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Performance Analysis of Long Term Evolution: Physical Channels

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Abstract

Long Term Evolution (LTE) is an advanced standard of the mobile communication systems. LTE is a fourth generation technology which is expected to provide mobile broadband platform for services in innovation in the foreseeable future. It is a next generation standard by 3rd Generation Partnership Project (3GPPP). In this paper the analysis of physical layer (PHY) of LTE transceiver in downlink and uplink transmissions is done. Simulations of the physical layer of LTE transceiver are obtained using Mathworks LTE System Toolbox. To show the performance of LTE transceivers in Physical Downlink Shared Channel (PDSCH) and Physical Uplink Shared Channel (PUSCH) simulation results are being presented. Measurements of Bit Error Rate (BER) and throughput are respectively obtained for different simulation configurations.

Keywords*: LTE, PDSCH, PUSCH, PHY*

1. Introduction

LTE has been developed to meet the requirements of this era and to realize the aim of achieving global broadband mobile communications. The objectives of this evolved system includes higher radio access data rates, improved system capacity, coverage, flexible bandwidth operations, improved spectral efficiency, low latency, reduced operating costs and seamless integration with the Internet and existing mobile communication systems. It relies on the technologies such as Orthogonal Frequency Division Multiplexing (OFDM) and Multiple-Input and Multiple- Output (MIMO), robust channel coding and link adaptation techniques [2]. LTE supports both division duplex schemes as well as frequency division duplex schemes (TDD/FDD). Here 15 frequency bands are FDD and 8 bands are TDD [6]. Modulation schemes such as QPSK, 16-QAM and 64-QAM are supported by LTE. Downlink transmission scheme of LTE is based on Orthogonal Frequency Division Multiple Access (OFDMA) whereas the uplink transmissions are based on Single Carrier Frequency Division Multiple Access (SC-FDMA). OFDMA suffers from Peak to Average Power Ratio (PAPR). So SC-FDMA performs much better in the uplink transmissions due to its lower PAPR as compared to OFDMA.

The protocol entities comprised by LTE Radio Access Network (RAN) includes Packet Data Convergence Protocol (PDCP), Medium Access Control (MAC), Radio Link Control (RLC) and The Physical layer (PHY). Using transport blocks, information to and from the MAC layer is transferred by the Physical layer. This primary focus of this paper is on the physical layer of LTE. The LTE physical layer is a highly efficient means to convey both data and control information between a mobile User Equipment (UE) and an enhanced base station (eNodeB). Simulations with the help of System toolbox of LTE are carried out in the Physical Downlink Shared Channel (PDSCH) and Physical Uplink Shared Channel (PUSCH).

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This paper is organized as follows: In Section II and III, the PDSCH downlink transmission and PUSCH transmission are analyzed respectively. The simulation results are shown in Section IV. Finally, conclusions are given in Section V.

2. LTE Downlink Transceiver

LTE downlink transmission that is from tower to device is based on OFDMA. Time-frequency resource grid represents the LTE downlink physical resources. Resource elements are grouped into Resource Blocks (RBs) and each RB includes 12 subcarriers with 15 kHz spacing in the frequency domain and in the time domain spacing of 7 consecutive OFDM symbols is done. The number of available RBs in the frequency domain varies depending on the channel bandwidth, and channel bandwidths may vary between 1.4 MHz and 20 MHz

Table 1

Channel Bandwidth (MHz)	Number of resource blocks
1.4	6
3	15
5	25
10	50
15	75
20	100

PDSCH Transceiver

Physical Downlink Shared Channel is used for the transmission of Downlink Shared Channel (DL-SCH). DL-SCH is the transport channel that is used for transmitting downlink data (a transport block). Depending on the precoding scheme used one or two coded transport blocks (codewords) can be transmitted simultaneously on the PDSCH. The processing steps of transmitting downlink data in PDSCH are given below:

