BER Performance of CRC Coded LTE System for Various Modulation Schemes and Channel Conditions

Md. Ashraful Islam
Department of Information and Communication Engineering
University of Rajshahi, Rajshahi-6205, Bangladesh
ras5615@gmail.com

Dipankar Das
Department of Information and Communication Engineering
University of Rajshahi, Rajshahi-6205, Bangladesh
dipankar_ru@yahoo.com

Halida Homyara
Department of Information and Communication Engineering
University of Rajshahi, Rajshahi-6205, Bangladesh
lata_ice@yahoo.com

A. Z. M. Touhidul Islam
Department of Information and Communication Engineering
University of Rajshahi, Rajshahi-6205, Bangladesh
touhid_ice@ru.ac.bd

Abstract- **In this paper we presents the bit error rate (BER) performance of the Cyclic Redundancy Check (CRC) coded Long Term Evolution (LTE) system under various digital modulations (BPSK, QPSK and 16PSK) over an additative white gaussian noise (AWGN) and other multi path fading (Raleigh and Rician) channels. It is apparent from the Matlab based simulation study that the proposed LTE system outperforms with BPSK as compared to other modulation schemes under AWGN noisy and Rayleigh and Rician fading channels. The transmitted data is found to have retrieved effectively at the receiver end under the implementation of CRC coding/decoding algorithm. It has been also predictable that the performance of the CRC-based LTE system degrades with the increase of noise power.**

Index Terms— **Performance Analysis, 3GPP LTE, CRC Coding, MIMO, OFDM, BPSK, QPSK, 16PSK**

I. Introduction

In order to satisfy the demand for high speed and widespread network access in wireless communication systems, a new wireless data networks has been emerged and standardized by the 3rd Generation Partnership Project (3GPP). This new standard is marketed as 4G Long Term Evolution (LTE). The 3GPP LTE system marks the evolutionary move from third generation of Universal Mobile Telecommunication System (UMTS) to fourth generation mobile technology. It promises high peak data rates for both uplink and downlink transmission, spectral efficiency, low bit rates, and so on [1].

In LTE, the wireless data speed and data throughput are increased by using a combination of a number of novel technologies namely Multiple-Input Multiple-Output (MIMO) antennas, Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiple Access (OFDMA) at the downlink, Single Carrier Frequency Division Multiple Access (SCFDMA) at the uplink, support for 16 Quadrature Amplitude Modulation (16QAM), 64QAM, Quadrature Phase Shift Keying (QPSK) and so on. The MIMO technology offers a significant increase in system capacity within a given bandwidth [2]. MIMO technology involves the use of multiple antennas at the transmitter, receiver or both. The diversity and multiplexing modes are the two main modes of operation of multiple antenna systems. On the other hand, OFDM is a modulation technique which transforms frequency selective channel into a set of parallel flat fading channel [3]. In LTE, for a given transmission power, the system data throughput and the coverage area can be optimized by employing Adaptive modulation and coding techniques.

The performance of a MIMO-OFDM communication system significantly depends upon the estimation of channel. Channel estimation techniques for MIMO-OFDM system are discussed in many articles [4,5]. The 3GPP LTE is a new standard with laudable performance targets, therefore it is imperative to evaluate the performance and stability of this new system at an early stage in order to promote its smooth and cost-efficient introduction and deployment. This work therefore aims at evaluating the performance of LTE downlink systems under various digital modulations and channel

conditions. This evaluation will be based on performance metrics such as BER vs. SNR.

This work is organized as follows. Section 1 provides the Introduction. Section 2 gives a brief review of earlier studies on the performance study of LTE system. Section 3 presents the simulation model and its explanation. Section 4 focuses on the simulation results and evaluates the performance of LTE system under various digital modulations and channel conditions. Section 5 gives the conclusion of this work.

