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Simulation Of A LTE Downlink Physical Layer Using MATLAB

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***Abstract*— Long-term evolution (LTE) represents an emerging and promising technology for providing broadband ubiquitous Internet access. In order to evaluate the performance of new mobile network technologies, system level simulations are crucial. For this reason, several research groups are trying to optimize its performance. In this paper, we introduce a Matlab based LTE downlink physical-layer simulator according to 3GPP specifications (Release 10) and other related proposals. The simulation is carried out for the single downlink, from one E-UTRAN (eNodeB) to one User Equipment (UE). Analysis of Bit Error Rate has been done for this system under different system settings.**

Keywords—**LTE; 4G; 3GPP; MIMO; OFDM**

I. Introduction

The Long Term Evolution (LTE) standard, specified by the 3rd Generation Partnership Project (3GPP) in Release 8, defines the next evolutionary step in 3G technology [1]. LTE offers significant improvements over previous technologies such as Universal Mobile Telecommunications System (UMTS) and High-Speed Packet Access (HSPA) by introducing a novel physical layer and reforming the core network. The main reasons for these changes in the Radio Access Network system design are the need to provide higher spectral efficiency, lower delay, and more multi-user flexibility than the currently deployed networks. In the development and standardization of LTE, as well as the implementation process of equipment manufacturers, simulations are necessary to test and optimize algorithms and procedures. This has to be performed on both, the physical layer (link-level) and in the network (system-level) context [2].

LTE is based mainly on three technologies, Turbo Coding which is used as the primary error detection and correction mechanism, Orthogonal Frequency Division Multiple Access (OFDMA) is used as the downlink scheduling scheme and OFDM along with Multiple Input and Multiple Output (MIMO) antennas are used to give enhanced data rates. These various aspects have been included in our Matlab based simulator for the physical layer of a LTE system to check its performance parameters.

II. SIMULATOR OVERVIEW

This section presents the scope of the paper and also describes in detail the structure of the simulator along with the requirements and some constraints on the implementation of the LTE system.

The implementation is based on LTE release 10 of the 3GPP specification. And the platform used is Matlab.

In the simulation data transmission between only one eNodeB and one user equipment is considered. The focus mainly being on the Physical Downlink Layer. Only PDSCH (Physical Downlink Shared Channels) are considered, control channels have not been considered. Only FDD(Frequency Division Duplex) is considered [3]. Thus this simulation mainly focuses on implementing the transmitter and receiver of a LTE system. The simulation is currently based on Matlab files and we plan to move this to a simulink work in the future. The implementation using Matlab helps understand and improve the algorithms employed at different areas of the system.

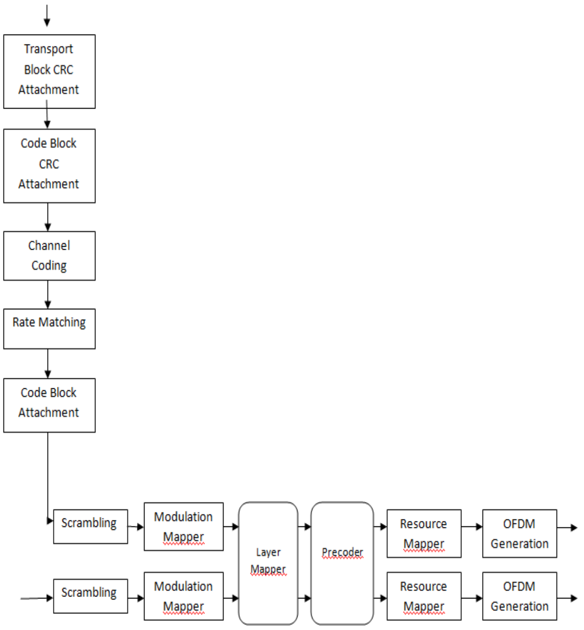

Fig 1 Physical Layer block Diagram

Fig 1 represents a block wise representation of the various steps involved in an LTE physical layer. The LTE PHY specification is designed to accommodate bandwidths from 1.25 MHz to 20 MHz. OFDM was selected as the basic modulation scheme because of its robustness in the presence of severe multipath fading. Downlink multiplexing is accomplished via OFDMA.
Firstly the input data sequence is scrambled and then undergoes channel encoding. Here the bit sequence is encoded using turbo encoder and then it is interleaved. All of this is done as per 3GPP Release 10 specifications. This data is then modulated according to a scheme which is most suitable for the current channel response. This mapping is done in the modulation mapper and the various schemes used are QPSK, QAM and MSK. Once done the data is divided into orthogonal carriers for OFDM transmission and the MIMO antennas are used to transmit this bit stream. MIMO combined with OFDM allows the LTE system to achieve a much greater transmission rate and robustness as compared to any other mobile communication technique.