- Transport Block CRC Attachment: It is performed for checking errors. For calculating CRC parity bits each transport block is used.
- Code Block Segmentation: In LTE, a minimum and maximum block sizes are specified so as to make the block sizes compatible with the block sizes supported by the turbo interleaver. The minimum and maximum block size is 40 bits and 6144 bits respectively. Segmentation is performed if the input block size is greater than the maximum size.
- Channel Coding: Turbo coding is used as the channel coding scheme. A turbo encoder constitutes two identical convolutional coders of special type such as feedback recursive systematic (RSC) type with parallel concatenation. A contention free Quadratic Permutation Polynomial (QPP) interleaver separates the two encoders.
- Rate Matching: In order to create an output bitstream with a desired code rate, rate matching is performed. The three bitstreams from the turbo encoder are interleaved. Bit collection creates a circular buffer. Then in order to create a single output bitstream the bits are selected and pruned from the buffer.
- Code Block Concatenation: To create the output of the channel coding the rate matched code blocks are concatenated back together.

The steps involved in PDSCH processing are:

- PDSCH Scrambling: Using length-31 Gold sequence generator the codewords are bit-wise multiplied with an orthogonal sequence or with a scrambling sequence created. Scrambling provides intercell interference rejection.
- Modulation: The scrambled codewords can be modulated using QPSK, 16QAM or 64QAM modulation schemes. This provides flexibility depending on the channel conditions to allow the scheme to maximize the data transmitted.
- Precoding: Precoding schemes supported by LTE are spatial multiplexing; transmit diversity, and single antenna port transmission. Spatial multiplexing further includes two schemes: precoding with large delay cyclic delay diversity (CDD) also known as open loop spatial multiplexing, and precoding without CDD that is also known as closed loop spatial multiplexing.
- Mapping to Resource Elements (RE): Here in sequence to resource elements, the complex valued symbols that were not occupied by synchronization and reference signals are mapped.
- OFDM Modulation: The data streams undergo modulation on orthogonal sub channels referred to as subcarriers. It offers high spectrum efficiency, MIMO transmission, robustness to multipath fading and inference rejection.

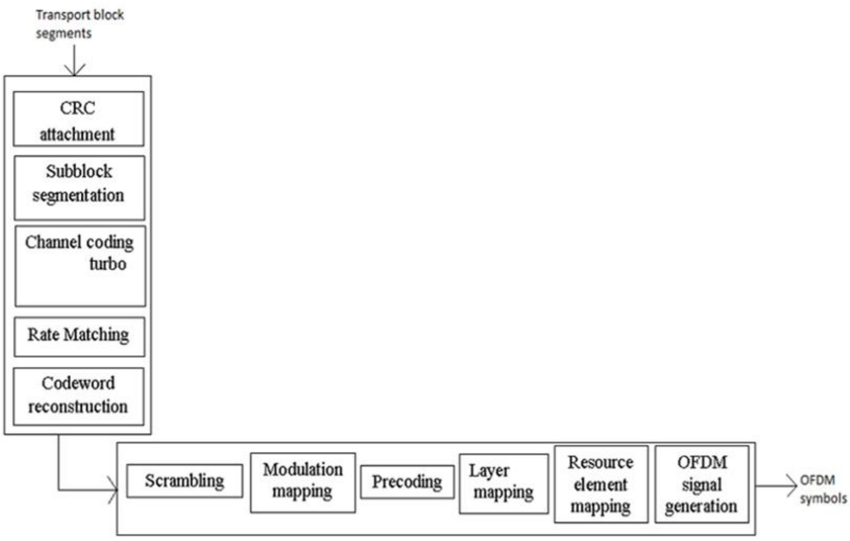

Figure 1. The LTE Downlink Physical Layer

3. LTE Uplink Transceiver

LTE uplink transmission i.e. from device to tower is based on SC-FDMA. Uplink transmission is organized in a frame structure with the frame duration of 10ms. SC–FDMA uses several frequencies for carrying the data of a single user and thereby increases the capacity of the users and augments the BER.

