UDC 621.396.946.2

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# SNR EFFECT ON CQI APPLYING MULTIPLE ANTENNAS IN CLOSED LOOP SPATIAL MULTIPLEXING MODE IN LTE TECHNOLOGIES

**Хайдер Аль-Заяді, Муштак Аль-Шурайфі, Таліб Аль-Шаріфі. Вплив SNR на CQI за умови роботи багатоелементних антен в режимі замкненого петльового просторового мультиплексування в LTE технологіях.** У статті розглянуто вплив SNR на CQI та його відображення за умови роботи багатоелементних антен в різних режимах замкненого петльового просторового мультиплексування (режим передачі 4) в LTE технологіях. Враховано, що в LTE технологіях адаптивна модуляція та кодування (AMC) мають забезпечувати значення BLER не більше ніж 10%. Для досягнення цієї мети необхідно відображувати вплив SNR на CQI та детально розглядати його. Проведено дослідження впливу SNR на CQI та його відображення для релеївського каналу з рівномірною частотною характеристикою в "режимі передачі 4" із швидким затуханням за умови замкненого петльового просторового мультиплексування. Розроблені та проаналізовані моделі каналів Ped A та Ped B в режимі передачі згідно з умовами моделювання.

***Ключові слова:*** SNR, CQI, LTE технології, BLER, CLSM, мультиплексування, передача

**Хайдер Аль-Заяди, Муштак Аль-Шурайфи, Талиб Аль-Шарифи. Влияние SNR на CQI при работе многоэлементных антенн в режиме замкнутого петлевого пространственного мультиплексирования в LTE технологиях.** В статье рассмотрено влияние SNR на CQI и изображение этого влияния при работе многоэлементных антенн в разных режимах замкнутого петлевого пространственного мультиплексирования (режим передачи 4) в LTE технологиях. Учтено, что в LTE технологиях адаптивная модуляция и кодирование (AMC) должны обеспечивать значение BLER не более чем 10%. Для достижения этой цели необходимо отражать влияние SNR на CQI и тщательно исследовать его. Проведено исследование влияния SNR на CQI и его отображение для релеевского канала с равномерной частотной характеристикой в "режиме передачи 4" с быстрым затуханием в условиях замкнутого петлевого пространственного мультиплексирования. Разработаны и проанализированы модели каналов Ped A и Ped B в режиме передачи в соответствии с условиями моделирования.

***Ключевые слова:*** SNR, CQI, LTE технологии, BLER, CLSM, мультиплексирование, передача

**Al-Zayadi Haider, Al-Shuraifi Mushtaq, Al-Sharify Talib. SNR effect on CQI applying multiple antennas in closed loop spatial multiplexing mode in LTE technologies.** The article deals with the influence of SNR to CQI mapping for multiple antennas in mode of closed loop spatial multiplexing (transmission mode 4) in LTE technologies. It has been considered, that in LTE technologies adaptive modulation and coding (AMC) have to ensure a block error rate (BLER) value for no more than 10%. To achieve this goal the SNR-to-CQI mapping is required. SNR to CQI mapping for flat Rayleigh channel in fast fading using transmission mode, which represents closed loop spatial multiplexing (CLSM), has been performed. Pedestrian A (Ped A) channel and pedestrian B (Ped B) channel models in terms of "transmission mode 4", that we used according to simulation, have been analyzed.

***Key words***: SNR, CQI, LTE technologies, BLER, CLSM, multiplexing, transmission

**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 sub-channels. 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]. 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, CDMA 1, W-CDMA (UMTS), and CDMA2000. The next step for LTE evolution is LTE Advanced and is currently being standardized in 3GPP Release 10 [2]. In [3] 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 SNR to CQI 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.

**II. Methods of channel quality with feedback.** In order to improve spectral efficiency and low transmission errors, scheduling is performed adapting the modulation and coding scheme of the transmission to the channel state between the eNodeB and UE. In downlink such information is not directly accessible by the eNodeB, so the UE must deliver a channel quality indicator (CQI) that consist of the highest MCS index that it can decode with a block error rate below say, 10%. This index is the result of measurements based on signal to interference-plus-noise ratio (SINR) estimated by listening to some reference symbols. To achieve maximum frequency diversity gains in DL, each UE should estimate the channel quality per PRB, across the whole bandwidth. However a signaling policy like that, especially with VoIP traffic where an high number of UE can be scheduled together, can lead to serious issues with the control channel capacity due the amount of UL control channels overhead that can reach 8% for 10MHz [4]. Hence, it is mandatory to reduce the channel quality feedback in time or frequency domains. The time domain reduction depends on the speed of the UE [5]. A simple method to reduce the control overhead in frequency domain is to set a rougher granularity of the estimation. The frequency resolution of the measurements is controlled by the eNodeB defining the number of contiguous physical resource blocks (PRBs) [6] to estimate. The main frequency selective schemes are:

• *Wideband Feedback*: only a single CQI value is sent for the whole system bandwidth [4]. This modality allows a reduction of the number of bits to report the channel condition, and therefore the signaling overhead, but at the same time reduces the user frequency selectiveness to zero.