II. Related Works

Jethva et *al.* [6] compares the performance of various MIMO detectors for LTE and WLAN systems with ZF and MMSE deectors in spatial multiplexing environment. They shown that for lower order modulation schemes (BPSK, 4QAM, QPSK) MMSE detector is better in performance than ZF detector. For higher order modulation scheme (16QAM, 16PSK), BER performance of ZF and MMSE detectors almost remain same. The authors in Ref. [7] studied the performance of LSE and LMMSE channel estimators for LTE downlink systems. It was observed that when the CP length is equal to or longer than the channel length, LMMSE performs better than LSE but at the cost of computational complexity. When the CP length is shorter than the channel length, LMMSE continue to improve its performance only for low SNR values but it degrades for higher SNR values where LS shows better performance. Manikandan et *al.* [8] analyzed the performance of LTE physical layer based on Release 8 and 9. They pointed out that the packet loss and bit loss is zero for AWGN channel but it is line of sight. For non line of sight channel (Rayleigh and Rician) there is some packet loss. Rician channel performs better as compared to Rayleigh channel.

The authors in Ref. [9] designed and studied the performance of the 3GPP LTE Transceiver Physical Layer in SUI channels. The performance of MIMO based LTE downlink in underground mine environment is studied by Mabrouk et *al.* [10]. Their results suggest that LTE is able to support multi-stream transmission with very high data rates within an underground mine gallery.

III. Simulation Model

The transmitter and receiver sections of the LTE communication system are shown in the block diagram of Fig. 1. In this setup, we have just implemented the mandatory features of the specification, while leaving the implementation of optional features for future work. The channel coding part is composed of coding techniques of the Cyclic Redundancy Check (CRC). The complementary operations are applied in the reverse order at channel decoding in the receiver end. We do not explain each block in details. Here we only give the emphasis on communication channel i.e. AWGN and Fading (Rayleigh and Rician), Cyclic Redundancy Check (CRC) channel coding and different modulation technique used.

The transmitter in the physical layer starts with the grouped resource data which are in the form of transport blocks. In each TTI, one transport block will be transferred first to the channel coding part which consists of two CRC encoders and one Turbo encoder. Then the block of the coded bits is named as a code block. The rate-matching block which cooperates with Hybrid ARQ is a kind of rate coordinator between the channel coding and the following blocks. Cyclic Redundancy Check (CRC) codes are a subset of class of linear codes, which satisfy the cyclic shift property such as if $C=[C_{n-1}, C_{n-2} \ldots\ldots, C_O]$ is a codeword of a cyclic code, then $[C_{n-2} \quad C_{n-2}, \ldots, C_0, C_{n-1}]$, obtained by a cyclic shifts of the elements of C, is also a code word. In other word all cyclic shifts of C are code words. From the cyclic property, the codes possess a great deal of structure which is exploited to greatly simplify the encoding and decoding operation

As illustrated in Fig. 1, there are two process lines before the layer mapping block. The two lines correspond to the parallel processing of two codewords1 in the case of spatial multiplexing transmission. Otherwise only one process line works. The layer mapping and precoding combined with different transmit schemes are two key approaches to achieve the MIMO functionality in LTE. Both of them are contained in the antenna mapping block of the LTE simulator.

In the LTE downlink simulator, the receiver side simulates the operation of one user equipment that processes the received signals. After the steps of inverse-OFDM and inverse resource mapping, the receiver has to do the channel estimation to provide the necessary channel information to the following blocks of equalizer and PMI calculation. After the layer extracting, up to two processing lines operates in parallel in case of spatial multiplexing. Otherwise there is one process line in action. In each TTI, the following blocks of demodulation, inverse rate-matching, channel decoding, and HARQ will detect each transmitted bits and ask for a retransmission if any errors remain after the Turbo decoding .Finally, the PMI will be fed back to the block, and the decoded bits are transferred to the output calculation block to evaluate the simulator performance in each TTI.

IV. Simulation Results and Discussion

The computer simulation has been performed using Matlab 7.5 programming language to evaluate the BER performance of the CRC coded MIMO-OFDM-based LTE system under different modulation schemes. The simulation parameters are listed in Table 1. Figures 2 through 4 show the BER performance vs. SNR plots of the proposed LTE system under three types of digital modulations (BPSK, QPSK and 16PSK) on both AWGN and fading channels (Rayleigh and Rician).