PUSCH Transceiver

The physical uplink shared channel is used for the transmission of uplink shared channel (UL-SCH) and control information (L1 and L2) respectively. PUSCH channel can be categorized into bit level, symbol level and sample level [7]. UL-SCH is the transport channel which is used for transmitting uplink data (a transport block) which undergoes transport block coding. Since it has lower PAPR it increases the efficiency of the power amplifiers and the output power. The PUSCH transmission processing steps for the PUSCH includes [1]:

- Transport block CRC attachment, Code block segmentation and CRC attachment, Channel coding, Rate Matching, Code Block Concatenation
- Data and Control Multiplexing: The transport data and control multiplexing is performed so that HARQACK information is present in both slots and is mapped to resources around the demodulation reference signals. Mapping analysis is important as it assumes that the channel estimation is of better quality.
- Channel Interleaver: The channel interleaver implements a mapping of modulation symbols onto the transmit waveform. Channel interleaver at the same time also ensures that HARQ information is present on both the slots.
- Scrambling
- Modulation
- Precoding: In uplink precoding the block of complex valued symbols is divided into sets. Each set corresponds to one SC-FDMA symbol. A Discrete Fourier Transform is then applied to each and every set.
- Mapping to Resource Elements.: In this block the mapping of the symbols to the allocated physical resource elements is done. The allocation sizes are limited to values whose prime factors are 2, 3 and 5. The mapping of symbols is performed in the increasing order, beginning with subcarriers and then the SC-FDMA symbols mapping is done.
- SC-FDMA modulation: SC-FDMA modulation is based on the OFDM approach; however, a Discrete Fourier Transform (DFT) precoding of the signal is employed. This operation spreads individual subcarriers that are known from the OFDM system over the assigned bandwidth and convert it to a single-carrier transmission. This process effectively reduces the PAPR, improves the cell edge coverage and User Equipment (UE) battery life.

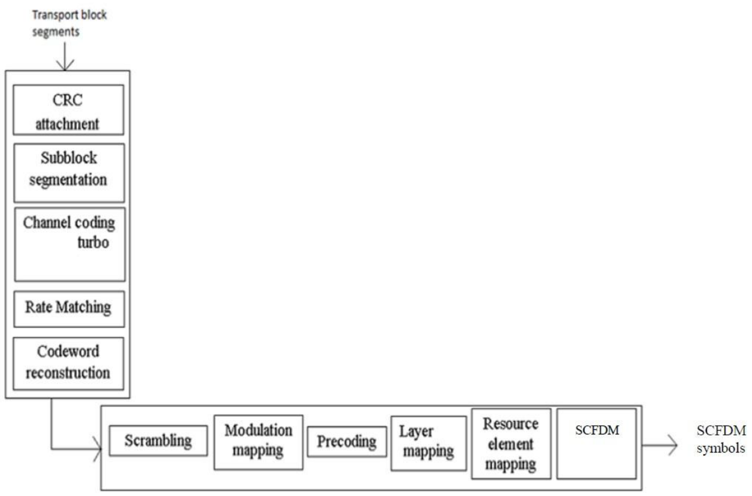

Figure 2. LTE Uplink Physical Layer

4. Simulation Results and Analysis

Simulations are done in this paper using the Mathworks LTE System Toolbox. For PDSCH transceiver and PUSCH transceiver Throughput and Bit Error Rate (BER) performance results are analyzed.

A. PUSCH Throughput Simulation

Channel noise is added to the received waveform and it is then SCFDMA demodulated, which results in a received resource grid for each receive antenna. In order to determine the channel between each transmit/receive antenna pair channel estimation is performed. PUSCH data is then extracted and decoded from this recovered resource grid [1]. In Table 2, PUSCH throughput simulation configuration is shown. For 10 frames as shown in figure 3, the throughput is above 70% when SNR is -2.2dB and above. Also, the throughput is steady when SNR is -1.2dB and above. For 20 frames as is shown in figure 4, the throughput is above 70% when SNR is -1.2dB and above. When SNR is 3.4dB and above the throughput increases and becomes steady.

