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Analysis of LTE Physical Layer

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ABSTRACT: Long Term Evolution (LTE) is introduced as a new standard for mobile communication by the 3rd Generation Partnership Project (3GPP). It is currently marketed as 4G LTE. It is revolutionising the field of wireless communication at a furious pace. In this work, the physical layer (PHY) of LTE is analyzed by considering the downlink and uplink transmissions. The uplink and downlink transmitters are studied in detail. Simulations are carried out with the help of LTE System Toolbox by Mathworks. The throughput and BER performance are analyzed for various SNR values. The error vector measurements for both uplink and downlink are also calculated.

KEYWORDS:LTE, PHY, PDSCH, PUSCH

I. INTRODUCTION

Long-Term Evolution (LTE) is a new standard specified by 3GPP for fourth generation (4G)wireless communications. LTE provides various features like high peak data rates, low latency, reduced operating costs, multi-antenna support, flexible bandwidth operations, improved system capacity and coverage. It operates on technologies like Orthogonal Frequency Division Multiplexing (OFDM) and Multiple-Input and Multiple-Output (MIMO), robust channel coding, scheduling and link adaptation [1]. LTE exhibits better performance compared to the previous technologies such as High speed Packet Access (HSPA) and Universal Mobile Telecommunications system (UMTS). This is achieved by the introduction of a physical layer and redefining the core network. The Physical Layer (PHY) of LTE is one among the protocol entities of LTE Radio Access Network (RAN). The PHY is responsible for transferring of information to and from the MAC layer. It also performs the function of transfer of data between the base station and user equipments. It carries out operations such as coding, decoding, modulation, demodulation, mapping etc.

In this paper, the LTE transmissions in uplink and downlink are analyzed. The LTE uplink transmission is based on Single Carrier Frequency Division multiple Access (SC-FDMA) and the downlink transmission is based on Orthogonal frequency Division Multiple Access (OFDMA). OFDMA suffers from Peak to Average Power Ratio (PAPR). In the uplink transmissions, SC-FDMA performs much better due to its lower PAPR compared to OFDMA. Hence it is more power efficient and improves the efficiency of power amplifiers used in the user equipments. The PHY is analyzed for its throughput and bit error rates (BER) for various signal to noise ratio (SNR) values. The simulation is carried out with the help of LTE System Toolbox. The downlink as well as uplink transmissions show similar throughput performances. The BER plots show that 64 QAM is a better modulation scheme compared to QPSK and 16 QAM. The error vector measurements for downlink and uplink transmissions are also done in this work.

II. RELATED WORKS

The physical layer of LTE is a topic of study for many years. Many works are carried out in this field. Some of them are mentioned here. In [1], the LTE downlink and uplink transceivers are studied in detail. The throughputs are measured for both uplink and downlink. The BER curves are also plotted. In [2], the physical downlink shared channel of LTE is studied. The transmitter section focusses on turbo coding and OFDM.At the receiver side, the functionalities like turbo decoding and OFDM demodulation are developed. The parameters like SNR and BER are evaluated. In [3], a physical layer simulator is explained. Both the uplink and downlink transmissions are discussed. In [4], the physical layer of LTE as specified by the 3GPP is discussed in detail. The main focus is given to the complexity and the newness of the physical layer. The simulations are carried out for the complex physical layer and the modulation scheme used.

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III. THE LTE PHYSICAL LAYER (PHY)

The Physical Layer is incorporated in LTE system to improve its performance compared to the older technologies. It is responsible for the transfer of data and control information between the base station and the user equipment. In this study, the downlink and uplink transmissions of LTE are taken into consideration. Hence, the Physical Downlink shared Channel (PDSCH) and Physical Uplink Shared Channel (PUSCH) are considered.

The transmitter section of LTE Downlink is shown in Figure 1. It consists of two separate sections: Downlink Shared Channel (DL-SCH) processing and Physical Downlink Shared Channel (PDSCH) Processing. The steps involved in DL-SCH coding are [5]:

- Transport Block CRC Attachment: It is done for error checking. Each transport block is used to calculate the CRC parity bits. A 24 bit CRC is performed. The transport block is divided by a cyclic generator polynomial, described as g_{CRC24A}.

