SIMULATION OF LTE DOWNLINK SIGNAL

Andrei Vasile IORDACHE[1]

This paper investigates the effect of SINR in LTE downlink transmission. 3GPP Long Term Evolution (LTE) is the evolution of the Universal Mobile Telecommunications System (UMTS) which will make possible to deliver next generation high quality multimedia services according to the users' expectations. The results of this simulation can be used to evaluate the OFDM-MIMO LTE performance in different environments. Finally an average BER and throughput vs. average SINR are analyzed. An LTE system-level simulator was used. The simulator can be obtained for free under an academic, noncommercial use license.

Keywords: LTE, downlink, SINR.

1. Introduction

The 3rd Generation Partnership Group standardized LTE to be used as a Next Generation Wireless Network. LTE is designed to increase data rates and cell edge bitrates, improve spectrum efficiency and allow spectrum flexibility for flexible radio planning.

For the downlink, LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) since this is the most appropriate technique available for achieving high spectral efficiency and meeting current network needs, as opposed to UMTS, which was based on Wideband-CDMA (WCDMA). It presents new challenges such as: channel estimation [1], frequency offset correction [2], HARQ (Hybrid automatic repeat request) modeling [3], or feedback calculation [4].

Another feature of LTE is the X2-interface between base stations. This interface can be used for interference management aiming at decreasing inter-cell interference [5]. The exact implementation of the interference mitigation remain vendor specific and are currently a hot topic in research, see for example [6-8].

The LTE system-level simulator [9] supplements an already freely-available LTE link-level simulator [5]. The license under which the simulators are published allows for academic research and a closer cooperation between different universities and research facilities. This simulator emulates the MIMO (Multiple-Input and Multiple-Output) algorithms, the OFDM signal, the spatial channel model, the channel modulation, the coding scheme, the rate matching and the HARQ process on the communication involved in the LTE downlink between the

[1] Ph.D. student, Faculty of Electronics, Telecommunications and Information Tehnology, University POLITEHNICA, Bucharest, Romania, e-mail: andrei_yordache@yahoo.com

transmitter, the base station enhanced-NodeB, and the receiver, the user equipment (UE).

Most parts of the LTE simulator are written in plain Matlab code. Only computationally intensive functions like soft-sphere or channel decoding are implemented in ANSI-C as MEX functions.

This paper is structured as follows: in Section 2 is presented a description of the LTE simulator. Simulations and results are presented in Section 3. Section 4 presented the conclusions.

2. Simulator description

The simulator presented in this document is based on the E-UTRA physical layer specifications [10] and [11] and it has been developed by means of ad-hoc C/C++ programs.

The simulator is flexible designed and a complete set of parameters can be configured to define the LTE link level performance: the values of SINR or, equivalently, E_b/N_o (where N_o includes all the sources of noise); the mobile radio channel model (outdoor/indoor, pedestrian/vehicular); the MIMO channel correlated or uncorrelated; the MIMO transmit/receive procedures; the modulation and bandwidth; the channel coding rate and the resource allocation [12].

From theory it is well known that in MIMO systems the multiple antennas at the transmitter and the receiver can be used in two different modes, namely the diversity and multiplexing modes. Diversity mode can be implemented at the receiver (Receive Diversity) or at the transmitter (Transmit Diversity). Where receive diversity is simply a combining operation of different replica of the same transmitted signal, transmit diversity requires a space time coding operation of the transmitted signal. In LTE both different modes are defined.

The MIMO channel model and reference scenarios employed as reference for the DL link level simulator are described in [13]-[16] and [17], [18] and [19], respectively.

The inputs of this simulator are: SINR, channel model, MIMO correlation, MIMO scheme, symbol modulation and bandwidth. The output is the brute Bit Error Rate (BER) [12]. Finally, as a result of these LTE link level simulations, an average BER and throughput vs. average SINR are calculated [12].

All simulations were performed with LTE system-level simulator using 2.14 GHz and 1.4 GHz frequency bands. The simulations given in this paper uses 1.8 GHz frequency band.

3. Simulations and results

3.1. Parameters

An ideal channel estimation, a MIMO configuration of 2 antennas at the transmitter and 2 antennas at the receiver and also a SISO (Single-Input and Single-Output) configuration, and the Extended Pedestrian A (EPA) with 3.5 Km/h pedestrian speed as the multipath channel model has been assumed for the simulation process [17]-[18] .

Concerning the physical resource allocation, it has been only considered one Physical Resource Block (PRB) per one simulated user, although the 3GPP specification establishes a minimum allocation of 4 PRB for the case of 20MHz bandwidth [20]. E-UTRA turbo code block size ranges from a minimum of 40 bits to a maximum of 6144 bits and the code block sizes from 40 to 120 bits have been used for the simulations [11]. The turbo code internal interleaver parameters are the ones specified in [12].