Table 2. PUSCH Throughput Simulation Configuration

Codeword	Single
Number of Receivers	2
Propagation Channel	Extended Pedestrian A(EPA 5)
Number of Frames	10 (first simulation) and 20 (second simulation)
Signal to Noise Ratio (SNR) Range	[-5.6, -4.4, -3.4, -2.2, -1.2, 0.2, 1.2, 2.2, 3.4, 4.4]

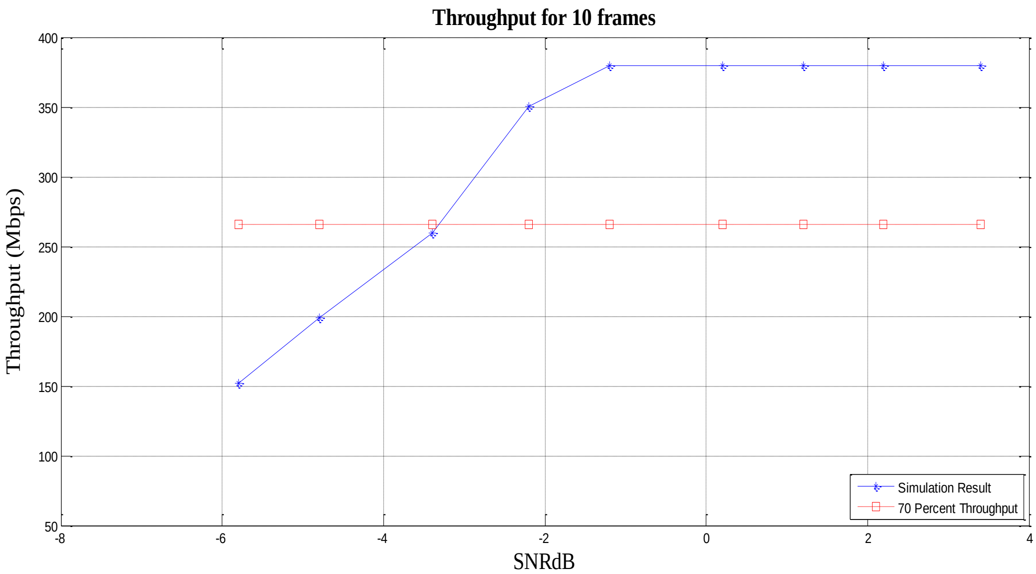

Figure 3. PUSCH Throughput against the Range of SNRS for 10 Frames

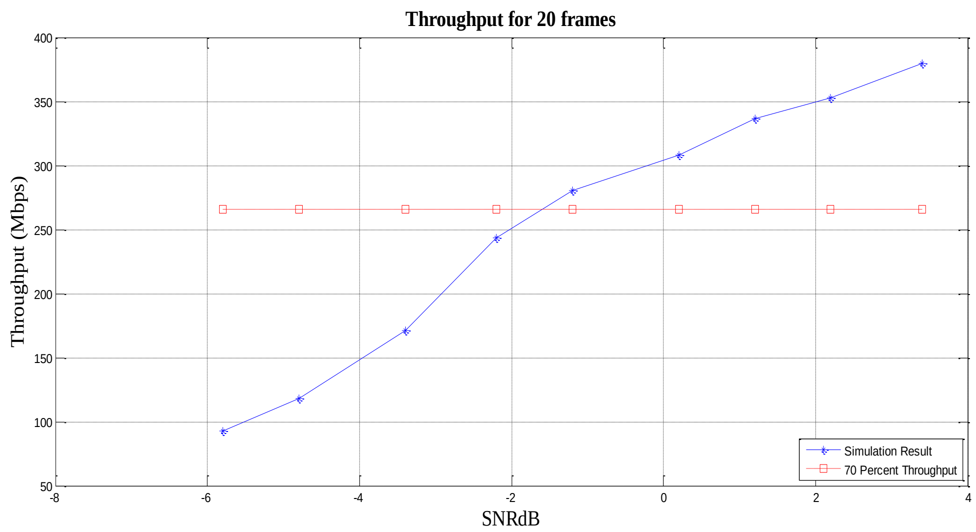

Figure 4. PUSCH Throughput against the Range of SNRS for 20 Frames

B. PDSCH Transmit Diversity Throughput Simulation

In order to show the PDSCH throughput of a transmit/receive chain LTE System Toolbox functions are used. Channel noise is added to the received waveform which afterwards is OFDM demodulated that results in a received resource grid for each receive antenna. To analyze the channel between each transmit/receive antenna pair channel estimation is performed. From this recovered resource grid PDSCH data is then extracted and decoded [1]. In Table 3, PDSCH Transmit Diversity throughput simulation configuration is shown. For 10 frames