Long Term Evolution Downlink Physical Layer Simulation in Matlab and Simulink

Karthik Ravindhra, Siva Subramanian Manohar, and Uma Sankar Govindaswamy

***Abstract*—Long-term evolution (LTE) represents an emerging and promising technology for providing broadband ubiquitous Internet access. For this reason, several research groups are trying to optimize its performance. In this paper, we introduce a Matlab and Simulink-based LTE downlink physical-layer simulator according to 3GPP specifications and related proposals. The simulation is carried out for the single-downlink, from one E-UTRAN (eNodeB) to one User Equipment (UE). Brief introduction of every part is given along with physical concepts and analysis for bit error rate and throughput are studied for different system settings.**

***Index Terms*—LTE, 3GPP, MIMO, OFDM**

I. Introduction

Long Tem Evolution (LTE) [1] can provide high data rates, low latency and flexible bandwidth. To achieve these targets, Orthogonal Frequency Division Multiplexing (OFDM) and Multiple-Input and Multiple-Output (MIMO) are adopted as basic technologies [2]-[5]. Besides, other technologies like robust channel coding, scheduling, link adaptation and hybrid ARQ are also important.

The LTE downlink transmission scheme is based on Orthogonal Frequency Division Multiple Access (OFDMA) which converts the wide-band frequency selective channel into a set of many flat fading subchannels. The flat fading subchannels have the advantage that even in the case of MIMO transmission optimum receivers can be implemented with reasonable complexity, in contrast to WCDMA systems. OFDMA additionally allows for frequency domain scheduling; typically try assigning only "good" subchannels to the individual users [6, 7]. This offers large throughput gains in the downlink due to multi-user diversity [8, 9]. 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 [10], [11].

II. Simulator Structure

It is necessary to present the scope of the paper, including the requirements and some constraints on the implementation of the LTE system.

The implementation is based on the LTE Release 9 of the 3GPP specification.

The platform is MATLAB Simulink (version 7, release 14)

Only considered is the LTE downlink built between 1 base station (eNodeB) and 1 user equipment (UE).

The focus is mainly on the physical layer and partly on the MAC layer.

Only PDSCH (Physical Downlink Shared Channel) is considered and no control channels are considered.

Only FDD (Frequency-Division Duplexing) is supported.

Thus, this simulation focuses on the implementation of the transmitter and the receiver in LTE downlink. The implementation is based in matlab files, and then migrated to the Simulink simulation environment (masked subsystem to "wrap" each relevant module). The implementation based in matlab files allows easy evaluation of the suitability of each algorithm involved.

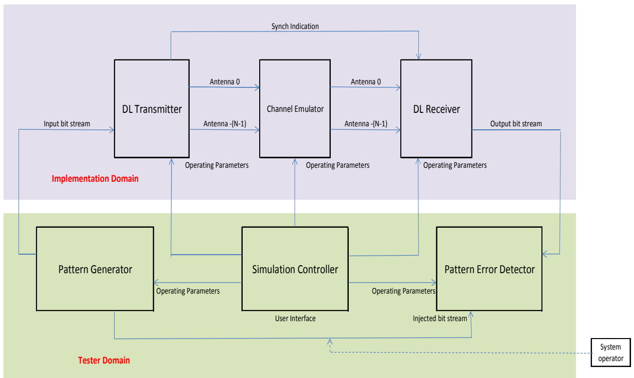

Fig. 1. LTE DL system

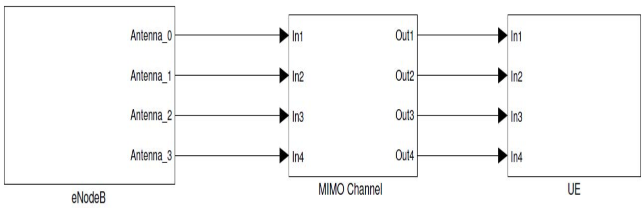

Fig. 2. LTE DL system (simulink)

The simulator implements the DL link from one eNodeB to a mobile subscriber station. It includes a configuration/control entity that emulates the control plane of the LTE PHY, however only the user data-plane is considered. A selection of typical LTE working scenarios is covered.

