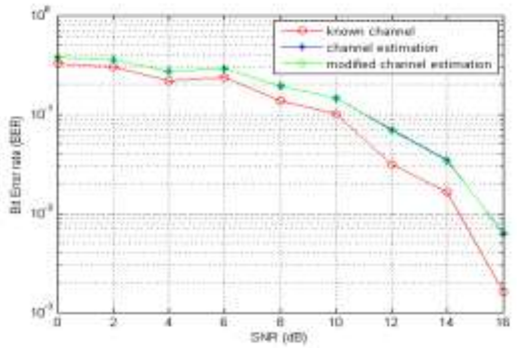

Fig. 5. Different types of BER vs. SNR curve for using MMSE equalizer

B. Comparison of BER vs. SNR curve of ZF equalizer and MMSE equalizer for channel estimation for given number of reference signals

Fig. 6 contains two outputs: blue color for MMSE equalizer and green color for ZF equalizer. From this Figure, we see that MMSE equalizer is better than ZF equalizer.

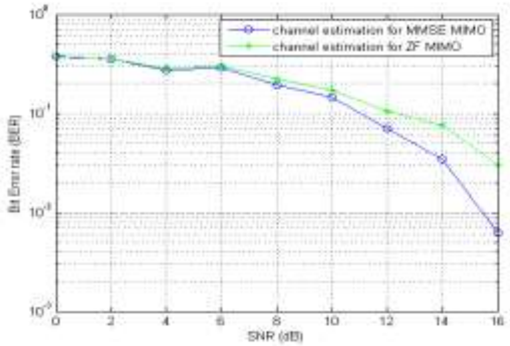

Fig. 6. Comparison of BER vs. SNR curve for ZF equalizer and MMSE equalizer

C. Comparison of channel response of ideal channel, estimated channel and modified estimated channel

In Fig. 7, blue color for ideal channel (actual hf), red color for estimated channel (estimate hf) and

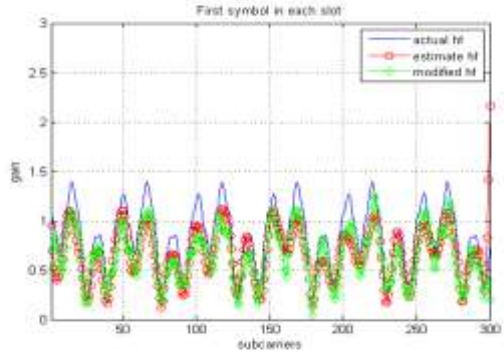

Fig. 7. Comparison of channel response of ideal channel, estimated channel and modified estimated channel of first symbol in each subframe for MMSE equalizer at SNR = 16dB

green color for modified estimated channel (modified hf). Estimated channel and modified estimated channel follow the ideal channel, but a dc value presents between estimated channel and ideal channel. Dc value of modified estimated channel is smaller than estimated channel.

X. CONCLUSION

In this paper, we have studied overall OFDM process, LTE Frame structure, Downlink Physical channels and LTE Downlink process. Our main objective was to implement LTE Downlink Physical Channels and Channel estimation. We discussed about 4G communication and LTE technology. Subsequently OFDM based system, LTE frame structure, Physical channels and structures are presented. Then we implemented LTE Downlink process in MATLAB where we verified the individual blocks and overall system performance. In this process, channel estimation was our main focus. We also provided additional reference signals for improvement of channel estimation. Finally we showed the performance from various BER vs. SNR curve.

The studies presented thus far in this work point to implementation of LTE Downlink Physical Channel and channel estimation. In the future, we will work with Uplink Channels, estimate the Signal to Interference plus Noise Ratio (SINR) and the resulting Channel Quality Indicator (CQI) and also work with Multiple Input Multiple Output (MIMO) channel.

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