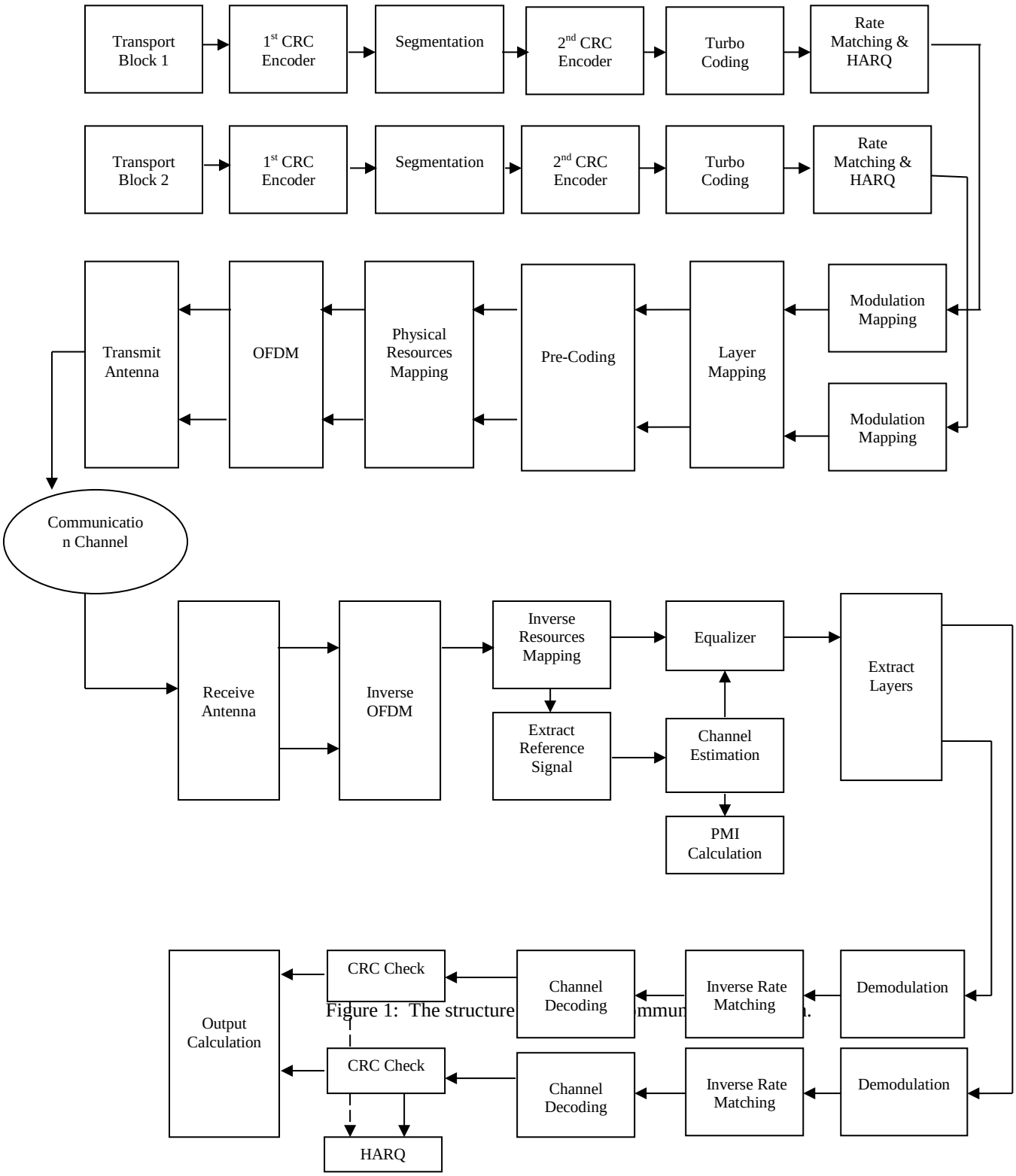

Figure 1: The structure mmun n.

Fig. 1. The structure of the LTE Communication System.

TABLE I. SIMULATION PARAMETERS.

Parameters	**values**
Number Of Bits	44000
CP	1/4
Coding	Cyclic Redundancy Check (CRC) & Turbo Code
Code rate	2/3
Constraint length	7
SNR	0-25
Modulation	BPSK, QPSK, 16PSK
Channels	AWGN, Rayleigh, Rician
K-factor	4
Doppler Shift	100

From Fig. 2 it is seen that the CRC channel encoded MIMO-OFDM based LTE system outperforms at BPSK modulation while it shows worst performance in case of 16PSK in AWGN channel. For a typical E_b/N_0 value of 5 dB, the BER values for BPSK and 16PSK are 0.0008 and 0.05 respectively. It implies that the LTE system performance with BPSK modulation is improved by 18 dB than that of the system with 16PSK modulation for a typical E_b/N_0 value of 5 dB.