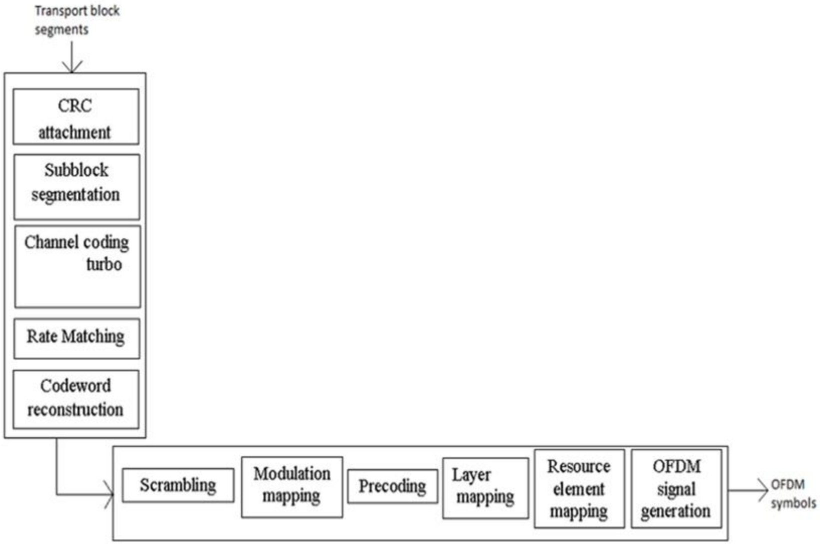

Figure 1: The LTE downlink physical layer

- Code Block Segmentation: In LTE, inorder to make the block sizes compatible with the block sizes supported by the turbo interleaver, a minimum and maximum block sizes are specified. The minimum block size is 40 bits and maximum 6144 bits. If the input block size is greater than the maximum size, then it is segmented.
- Channel Coding: Turbo coding is used as the channel coding scheme. A turbo encoder is built using two identical convolutional coders of special type, such as, feedback (recursive) systematic (RSC) type with parallel concatenation. The two encoders are separated by a contention free Quadratic Permutation Polynomial (QPP) interleaver.
- Rate Matching: The rate matching block creates an output bitstream with a desired code rate. The three bitstreams from the turbo encoder are interleaved. A circularbuffer is created by bit collection.Then the bits are selected and pruned from the buffer to create a single output bitstream.
- Code Block Concatenation: The rate matched code blocks are concatenated back together to create the output of the channel coding.

The steps involved in PDSCH processing are [5]:

- PDSCH Scrambling: The codewords are bit-wise multiplied with an orthogonal sequence or a scrambling sequence created using a length-31 Gold sequence generator. The main aim of scrambling is to provide intercell interference rejection.
- Modulation: The scrambled codewords can use QPSK, 16QAM or 64QAM modulation. This provides flexibility to allow the scheme to maximize the data transmitted depending on the channel conditions.

- Layer Mapping: Depending on the number of transmit antennas used, the complex symbols are mapped to one, two, or four layers.
- Precoding: Three types of precoding are available in LTE for the PDSCH—spatial multiplexing, transmit diversity, and single antenna port transmission. Within spatial multiplexing, there are two schemes—precoding with large delay cyclic delay diversity (CDD), also known as open loop spatial multiplexing, and precoding without CDD, also known as closed loop spatial multiplexing.
- Mapping to Resource Elements (RE):The complex valued symbols are mapped in sequence to resource elements not occupied by synchronization and reference signals. The number of resource elements mapped depends upon the number of resource blocks allocated to the PDSCH.
- OFDM Modulation: The data streams undergo modulation on orthogonal sub channels referred to as sub carriers. It offers high spectrum efficiency, robustness to multipath fading, inference rejection and MIMO transmission.

The transmitter for LTE Uplink is shown in Figure 2. From the figure it can be seen that it also consists of two sections: Uplink Shared Channel (UL-SCH) processing and Physical Uplink Shared Channel (PUSCH) processing. The uplink transmissions are based on SC-FDMA. It increases the efficiency of the power amplifiers and the output power since it has lower PAPR. All the steps other than this are same as in the case of PDSCH.

