Downlink SNR to CQI Mapping for Different Multiple Antenna Techniques in LTE

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Abstract—**Long Term Evolution (LTE) is a step towards the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile wireless access. In Release 8, LTE was standardized by 3GPP as the successor of the Universal Mobile Telecommunication System (UMTS).Before full commercial deployment of LTE, downlink SNR to CQI mapping for different multiple antenna techniques can be of enormous significance for the operators. Such vital RF parameters should be tuned before full-fledged commercial launch. In LTE, Adaptive Modulation and Coding (AMC) has to ensure a BLER value smaller than 10%. The SNR-to-CQI mapping is required to achieve this goal. In this paper, Downlink SNR to CQI Mapping for LTE has been performed for Flat Rayleigh channel in fast fading in different transmission modes considering HARQ.**

Index Terms—**BLER, CQI, LTE, Multi transmission, SNR.**

I. Introduction

LTE is the latest standard in the mobile network technology tree that previously realized the GSM/EDGE and UMTS/HSxPA technologies and these technologies now account for over 85% of all mobile subscribers. LTE will ensure 3GPP's competitive edge over other cellular technologies. 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 at fading subchannels. The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and RAN round-trip times of less than 10 ms. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time division duplexing (TDD) [1]-[3].

The main advantages with LTE are high throughput, low latency, plug and play, FDD and TDD in the same platform, an improved end-user experience and a simple architecture resulting in low operating costs. LTE will also support seamless passing to cell towers with older network technology such as GSM, cdmaOne, W-CDMA (UMTS), and CDMA2000. The next step for LTE evolution is LTE Advanced and is currently being standardized in 3GPP Release 10 [1] [2].

In [4] CQI to SNR mapping has been performed on AWGN channel for single antennas without any HARQ retransmissions. A more meticulous investigation is deemed justified where CQI to SNR mapping is determined for different multiple antenna techniques as well as for different HARQ retransmissions. Such investigation has been performed in this paper with Flat Rayleigh channel. It finds out appropriate threshold levels of SNR to report a particular CQI for 10% BLER.

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II. Channel Quality Indicator (CQI)

The UE sends CQI feedback as an indication of the data rate which can be supported by the downlink channel. This helps the eNodeB to select appropriate modulation scheme and code rate for downlink transmission.

The UE determines CQI to be reported based on measurements of the downlink reference signals. The UE determines CQI such that it corresponds to the highest Modulation and Coding Scheme (MCS) allowing the UE to decode the transport block with error rate probability not exceeding 10%.

TABLE I: Overview of Different CQI

CQI Index	Modulation	Code Rate X 1024	Efficiency
0	No transmission		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

The CQI report not only indicates the downlink channel quality but also takes the capabilities of the UE's receiver into account. A UE with receiver of better quality can report better CQI for the same downlink channel quality and thus can receive downlink data with higher MCS. Table I shows modulation scheme, code rate along with efficiency for various CQI index [5], [6].

The eNodeB may select Modulation and Coding Scheme (MCS) such that the modulation order and the transport block size correspond to a code rate which is the closest possible to

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the code rate indicated by the CQI index. If more than one combination of modulation order and the transport block size correspond to a code rate equally close to the code rate indicated by the CQI index, then the combination with the smallest of such transport block sizes may be selected.

III. Transmit Diversity And Spatial Multiplexing

Transmit diversity increases the signal to noise ratio at the receiver instead of directly increasing the data rate. Each transmit antenna transmits essentially the same stream of data and so the receiver gets replicas of the same signal. A suitable signal combining technique reduces fading variation and increases the signal to noise ratio at the receiver side. Thus, the robustness of data transmission is achieved especially in fading scenarios. An additional antenna-specific coding is applied to the signals before transmission to increase the diversity effect.

Transmit diversity is only defined for 2 and 4 transmit antennas and one data stream in LTE. Transmit diversity is applied using Space-Frequency Block Coding (SFBC) and Frequency Switched Transmit Diversity (FSTD).

Spatial multiplexing allows multiple antennas to transmit multiple independent streams and if the receiver also has multiple antennas, the streams can be separated out using space-time processing. Instead of increasing diversity, multiple antennas are here used to increase the data rate or the capacity of the system. Spatial multiplexing is used applying either Single User MIMO (SU-MIMO) or Multiple Users MIMO (MU-MIMO) mode.

In case of Open-loop Spatial Multiplexing, the feedback from the UE indicates only the rank of the channel using Rank Indication (RI) and not a preferred precoding matrix. A channel-independent fixed precoding with large delay Cyclic Delay Diversity (CDD) is used [6], [7].