Table 1 summarizes the parameters used for the simulations.

3.2. Results

Figs. 1, 2 and 3 shows the uncoded BER performance for different modulations schemes for **1.8 GHz LTE network**. We observe that the performance of QPSK modulation is superior to that of OFDMA when using localized allocation. This is an expected result as shown in [2].

The uncoded BER performance results get worst when the MIMO correlation matrix coefficients rise. Therefore the ideal case is the low correlation MIMO that is the uncorrelated case, and medium and high correlation cases obtain worst results [12].

Fig. 4 shows the maximum throughput performance results vs. the average simulated SINR for 1.8 GHz LTE network.

In the case of uncorrelated MIMO channel, MMSE detector gets higher throughputs than Alamouti/MRC detector for an average SINR higher than 12 dB. Then, at lower average SINR, MMSE and Alamouti/MRC obtain the same throughput [12].

Table 1

Parameters used for the simulations

Parameter	Value
Carrier frequency	1.8 GHz
Sub-carrier spacing	15 kHz
Transmission Bandwidth	20 MHz
FFT Size	2048
OFDM Cyclic Prefix	CP of 4.69/5.12μs and 7 modulation symbol/subframe
OFDM symbol duration	71.43 μs
Sub-frame duration	0.5 ms
TTI length	1 ms
Number of Useful subcarriers	1200
Number of sub-carriers per PRB	12
Maximum Number of PRBs	100
Number of simulated PRB per simulated user	1
Number of OFDM symbols per TTI	14 (4 for control)
Power Delay Profile	EPA channel model, pedestrian speed 3,5 Km/h
Channel Coding	Turbo Code basic rate 1/3
Code block sizes	40-120 bits
Rate Matching and H-ARQ	According to [11], Max. 4 IR transmissions.
AMC formats	QPSK: 1/3, 1/2, 2/3, 4/5 16QAM 1/2, 2/3, 4/5 64QAM 2/3, 4/5
Channels Estimation	Ideal
Antenna schemes	SISO 1x1 and MIMO 2x2
SISO receiver	One tap equalizer
MIMO channel correlation	Low Correlation (Uncorrelated) (LC), Medium Correlation (MC) High Correlation (HC) according to [18]
MIMO receiver	ZF, MMSE and Alamouti/MRC

In short, in case of correlated MIMO channels transmit diversity throughput over performs the spatial multiplexing throughput at lower SINRs. Therefore, MMSE detector has more sense at higher SINRs, leaving Alamouti/MRC scheme for lower SINRs [12].

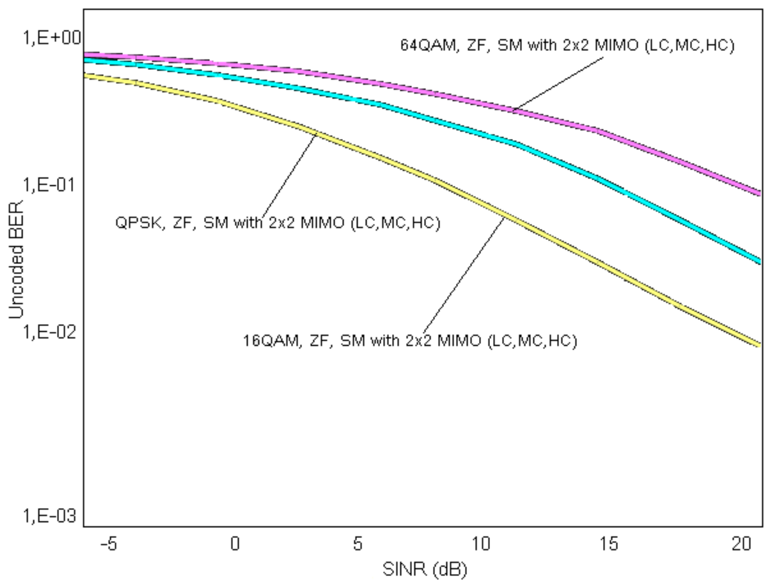

Fig.1 - Uncoded BER performance results in case of Spatial Multiplexing, ZF Detector and 2 x 2 MIMO