as shown in figure 5, the throughput is above 70% when SNR is -2.1dB and above. Also, the throughput is steady when SNR is 0.2dB and above. For 20 frames, the throughput is above 70% when SNR is -2.2dB and above. Then the throughput increases and becomes steady when SNR is 3.2dB and above.

Table 3. PDSCH Transmit Diversity Throughput Simulation Configuration

Codeword	Single
Transmission Scheme	Transmit Diversity
Number of Transmitters	4
Number of Receivers	2
Propagation Channel	Extended Pedestrian A(EPA5)
Number of Frames	10 (first simulation) 20 (second simulation)
Signal to Noise Ratio (SNR) Range	[-5.4, -4.4, -3.4, -2.2, -1.2,-1, 0.2, 1.2, 2.2, 3.4, 4.4]

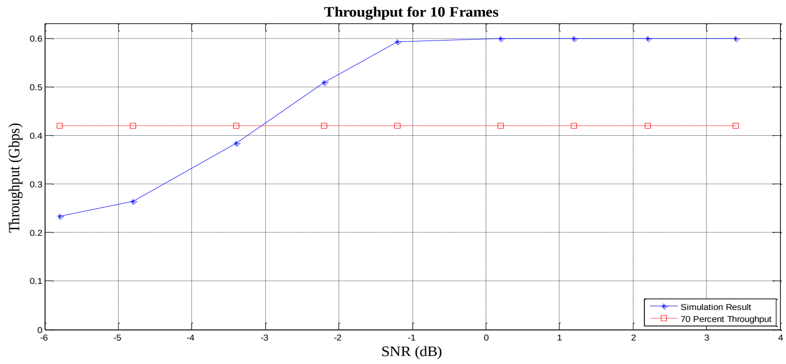

Figure 5. PDSCH Throughput against the Range of SNRS for 10 Frames

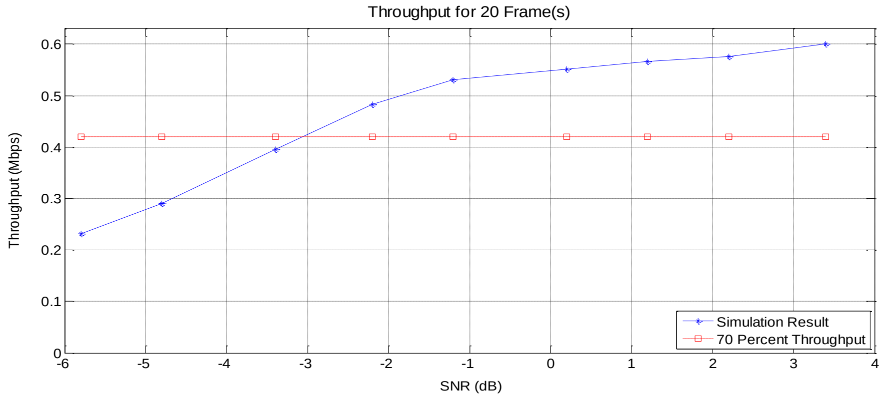

Figure 6. PDSCH Throughput against the Range of SNRS for 20 Frames

The total throughput percentage against the SNR range for both PDSCH and PUSCH is shown in Figure 9 and Figure 10 respectively and it is found that the throughput performance is similar in both PDSCH and PUSCH.