The block-diagram plotted in Fig. 1 consists of the following modules:

Pattern generator: it generates a random bit stream in order to inject data to the system

DL Transmitter: it includes channel coding, modulation, MIMO processing, resource mapping, OFDM modulator.

Channel simulator: it simulates an ideal line-of-sight AWGN channel.

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DL receiver: it consists of an OFDM demodulator (symbol synchronization, channel estimation and equalization, MIMO layers splitting), OFDM demapping, channel decoder, and HARQ chase combiner.

Pattern error detector: it computes the packets/bits error rate.

Simulation controller: it controls the specific working scenario for all the components, provides coordination and synch control over all modules, and finally establishes static parameters to the modules developed.

The actual implementation is the set of entities formed by the DL transmitter + DL receiver + channel simulator. The other entities are for testing and verification purposes. In next subsections, a more detailed description of the implementation modules is provided.

A. Transmitter

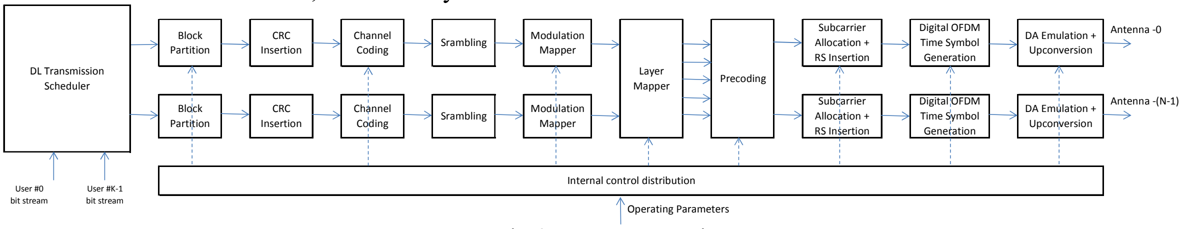

Fig. 3. LTE DL transmitter

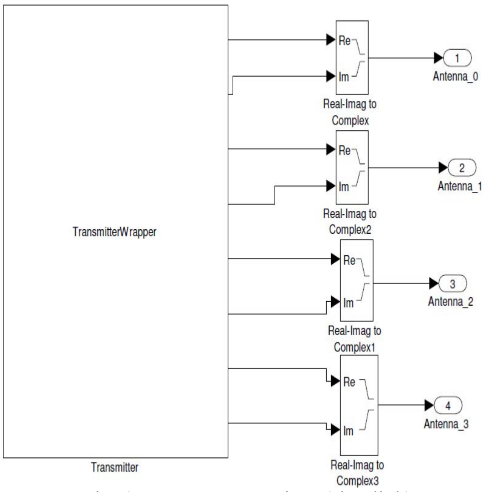

Fig. 4. LTE DL transmitter (simulink).

The DL transmitter is a typical LTE eNodeB transmitter. A very simple input data scheduler: only one user is considered. This module performs the partition of traffic data into a set of codeword flows. These codewords flows are aligned with the physical resource blocks that are finally allocated in the LTE frame/subframe. Some of these codeword flows corresponds with the broadcasting and other control channels. In this system, these resource elements will be filled with dummy data, as the control is going to be performed by the Simulation Controller top module.

A set of codeword processing chains, formed by block partition, CRC insertion, channel coding, scrambler and modulation mapper. The output is fed into the layer mapper, for further MIMO transmission preparation. A layer Mapper and a pre-coding matrix processing blocks, which generate the digital data mapped to the subcarriers, which are fed in each antenna for transmission. MIMO encoding is performed here. A set of processing chains allocate the subcarriers into the assigned frame/subframe location, jointly with the reference signals, and to generate the actual OFDM time samples. Each of these chains drives each one of the transmitting antennas.

B. Channel Model

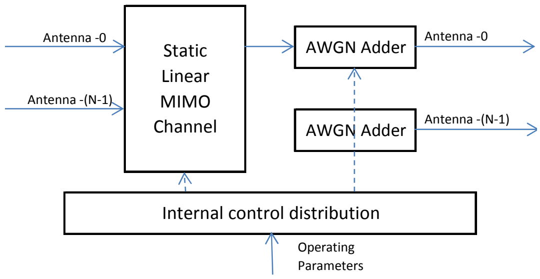

Fig. 5. MIMO & AWGN model.