• *Best-M Average*: the UE estimates the channel quality of small groups of PRBs and reports only a single value corresponding to an average of the M best ones. In this case the overhead depends on the number of selected PRBs which clearly in Table 1.

**Parameters of the CQI report for UE-selected sub-bands feedback** **Table 1**

| System bandwidth (RBs) | Sub-band Size K (RBs) | Number of preferred sub-band (M) |
|---|---|---|
| 6-7 | Wideband CQI Only | Wideband CQI Only |
| 8-10 | 2 | 1 |
| 11-26 | 2 | 3 |
| 27-63 | 3 | 5 |
| 64-110 | 4 | 6 |

• *Full CQI reporting*: the UE reports the channel quality of small groups of PRBs [7] increasing the frequency selectiveness accuracy but at the same time the signaling overhead. All methods above clearly in Fig. 1.

It is possible to note that an important aspect of CQI reporting consists of the uplink resource usage and optimization in terms of signaling overhead. For this reason the eNodeB can select the periodicity of each UE CQI report, according with the network condition, choosing between periodic or aperiodic report [4]:

• *Periodic CQI reporting*: the eNodeB requires the CQI feedback on the PUCCH in pre-defined time instant. The period can be set to 2, 5, 10, 16, 20, 32, 40, 64, 80, 160 ms or Off [6] and is configured via higher layer signaling. The size of a single report allows containing only little information about the frequency channel state [4].

• *Aperiodic CQI reporting*: the eNodeB can instruct the UE to send an individual CQI report [4] on the PUSCH when it needs precise channel state information.

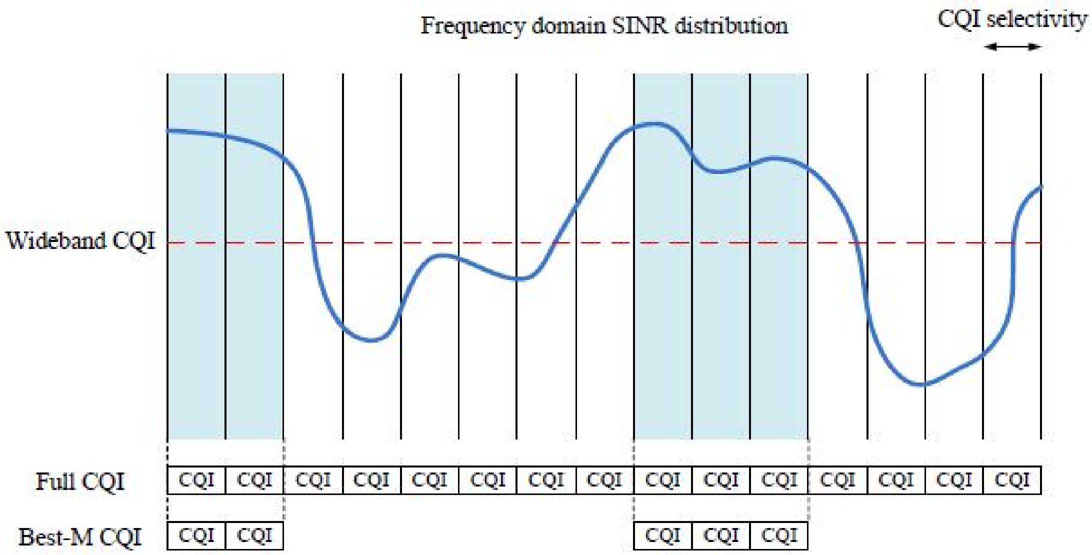


Fig. 1: Illustration of the three CQI reporting methods

In uplink the channel quality is estimated by the eNodeB requiring sounding reference signals (SRS) from the UE. SRS can be considered a counterpart for the CQI reporting but does not contain any type of feedback information like the CQI. SRS is transmitted on the last symbol of the subframe on PUSCH as a single or periodic transmission, with period from 2 to 320 ms [4]. To provide flexibility, it is possible to choose different bandwidth options according with the UE power characteristics. The configuration parameters are sent via higher layer signaling.

**III. LA and MCS.** In general, in any cellular communication systems, the quality of the received signal is compromised by different phenomena inherent to wireless environments, like path loss, interferences, multipath propagation phenomenon. The objective of Link Adaptation (LA) is to adapt the resource allocation to the user channel condition, matching the transmission parameters such as modulation and coding scheme (MCS), pre-coding as well as transmission power control for physical channels [8], in order to avoid strong variations in the quality of received signal, to guarantee the required quality of service of each UE. In the downlink transmissions, the eNodeB does not know the actual channel conditions of the UE, and for this reason, it can require a Channel Quality Indicator (CQI) feedback from the receiver to be assisted in selecting an appropriate MCS. The modulation scheme chosen for LTE consists in different-order QAM. In general, the eNodeB can select QPSK, 16-QAM and 64-QAM schemes and different code rates [6] to achieve a trade-off between high data throughput and low block error rate (BLER)which clearly in Table 2.