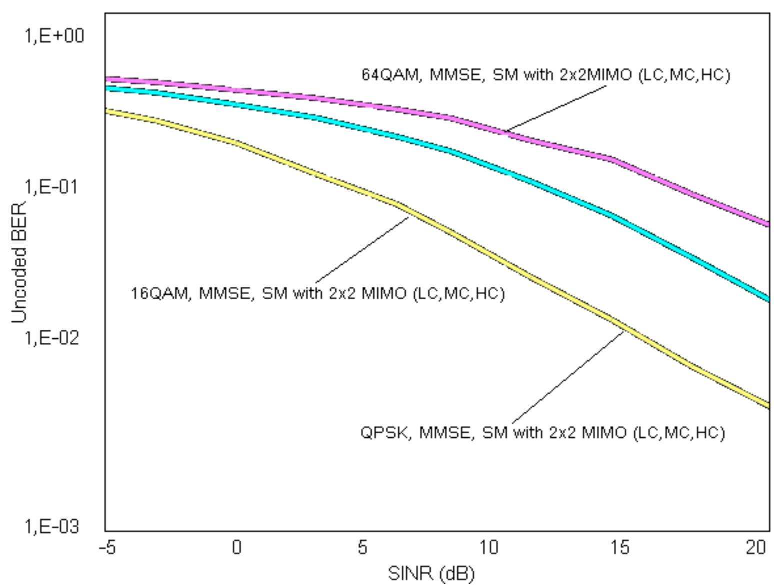

Fig. 2 - Uncoded BER performance results in case of Spatial Multiplexing, MMSE Detector and 2 x 2 MIMO.

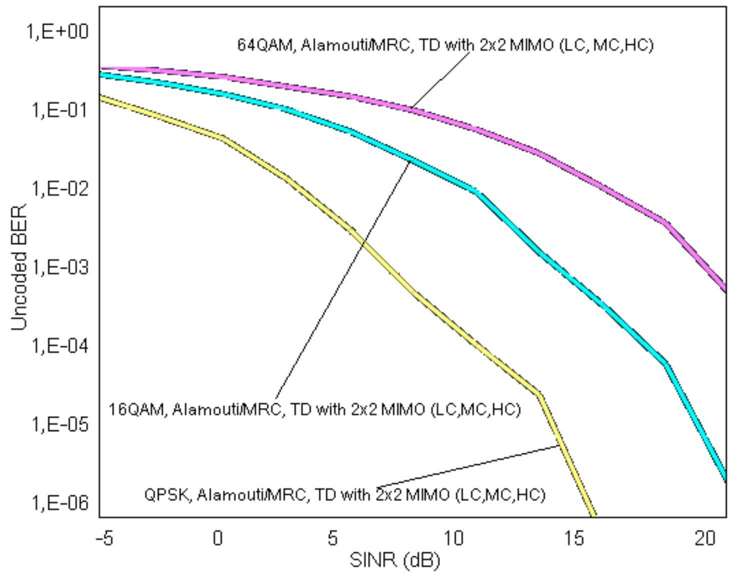

Fig. 3 - Uncoded BER performance results in case of Transmit Diversity, Alamouti/MRC and 2 x 2 MIMO.

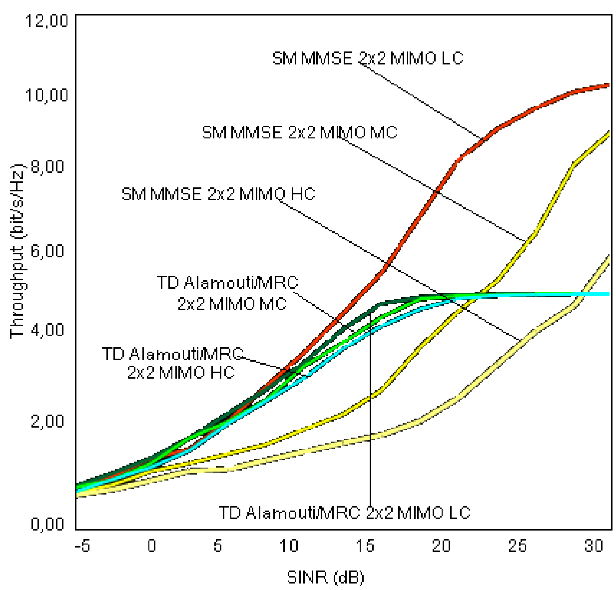

Fig. 4 - E-UTRA DL AMC 2x2 MIMO link level throughput of the MCS classes with H-ARQ (8 turbo decoding iterations. Code block size: 40-120)

4. Conclusions

The downlink LTE layer, as well as the entire LTE design, was optimized to meet the challenges and requirements from IP-based services ranging from low-rate real-time applications like VoIP (Voice over IP) to high-speed broadband access by providing high data rates and low delays combined with high reliability when required, for example, for TCP.