Figure 3 shows that the BER performance of the proposed CRC encoded LTE system under various digital modulations in Raleigh multi path fading channel. It is evident that the system outperforms with BPSK modulation while it shows worst performance at 16PSK modulation. The LTE system with 16PSK modulation is more influenced by the Doppler frequency shift and its performance degrades. At E_b/N_0 value of 5 dB (where the BER values for BPSK and 16PSK are 0.0005 and 0.08, respectively), the system performance with BPSK modulation is improved by 22 dB as compared with 16PSK.

The performance of the CRC channel encoded MIMO-OFDM based LTE system in Rician fading channel is shown in Figure 4. As seen from the figure, the system provides satisfactory performance with BPSK modulation. Due to multi path fading effect, the system performance undergoes considerable degradation with 16PSK modulation. Comparing the BER performance for different modulation schemes (BPSK and 16PSK), it is evident that the LTE system performance is improved by 19 dB in the case of BPSK for a typical E_b/N_0 value of 5 dB (where the BER values for BPSK and 16PSK are 0.001 and 0.08, respectively).

Finally, comparing the BER performance of the proposed CRC channel encoded MIMO-OFDM based LTE system under both the Rayleigh and Rician fading channels in Figures 3 and 4, respectively, it is observable that the system performance under Rician fading channel is better than that in Rayleigh fading channel.

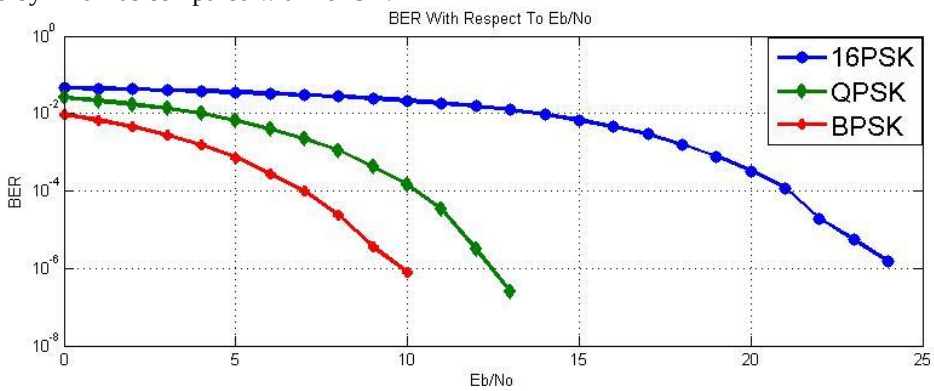

Fig. 2. Figure 2. BER of the CRC encoded LTE system for different modulation schemes over AWGN channel.

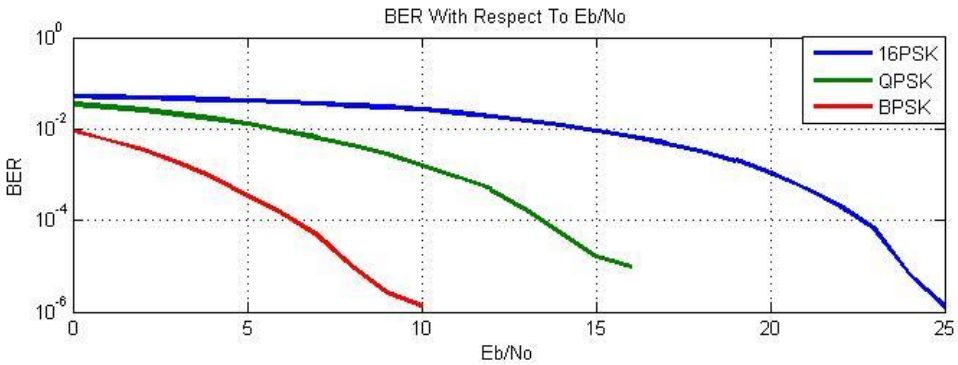

Fig. 3. Figure 3. BER of the CRC encoded LTE system for different modulation schemes over Rayleigh channel.