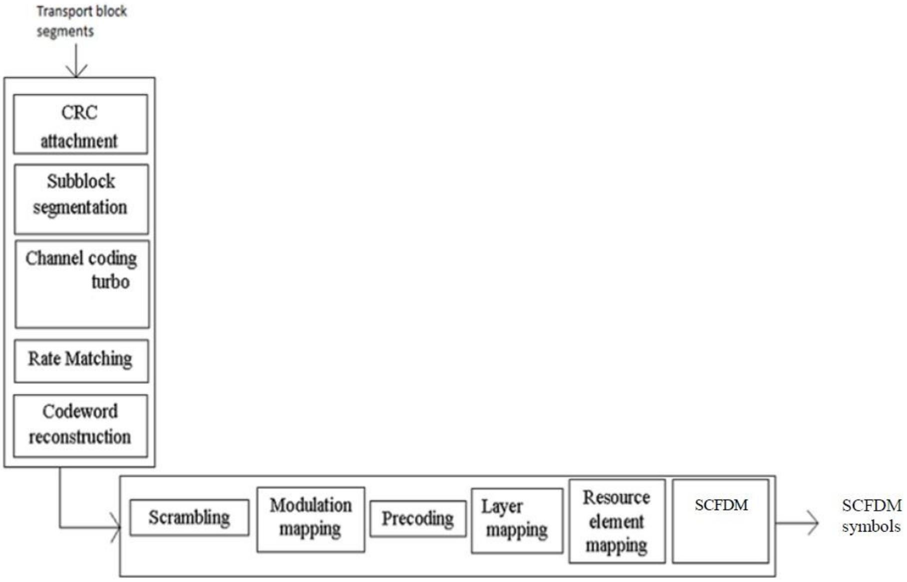

Figure 2: The LTE uplink physical layer

IV. SIMULATION RESULTS

Here, the simulation is carried out to analyze the LTE Physical layer. The LTE transmissions in uplink and downlink are considered for the study. The throughput and BER are analyzed with the help of the LTE System Toolbox by Mathworks. For PDSCH and PUSCH throughput analysis, Extended Pedestrian A (EPA 5) is taken as the propagation channel. For the first simulation 10 frames are taken and for the second 20 frames are taken[1].

1.PDSCH Throughput Simulation

Inorder to analyze the throughput for the PDSCH, some considerations are taken. Transmit diversity is taken as the transmission scheme. Four transmitters and two receivers are considered. The PDSCH data is OFDM modulated and noise is added in the channel which is then OFDM demodulated.

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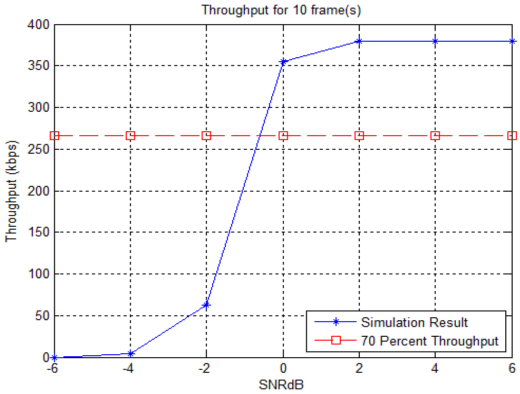

Figure 3: The PDSCH throughput for 10 frames

Figure 3 shows the throughput of PDSCH for 10 frames. The measured throughput is above 70% for SNR values of -1.2 dB and above. It increases and becomes steady for 2 dB SNR and above.

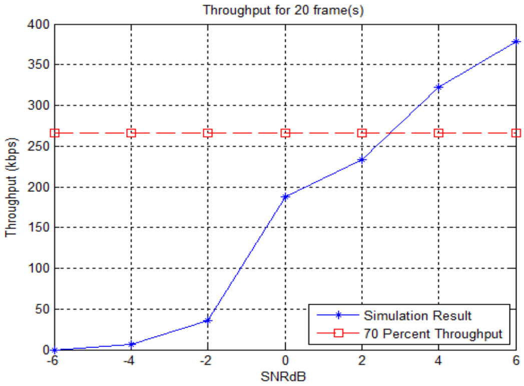

Figure 4: The PDSCH throughput for 20 frames

Figure 4 shows the throughput of PDSCH for 20 frames. It is found that the measured throughput is above 70 % for SNR values of 2.2 dB.

2.PUSCH Throughput Simulation

In this case, similar considerations are taken as PDSCH for its simulation. Low multi antenna correlation is considered. Almost similar performance is obtained for PUSCH as in PDSCH.

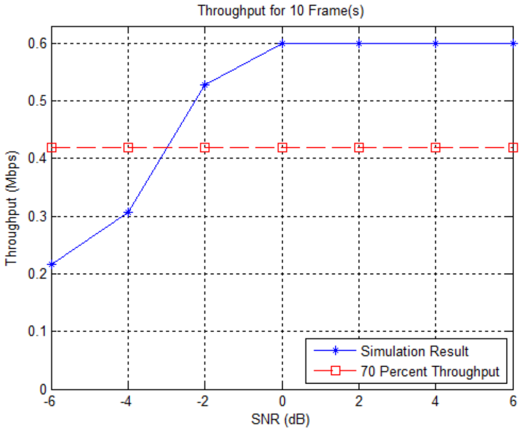

Figure 5: The PUSCH throughput for 10 frames

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Figure 5 shows the throughput of PUSCH for 10 frames. Themeasured throughput is above 70% for SNR values of -1.2 dB and above. It increases and becomes steady for 2 dB SNR and above.