Using downlink physical-layer simulator one can investigate the whole signaling process in an LTE network and can create an overview about this process.

So, if more transmit antennas are used, more pilot symbols are inserted in the OFDM frame and thus lower maximum throughput can be achieved.

The results confirm the ability of the simulator to work according to the 3GPP standards and enables easy reproducible research in the field of LTE downlink.

Acknowledgment

The author would like to thank the whole LTE research Group of Institute of Communications and Radio-Frequency Engineering Vienna University of Technology, Austria for support. The author would also like to thank Mr. Albert Serra Pagès for his research in 2.14 GHz LTE band.

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/107/1.5/S/76813.

R E F E R E N C E S

[1]. M. Šimko, C. Mehlführer, T. Zemen, and M. Rupp, "Inter-Carrier Interference Estimation in MIMO OFDM Systems with Arbitrary Pilot Structure," in Proc. IEEE VTC Spring 2011, Hungary, May 2011.

[2]. Q. Wang, C. Mehlführer, and M. Rupp, "Carrier frequency synchronization in the downlink of 3GPP LTE," in Proceeding of the 21st Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'10), Istanbul, Turkey, Sep. 2010.

[3]. J. C. Ikuno, C. Mehlfürer, and M. Rupp, "A novel LEP model for OFDM systems with HARQ," in Proc. IEEE International Conference on Communications (ICC) 2011, June 2011.

[4]. S. Schwarz, M. Wrulich, and M. Rupp, "Mutual information based calculation of the precoding matrix indicator for 3GPP UMTS/LTE," in ITG International Workshop on Smart Antennas (WSA), Bremen, Germany, February 2010.

[5]. C. Mehlführer, M. Wrulich, J. C. Ikuno, D. Bosanska, and M. Rupp, "Simulating the long term evolution physical layer," in Proc. of the 17th European Signal Processing Conference (EUSIPCO 2009), Glasgow, Scotland, Aug. 2009.

[6]. J. Andrews, “Interference cancellation for cellular systems: a contemporary overview," IEEE Transactions on Wireless Communications, vol. 12, no. 2, pp. 1929, Apr. 2005.
[7]. A. Simonsson, “Frequency reuse and intercell interference co-ordination in E-UTRA," in Proc. 65th IEEE Vehicular Technology Conference 2007 (VTC2007-Spring), Apr. 2007, pp. 30913095.
[8]. H. Zhang, L. Venturino, N. Prasad, and S. Rangarajan, “Distributed inter-cell interference mitigation in OFDMA wireless data networks," in Proc. 4th IEEE Broadband Wireless Access Workshop, New Orleans, LA, USA, Dec. 2008.
[9]. http://www.nt.tuwien.ac.at/ltesimulator/.
[10]. 3GPP TS 36.211 V8.5.0 (2008-12), “Evolved Universal Terrestrial Radio Access (E-UTRA) Physical Channels and Modulation (Release 8)”.
[11]. 3GPP TS 36.212 V8.5.0 (2008-12) , “Evolved Universal Terrestrial Radio Access (E-UTRA) Multiplexing and channel coding (Release 8)”.
[12]. Albert Serra Pagès , MSc Thesis „A Long Term Evolution Link Level Simulator”, University of Catalunya, February, 2009
[13]. Hoo-Jin Lee, Shailesh Patil, and Raghu G. Raj, "Fundamental overview and simulation of MIMO systems for Space-Time coding and Spatial Multiplexing", Wireless Networking and Communications Group (WNCG), Dept. of Electrical and Computer Engineering, The University of Texas at Austin, 2003.
[14]. L.Hanzo, M.Münster, B.J.Choi and T. Keller, “Chapter 17: Uplink Detection Techniques for Multi-User SDMA-OFDM”, ”OFDM and MC-CDMA for Broadband Multi-user Communications, WLANs and Broadcasting”, John Wiley and Sons, Ltd. 2003.
[15]. Albert van Zelst, “MIMO OFDM for Wireless LANs”, PROEFSCHRIFT, April 2004.
[16]. Na Wei, “MIMO Techniques for UTRA Long Term Evolution”, Dissertation, September 2007.
[17]. 3GPP TS 36.101 V8.4.0 (2008-12), “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception”.
[18]. 3GPP TS 36.104 V8.4.0 (2008-12), “Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception”.
[19]. 3GPP R4-070141, “Radio Propagation Modeling for E-UTRA performance requirement definition”, February 2007.
[20]. 3GPP TS 36.213 V8.5.0 (2008-12), “Evolved Universal Terrestrial Radio Access (E-UTRA) Physical layer procedure (Release 8)”.