The channel emulator holds a very simple linear AWGN model which enables MIMO decoding at the receiver side.

C. Receiver

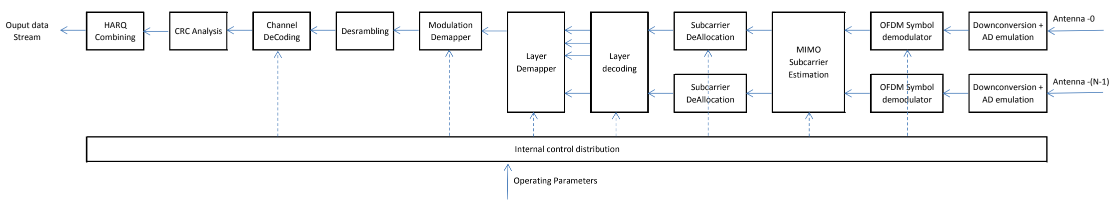

Fig. 6. LTE DL receiver

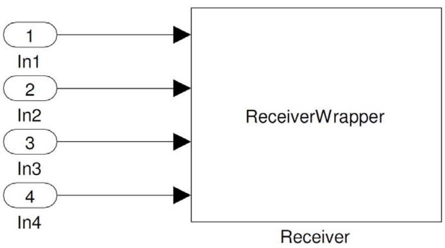

Fig. 7. LTE DL receiver (simulink).

The DL receiver is the transmitter counterpart. The following considerations have been taken into account on the OFDM demodulator:

The time synchronization is feed directly from the transmitter.

Frequency offset is considered as negligible.

A set of processing chains intended to deallocate the subcarriers from their assigned frame/subframe location, removing the reference signals and performing the subcarrier estimation accordingly with a maximum likelihood approach. It also covers OFDM demodulation, and the MIMO channel estimator that is in charge of separating the antenna transmissions whose linear combinations have been received at the receiver antennas. A layer de-mapper and a layer decoding matrix processing blocks recover the original subcarriers. MIMO decoding is performed here. A set of codeword processing chains, formed by modulation demapper, descrambler, channel decoding, CRC analysis, HARQ combining. Output data is the actual received bitstream.

III. Performance Results

The test methodology followed is fully based in the operation of the pattern generator + pattern error detector + simulation controller over the portion of the implementation, as described in Figure 1. It will allow a back-to-back oriented testing in the sense that it is ensured consistency between the DL transmitter and the DL receiver. Testing is always performed over portions of the implementation, under parametric control of the simulation controller, which it is used to set a desired test scenario.

The common simulation settings for the results present in the next section are summarized in Table 1. The SNR (that is the sum of the data subcarrier signal power divided by sum of the noise powers received on all data subcarriers). The results are provided for comparison to other stimulator and also to show that the stimulator is fully functional.

TABLE I: LTE DL Simulation Settings

Parameter	**Setting**
FrameStructureType	[1,2]
CyclicPrefixType	'extended','normal'
ModulationType	'QPSK', '16QAM', '64QAM'
ControlSymbolsNumber	[1:4] *(4 only for special cases: MBSFN or narrow system bandwidth)
DownlinkSystemBandwidth	System Bandwidth given as Number of resource Blocks [6, 25, 50, 75, 100]
VirtualResourceBlocks	[0: DownlinkSystemBandwidth-1]
VirtualResourceBlocksType	'localized'
LayerMappingMode	'Single Antenna', 'Spatial Multiplexing', 'Transmit Diversity'
PrecodingType	'Single Antenna', 'Spatial Multiplexing: zero delay', 'Spatial Multiplexing: large delay', 'Transmit diversity'
CodebookIndex	[0:3] - 2 antennas; [0:15] - 4 antennas