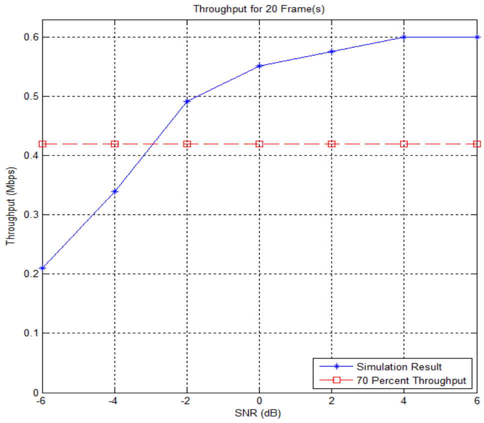

Figure 6: The PUSCH throughput for 20 frames

Figure 6 shows the throughput of PUSCH for 20 frames. It is found that the measured throughput is above 70 % for SNR values of 2.2 dB.

3.PDSCH BER performance

The BER curves for PDSCH are plotted using the LTE System Toolbox. Here, the SNR ranges from -10 to 10 dB and transport block (TB) sizes of 1000 and 1500. A random stream of bits as the size of transport block is generated. It undergoes the Downlink Shared Channel (DL-SCH) coding to rematch the transport block sizes to the available PDSCH bits.

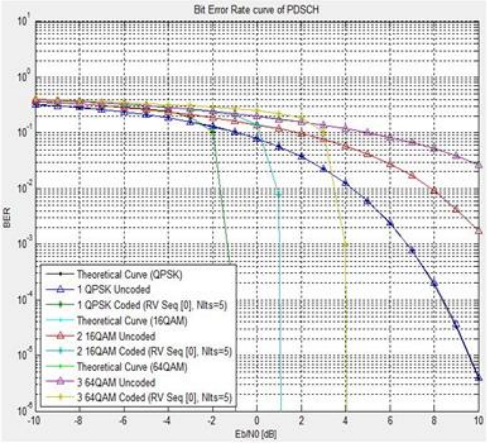

Figure 7: The BER curve for TB=1000

Figure 7 shows the BER curve for TB=1000 and Figure 8 shows the BER curve for TB=1500.

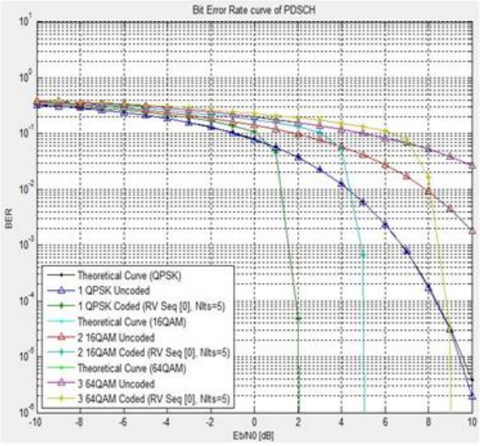

Figure 8: The BER curves for TB=1500

It can be seen from the curves that as the size of TB increases, BER values also increases. 64 QAM is found to be a better modulation scheme compared to QPSK and 16 QAM.

4. Error Vector Measurements

The Error Vector Measurements (EVM) for uplink and downlink is calculated. EVM is defined as the measure of the received signal constellation error. It is also referred to as the difference between the received waveform and the ideal waveform for the allocated resource blocks. A Reference Measurement Channel (RMC) signal is considered. The average EVM is measured at two different locations: high and low. The low and high positions refer to the positions of FFT window at the start and end of the cyclic prefix.Then these values are averaged together to obtain the overall EVM. The averaged EVM for downlink is obtained as 1.510 % and for uplink as 1.627 %. Thus, the EVM measurements for both the cases gives a comparable performance.

IV. CONCLUSION

In this work, LTE transceiver in downlink (PDSCH) and uplink (PUSCH) transmissions were analyzed. The throughput and BER performance were analyzed with the help of the LTE System Toolbox. PDSCH as well as PUSCH have similar throughput performance. The BER curves show that 64 QAM is the better modulation scheme for LTE. The EVM measurements are also made for downlink and uplink transmissions.

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