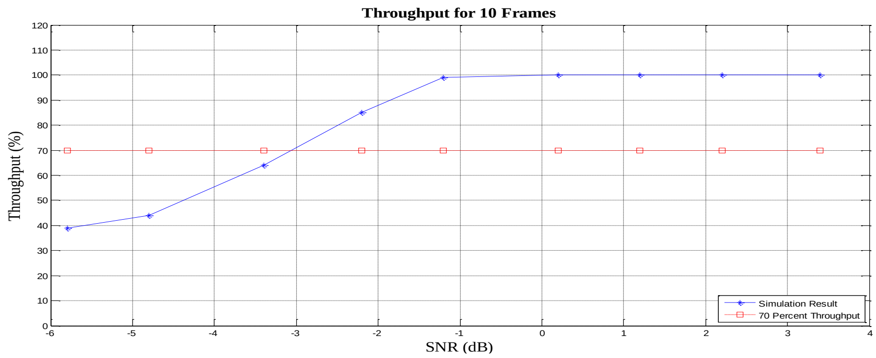

Figure 7. PUSCH Throughput Percentage for 10 frames

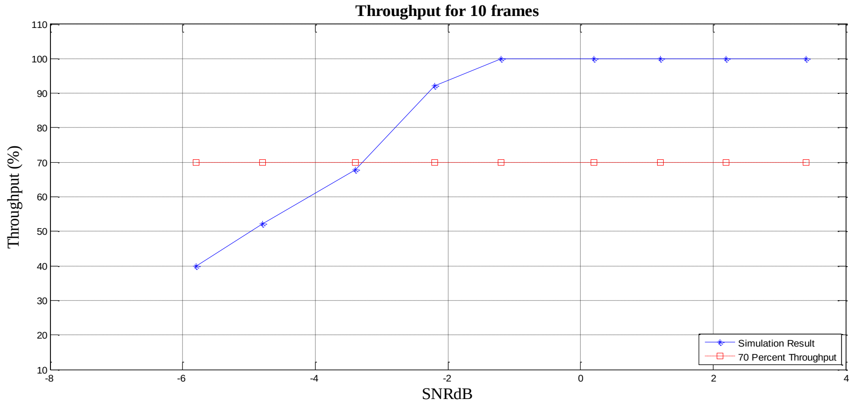

Figure 8. PDSCH Throughput Percentage for 10 Frames

C. PDSCH Bit Error Rate (BER) Simulation

Using LTE System Toolbox different BER curves are plotted for the parameters as-

Table 4

Parameter	Value
SNR range	-10 to 10
modulation schemes	QPSK, 16QAM, 64QAM
transport block Size	1000,1500

The BER curves in Figure 9 and Figure 10 show that the BER curves drops rapidly with increase in SNR for the coded modulation schemes. It is analyzed that when the transport block size is increased from 1000 to 1500 the BER curves increases. Also, the BER curves increases with the coded modulation schemes (QPSK, 16QAM, 64QAM) respectively.