A. Transmitter

The first section of transmission involves channel coding, multiplexing and interleaving [1].

The CRC code is generated using the generator polynomial,

$$g_{crc}(D) = D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^{7} + D^{6} + D^{5} + D^{4} + D^{3} + D + 1 \quad (1)$$

After CRC bits are added to the incoming bit stream the data undergoes channel coding. A turbo code as per 3GPP specifications has been used [4][5]. Turbo codes are parallel concatenated convolutional codes. The generator sequence is represented by the equation,

$$\mathrm{G(D)} = \left[1, \frac{\mathrm{g_1(D)}}{\mathrm{g_0(D)}}\right] \quad (2)$$

Where,

$$\mathrm{g_0(D)} = 1 + \mathrm{D}^2 + \mathrm{D}^3 \quad (3)$$

$$\mathrm{g_1(D)} = 1 + \mathrm{D} + \mathrm{D}^3 \quad (4)$$

The initial value of the shift registers of the 8-state constituent encoders shall be all zeros when starting to encode the input bits.

The turbo code inter leaver is used to interleave the coded data to add further resilience to the system. The bits input to the turbo code internal inter leaver are denoted by $c_0, c_{1,....,}c_{k-1}$, where *K* is the number of input bits. The bits output from the turbo code internal inter leaver are denoted as $c'_0, c'_1, \ldots, c'_{k-1}$.

The relationship between the input and output bits is as follows:

$$c'_i = c_{\pi(i)}, \ i=0, 1, \ldots, k-1 \quad (5)$$

The parameters f_1 and f_2 depend on the block size *K* and are summarized in Table 1.

i	K_i	f_1	f_2	i	K_i	f_1	f_2	i	K_i	f_1	f_2	i	K_i	f_1	f_2
1	40	3	10	**48**	416	25	52	**95**	1120	67	140	**142**	3200	111	240
2	48	7	12	**49**	424	51	106	**96**	1152	35	72	**143**	3264	443	204
3	56	19	42	**50**	432	47	72	**97**	1184	19	74	**144**	3328	51	104
4	64	7	16	**51**	440	91	110	**98**	1216	39	76	**145**	3392	51	212
5	72	7	18	**52**	448	29	168	**99**	1248	19	78	**146**	3456	451	192
6	80	11	20	**53**	456	29	114	**100**	1280	199	240	**147**	3520	257	220
7	88	5	22	**54**	464	247	58	**101**	1312	21	82	**148**	3584	57	336
8	96	11	24	**55**	472	29	118	**102**	1344	211	252	**149**	3648	313	228
9	104	7	26	**56**	480	89	180	**103**	1376	21	86	**150**	3712	271	232
10	112	41	84	**57**	488	91	122	**104**	1408	43	88	**151**	3776	179	236
11	120	103	90	**58**	496	157	62	**105**	1440	149	60	**152**	3840	331	120
12	128	15	32	**59**	504	55	84	**106**	1472	45	92	**153**	3904	363	244
13	136	9	34	**60**	512	31	64	**107**	1504	49	846	**154**	3968	375	248
14	144	17	108	**61**	528	17	66	**108**	1536	71	48	**155**	4032	127	168
15	152	9	38	**62**	544	35	68	**109**	1568	13	28	**156**	4096	31	64
16	160	21	120	**63**	560	227	420	**110**	1600	17	80	**157**	4160	33	130
17	168	101	84	**64**	576	65	96	**111**	1632	25	102	**158**	4224	43	264
18	176	21	44	**65**	592	19	74	**112**	1664	183	104	**159**	4288	33	134
19	184	57	46	**66**	608	37	76	**113**	1696	55	954	**160**	4352	477	408
20	192	23	48	**67**	624	41	234	**114**	1728	127	96	**161**	4416	35	138
21	200	13	50	**68**	640	39	80	**115**	1760	27	110	**162**	4480	233	280
22	208	27	52	**69**	656	185	82	**116**	1792	29	112	**163**	4544	357	142
23	216	11	36	**70**	672	43	252	**117**	1824	29	114	**164**	4608	337	480
24	224	27	56	**71**	688	21	86	**118**	1856	57	116	**165**	4672	37	146
25	232	85	58	**72**	704	155	44	**119**	1888	45	354	**166**	4736	71	444
26	240	29	60	**73**	720	79	120	**120**	1920	31	120	**167**	4800	71	120
27	248	33	62	**74**	736	139	92	**121**	1952	59	610	**168**	4864	37	152
28	256	15	32	**75**	752	23	94	**122**	1984	185	124	**169**	4928	39	462
29	264	17	198	**76**	768	217	48	**123**	2016	113	420	**170**	4992	127	234
30	272	33	68	**77**	784	25	98	**124**	2048	31	64	**171**	5056	39	158
31	280	103	210	**78**	800	17	80	**125**	2112	17	66	**172**	5120	39	80
32	288	19	36	**79**	816	127	102	**126**	2176	171	136	**173**	5184	31	96
33	296	19	74	**80**	832	25	52	**127**	2240	209	420	**174**	5248	113	902
34	304	37	76	**81**	848	239	106	**128**	2304	253	216	**175**	5312	41	166
35	312	19	78	**82**	864	17	48	**129**	2368	367	444	**176**	5376	251	336
36	320	21	120	**83**	880	137	110	**130**	2432	265	456	**177**	5440	43	170
37	328	21	82	**84**	896	215	112	**131**	2496	181	468	**178**	5504	21	86
38	336	115	84	**85**	912	29	114	**132**	2560	39	80	**179**	5568	43	174
39	344	193	86	**86**	928	15	58	**133**	2624	27	164	**180**	5632	45	176
40	352	21	44	**87**	944	147	118	**134**	2688	127	504	**181**	5696	45	178
41	360	133	90	**88**	960	29	60	**135**	2752	143	172	**182**	5760	161	120
42	368	81	46	**89**	976	59	122	**136**	2816	43	88	**183**	5824	89	182
43	376	45	94	**90**	992	65	124	**137**	2880	29	300	**184**	5888	323	184
44	384	23	48	**91**	1008	55	84	**138**	2944	45	92	**185**	5952	47	186
45	392	243	98	**92**	1024	31	64	**139**	3008	157	188	**186**	6016	23	94
46	400	151	40	**93**	1056	17	66	**140**	3072	47	96	**187**	6080	47	190
47	408	155	102	**94**	1088	171	204	**141**	3136	13	28	**188**	6144	263	480