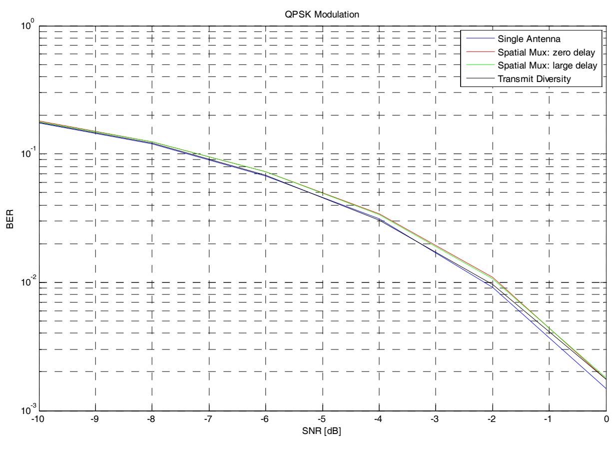

Fig. 8. BER for QPSK modulation

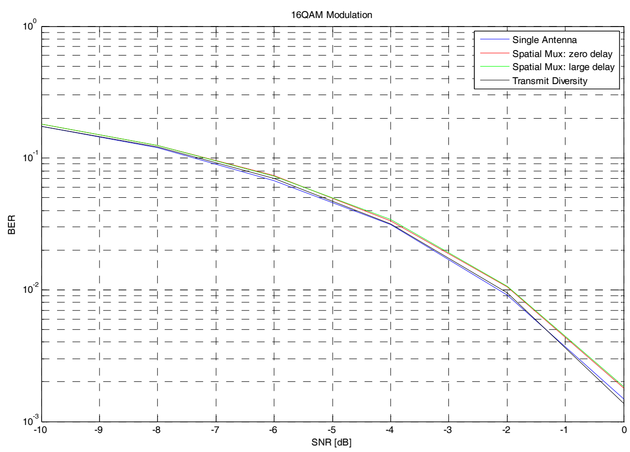

Fig. 9. BER for 16QAM modulation.

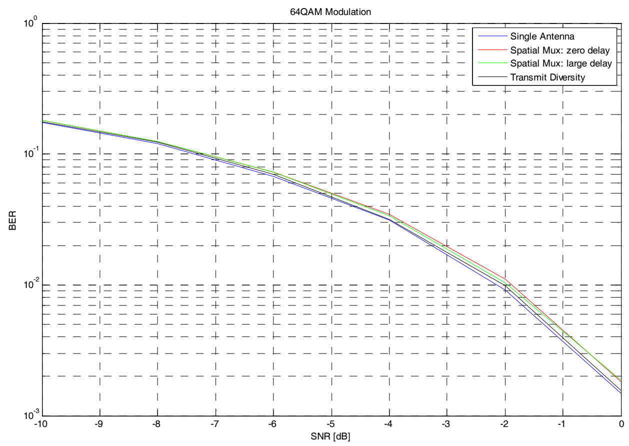

Fig. 10. BER for 64QAM modulation

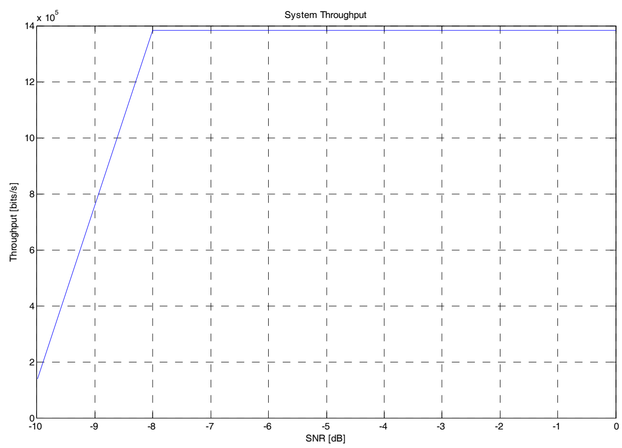

Fig.11. System throughput

The transmission of an OFDM signal requires also the transmission of a CP to avoid inter-symbol interference and the reference symbols for channel estimation. Note that the performance in the BER in the figure 3.1-3.3 looks very similar. The reason for the similar performance is that in an AWGN channel the switching between the modulation and coding schemes can be done perfectly and hardly any retransmissions are required.

IV. Conclusion

In this paper, we have given a brief description of 3GPP LTE downlink physical-layer simulation according to its specifications and details of our Matlab and Simulink-based simulator were presented. In the near future, we have planned to improve the simulator by implementing new features, such as more sophisticated channel and PHY models, which have not been included in the current model.

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