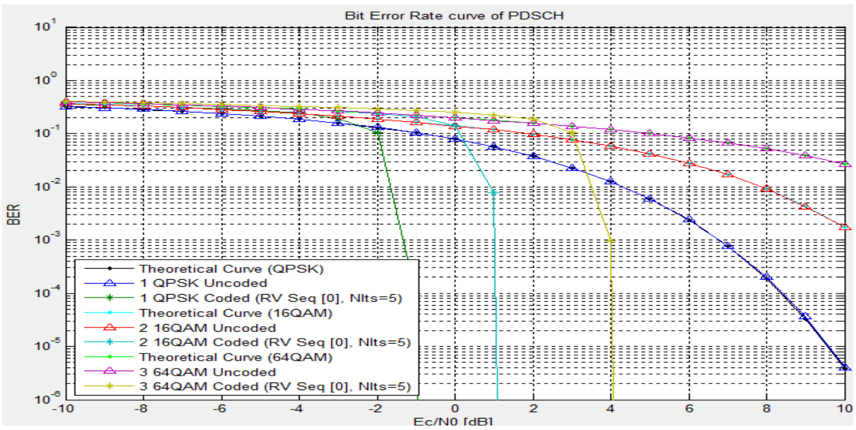

Figure 9. BER Curves for TB Size of 1000

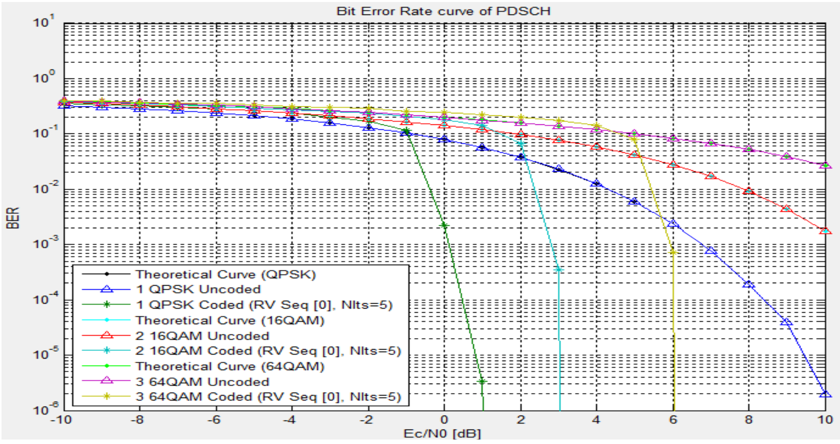

Figure 10. BER Curves for TB Size of 1500

5. Conclusion

This paper has analyzed LTE transceiver in downlink (PDSCH) and uplink (PUSCH) transmissions. The simulation results obtained from the LTE System Toolbox further analyzed the performance of the LTE transceiver by the measured throughput and BER graphs shown above. These results show clearly the throughput and BER that can be expected for different SNR values. Further work can be done by carrying out various downlink and uplink end to end simulations and modeling with the LTE System Toolbox.

References

[1] A.M. Abraham1 and B. Mathew2, "Analysis of LTE Physical Layer", IJAREEIE, vol. 4, no. 9, **(2015)**.
[2] T.O. Takpor and F.E. Idachaba, "Analyzing downlink and uplink transceiver of LTE", Proceedings of the World Congress on Engineering, **(2014)**.
[3] T. Mukherjee and S. Biswas, "Simulation and Performance Analysis of Physical Downlink Shared Channel in Long Term Evolution (LTE) Cellular Networks", Annual IEEE India Conference (INDICON), **(2014)**.
[4] N. Hou, K. Niu, Z. He and S. Sun, "Test and Performance Analysis of PUSCH Channel of LTE System," IEEE 5th International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless, **(2013)**.
[5] M.V.S. Lima, C.M.G. Gussen, B.N. Espindola, T.N. Ferreira, W.A. Martins and P.S.R. Diniz, "Open-Source Physical Layer Simulator for LTE Systems", IEEE Int. Conf. on Acoustics, Speech and Signal Processing (ICASSP), **(2012)**, Kyoto, Japan.
[6] F. Rezaei, M. Hempel and H. Sharif, "A Comprehensive Performance Analysis of LTE and Mobile WiMAX", 8th IEEE International Wireless Communications and Mobile Computing Conference (IWCMC), **(2012)**, Limassol, CYPRUS.
[7] J. Zhu and H. Li, "On the Performance of LTE Physical Downlink Shared Channel", Proceeding IEEE International Conference on Computer Science and Network Technology (ICCSNT), Harbin Normal University, Harbin, vol. 2, **(2011)**.
[8] H. Zarinkoub, "Understanding LTE with Matlab", Wiley Publications, **(2014)**.

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