IV. Transmission Modes For PDSCH

Physical Downlink Shared Channel (PDSCH) is used for downlink transmission of data. PDSCH is configured with one of the following transmission modes indicating a particular antenna technique. The choice of transmission mode may depend on the instantaneous radio channel conditions and may be adapted semi-statically [6].

1) Transmission Mode 1- Using of a single antenna at eNodeB
2) Transmission Mode 2- Transmit Diversity (TxD)
3) Transmission Mode 3- SU-MIMO Spatial Multiplexing: Open-Loop
4) Transmission Mode 4- SU-MIMO Spatial Multiplexing: Closed-Loop
5) Transmission Mode 5- MU-MIMO Spatial Multiplexing
6) Transmission Mode 6- Beamforming using Closed-Loop Rank-1 Precoding: It can also be seen as a special case of SU-MIMO Spatial Multiplexing.
7) Transmission Mode 7- Beamforming using UE-Specific Reference Signals

V. Overview of Simulation

For the simulation purpose and CQI to SNR mapping, transmission mode 1, 2 and 3 have been considered in this paper. Different parameters have been chosen for simulation as shown in Table II.

As shown, Flat Rayleigh channel is used with fast fading. 0 and 3 HARQ retransmissions were used for single antenna. For transmission mode 1, simulation has been performed over 2000 subframes; whereas for other modes, 1000 subframes were used in simulation scenario. The transmission setting 342 implies the use of transmission mode 3 with 4 transmitting antennas and 2 receiving antennas. The transmission settings, 111, 222, 322 and 342 were considered for simulation. In case of transmission mode 3; both 322 and 342 have been considered for simulation using [8]; which also plays a great role to show the effect of change in number of transmitting antennas.

TABLE II: Simulation Parameters

Parameters				
Channel	Fading Type	Sub frame	HARQ Re-tx.	Tx. Setting
Flat Rayleigh	Fast fading	2000	0	111
			3	111
		1000	0	222
				322
				342

VI. Simulation Results

For transmission mode 1, with transmission setting 111 both 0 and 3 HARQ retransmissions have been considered. For Transmission mode 2 and 3, with transmission settings 222, 322 and 342 respectively; only 0 HARQ retransmission has been considered.

The figures from 1 to 5 show Block Error Rate (BLER) vs. SNR (dB) plots for CQI value 7 (out of values from 1 to 15) in different transmission modes. Fig. 1 and 2 show BLER vs. SNR (dB) plot for transmission mode 1 at 0 and 3 HARQ retransmissions respectively.

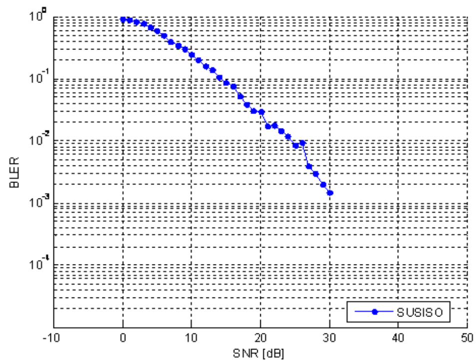

Fig. 1. Transmission mode 1 (0 re-tx)

Fig. 3, 4 and 5 show BLER vs. SNR (dB) plots for transmission modes 2 and 3 with transmission settings 222, 322 and 342 respectively.

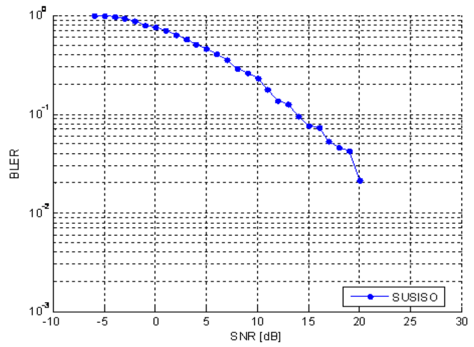

Fig. 2. Transmission mode 1 (3 re-tx)

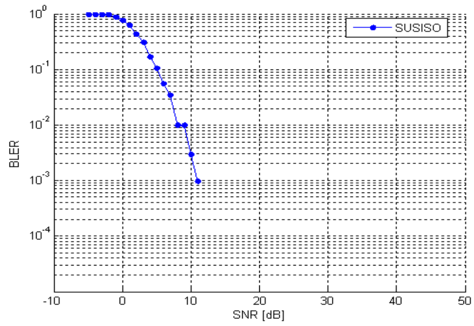

Fig. 3. Transmission mode 2 (222)

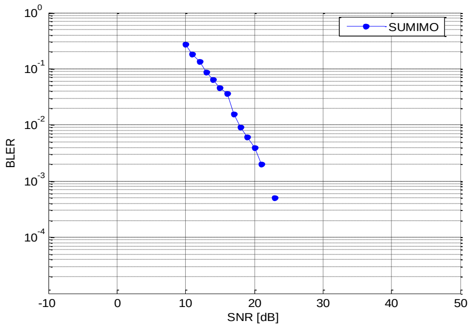

Fig. 4. Transmission mode 3 (322)