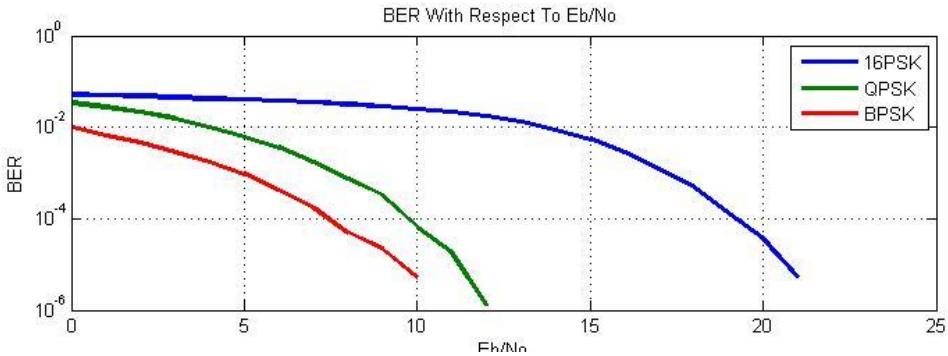

Fig. 4. Figure 4. BER of the CRC encoded LTE system for different modulation schemes over Rician channel.

V. Conclusions

In this paper we evaluated the BER performance of an MIMO-OFDM based LTE communication system with the implementation of Cyclic Redundancy Check (CRC) channel coding under different digital modulations over AWGN noisy, Raleigh and Rician fading channels. On the basis of the results obtained in the present Matlab-based simulation study, it can be concluded that the deployment of CRC channel coding scheme in LTE system under BPSK modulation is effective in proper retrieval of transmitted data in noisy and fading environments.

References

[1] Jemmali A., Conan J., and Torabi M. 2013. Bit Error Rate Analysis of MIMO Schemes in LTE Systems. The Ninth Int. Conf. on Wireless and Mobile Communicatios, 190-194.

[2] Paulraj A. J., Gore D. A., Nabar R. U., and Bolcskei H. 2004. An Overview of MIMO Communications-A Key to GiGabit Wireless. Proc. IEEE, 92 198-218.

[3] Muquet B., Wang Z., Giannakis G. B., Courville M. de., and Duhamel P. 2002. Cyclic Prefixing or Zero Padding for Wireless Multicarrier Transmissions. IEEE Trans. Commun., 50, 2136-2148.

[4] Li Y., Seshadri N., and Ariyavisitakul S. 1999. Channel Estimation for OFDM Systems with Transmitter Diversity in Mobile Wireless Channels. IEEE J. Sel. Areas Commun., 17, 464-471.

[5] Wan D., Han B., Zhao J., Gao X., and You X. 2003. Channel Estimation Algorithms for Broadband MIMO-OFDM Sparse Channel. Proc. 14th IEEE Int. Symp. on Personal, Indoor, and Mobile Radio Communications, 1929-1933.

[6] Jethva J. B., Porwal M. Kr., and Trivedi A. R. 2013. Performance Analysis for Different Modulation Schemes in MIMO for LTE and WLAN. Int. Journal of Engineering Technology and Advanced Engineering, 3, 580-583.

[7] Khlifi A., and Bouallegue R. 2011, Performance Analysis of LS and LMMSE Channel Estimation Techniques for LTE Downlink Systems. Int. Journal of Wireless and Mobile Networks, 3 141-149.

[8] Manikandan A., Venkataramanan V., Kavitha M., and Parvhati S. 2012. Performance Analysis of LTE Physical Layer based on Release 8 & 9 through Simulink Environment. Int. Journal of Advanced Technology and Engineering Research, 2, 92-97.

[9] Mnati M. J., Farhan S. H., and Gamaj M. I. 2014. Design and Performance of the 3GPP Long Term Evolution Transceiver Physical Layer in SUI Channels. Int. Journal of Soft Computing and Engineering, 3 93-95.

[10] Mabrouk I. B., Talbil L., Nedil M., and Denidni T. A. 2012. On the Performance of MIMO Systems for LTE Downlink in Underground Gold Mine. Progress in Electromagnetics Research Letters, 30 59-66.