Table 1

Depending on the channel conditions, QPSK, 16-QAM and 64-QAM modulation schemes are then used to modulate the signal. This signal is multiplexed using OFDM. A 2 X 2 MIMO antenna has been modeled for Transmission and reception [6].

B. Channel

An AWGN (Additive White Gaussian Noise) channel has been considered in the simulation.

C. Receiver

The UE receives the signal transmitted by the eNodeB and performs the reverse physical layer processing of the transmitter. The demodulation and soft decision decoding of the OFDM signal takes place [7]. The obtained output is then checked for error. The BER (Bit Error Rate) of the signal for varying values of Eb/N0 is calculated so as to estimate the performance of the system.

III. IMPLEMENTATION STATUS

Currently the simulation of the signal processing aspects of the physical downlink layer between one user equipment and a eNodeB has been completed with the above mentioned constraints. Desired levels of BER have been observed, demonstrating the robustness of a LTE system.

IV. RESULTS

The BER results for a LTE system was obtained as shown below in figure 2.

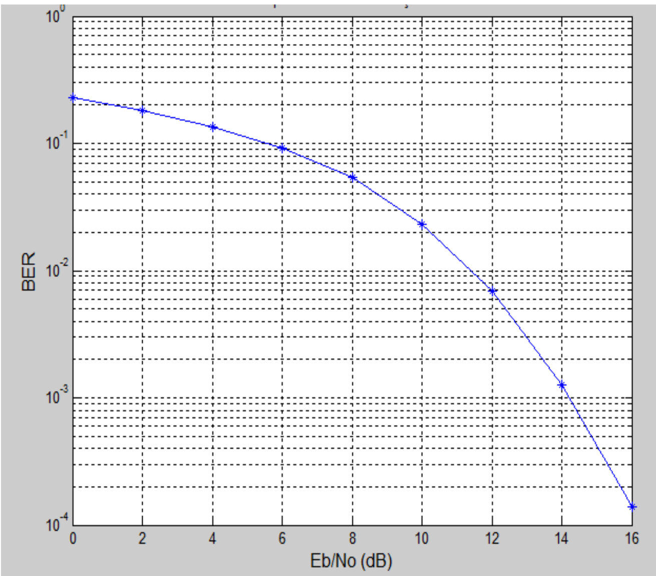

Figure 2: Results

By using a 4 X 2 or 4 x 4 MIMO antenna configuration and/or a more robust modulation scheme it is possible to further improve the performance of the system in terms of BER and ultimately the throughput while also saving on the transmission bandwidth.

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