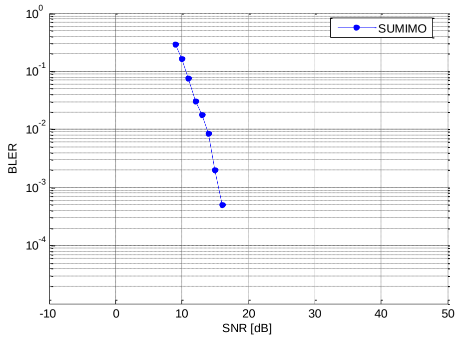

Fig. 5. Transmission mode 3 (342)

VII. CQI To SNR Mapping

From the BLER vs. SNR plot, SNR value for acceptable 10% BLER is taken for each CQI value ranging from 1 to 15. Thus, Table III is formed where for each CQI value from 1 to 15 noting SNR values that fulfill the underlying criterion of 10% BLER.

After plotting the values shown in Table III, the graph shown in Fig. 6 has been achieved. It gives a vivid comparison among the transmission modes for different CQI values in terms of SNR. Also, for the same transmission mode, the impact of increasing HARQ retransmissions is demonstrated.

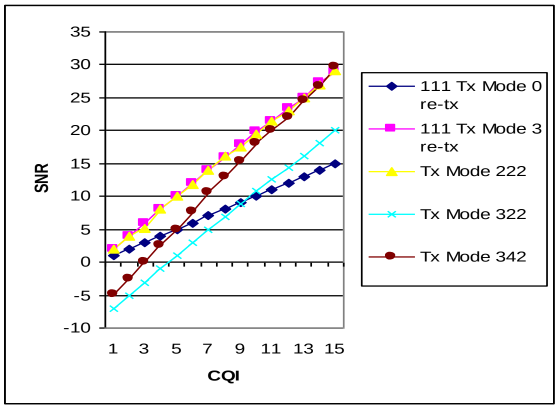

Fig. 6. SNR vs CQI for different Tx modes

TABLE III: Overall Comparison

CQI	SNR				
	Transmission Mode				
	111, 0 re-tx	111, 3 re-tx	222	322	342
1	1.95	2.00	-7.00	-3.10	-4.80
2	4.00	4.05	-5.00	-1.15	-2.60
3	6.00	5.10	-3.15	1.50	0.00
4	8.00	8.00	-1.00	4.00	2.60
5	10.00	10.00	1.00	6.00	4.95
6	11.95	11.80	3.00	8.90	7.60
7	14.05	13.90	5.00	12.70	10.60
8	16.00	16.10	6.90	14.90	12.95
9	17.90	17.45	8.90	17.50	15.40
10	19.90	19.50	10.85	20.50	18.10
11	21.50	21.50	12.60	22.45	20.05
12	23.45	23.10	14.35	23.20	22.00
13	25.00	24.90	16.15	24.90	24.55
14	27.30	27.00	18.15	27.00	26.80
15	29.00	29.10	20.00	29.10	29.60

VIII. Result Analysis

Using the obtained result, an effective SNR can be mapped to a CQI value that is signaled to the eNodeB for Flat Rayleigh channel in different transmission modes.

For the same transmission mode 1, it is demonstrated that 3 HARQ retransmissions improve BLER and thus, usually a lower SNR value led to 10% BLER compared to 0 retransmission. For the same transmission mode 3, the increase in number of Tx antenna also improves BLER significantly. As a result, the SNR value corresponding to 10% BLER decreases for the same CQI when the number of transmitting antenna is increased from 2 to 4.

Transmit diversity increases the effective signal to noise ratio at the receiver because the receiver gets replicas of the same signal [7]. As a result, the SNR values corresponding to 10% BLER were very low for transmission mode 2.

IX. Conclusion

The UE sends CQI feedback to indicate the data rate which can be supported by the downlink channel and this helps the eNodeB to select appropriate MCS level. Thus, based on the downlink SNR, the UE needs to determine CQI such that it corresponds to the highest Modulation and Coding Scheme (MCS) which leads a BLER not exceeding 10%. The UE needs to have proper estimate of the downlink SNR that would cause BLER close to 10%. Such an estimate is affected by different multiple antenna techniques and number of HARQ retransmissions. The simulation results shown in this paper for CQI to SNR mapping with different multiple antenna techniques and HARQ retransmissions can provide a reliable estimate and thus, it can significantly assist in successful commercial deployment of LTE.

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