Choosing a low-order modulation, the eNodeB guarantees a more robust transmission but a lower bit rate. Contrary, choosing high-order modulation the eNodeB allows higher data rate but lower robustness. The code rate adapts the chosen modulation scheme to the channel conditions in order to increase transmission reliability. For uplink transmissions, the eNodeB handles the link adaptation in the same way of the downlink case, but instead of requiring CQI feedback, it can self-estimate the supportable uplink data rate using Sounding Reference Signals (SRSs) or base it on the past measured SINR. QPSK and 16-QAM can be selected as modulation schemes and, for highest category of UE, also 64-QAM [6].

**Type of modulation and code rate for each CQIs Table 2**

| CQI | Mode | Rate (x1024) | Rate (1/2) |
|---|---|---|---|
| 1 | QPSK | 78 | 13.13 |
| 2 | QPSK | 120 | 8.53 |
| 3 | QPSK | 193 | 5.31 |
| 4 | QPSK | 308 | 3.32 |
| 5 | QPSK | 449 | 2.28 |
| 6 | QPSK | 602 | 1.70 |
| 7 | 16QAM | 378 | 2.71 |
| 8 | 16QAM | 490 | 2.09 |
| 9 | 16QAM | 616 | 1.66 |
| 10 | 64QAM | 466 | 2.20 |
| 11 | 64QAM | 567 | 1.81 |
| 12 | 64QAM | 666 | 1.54 |
| 13 | 64QAM | 772 | 1.33 |
| 14 | 64QAM | 873 | 1.17 |
| 15 | 64QAM | 948 | 1.08 |

**IV. Input parameters.** According to parameters below (Table 3) using simulation program name Vienna LTE Simulators System Level Simulator we Gate our results which appeared in Fig. 2, 3 and 4 below.

**Input parameters** **Table 3**

| | | | | |
|---|---|---|---|---|
| frequency: | 2.1400e+09 | | r_eNodeBs: | 0.5000 |
| bandwidth: | 20000000 | | channel_model: | [1x1 struct] |
| nTX: | 2 | | UE: | [1x1 struct] |
| nRX: | 2 | | UE_distribution: | constant UEs per cell |
| tx_mode: | 4 (CLSM) | | UE_per_eNodeB: | 20 |
| always_on: | 1 | | UE_speed: | 1.3889 |
| simulation_time_tti: | 100 | | antenna: | [1x1 struct] |
| ache_network: | 1 | | site_altiude: | 0 |
| network_cache: | 'auto' | | site_height: | 20 |
| UE_cache_file: | 'auto' | | rx_height: | 1.5000 |
| network_source: | 'generated' | | scheduler: | 'round robin' |
| inter_eNodeB_distance: | 500 | | scheduler_params: | [1x1 struct] |
| minimum_coupling_loss: | 70 | | power_allocation: | Homogeneous |
| macroscopic_pathloss_model: | 'TS36942' | | CQI_mapper: | [1x1 struct] |
| eNodeB_tx_power: | 4 | | feedback_channel_delay: | 3 |
| shadow_fading_map_resolution: | 5 | | SINR_averaging: | [1x1 struct] |
| shadow_fading_n_neighbors: | 8 | | antenna_azimuth_offsett: | 30 |
| shadow_fading_sd: | 10 | | | |

**V. Simulation & result.** To obtain the Block Error Ratio (BLER) and through- put for the Modulation and Coding Scheme (MCS) corresponding to each CQI value, AWGN simulations were performed. The MCS determines both the modulation alphabet and the Effective Code Rate (ECR) of the channel encoder. Fig. 2 shows the BLER results of CQIs 1-15 without using HARQ. Each curve is spaced approximately 2 dB from each other. We set the CQI to a fixed value of three and the maximum number of HARQ retransmissions to, BLER curves as shown in Fig. 3 are obtained .

In LTE, adaptive modulation and coding has to ensure a BLER value smaller than 10 %. The SINR-to- CQI mapping required to achieve this goal can thus be obtained by plotting the 10% BLER values of the curves in Fig. 2 over SNR, like it is shown in Figure 4. Using the obtained line, an effective SINR can be mapped to a CQI value that is signaled to the eNodeB. Besides the CQI mapping on the physical layer, to obtain the error probability of a received block as a function of the SINR and the MCS. When working with frequency- selective channels, an SINR averaging algorithm is required in order to compress the subcarrier SINR values into an effective SINR which is subsequently mapped to a CQI. Non-linear averaging methods such as the Ex- potential Effective SINR Mapping (EESM) [9, 10, 11] are usually employed to perform this compression.

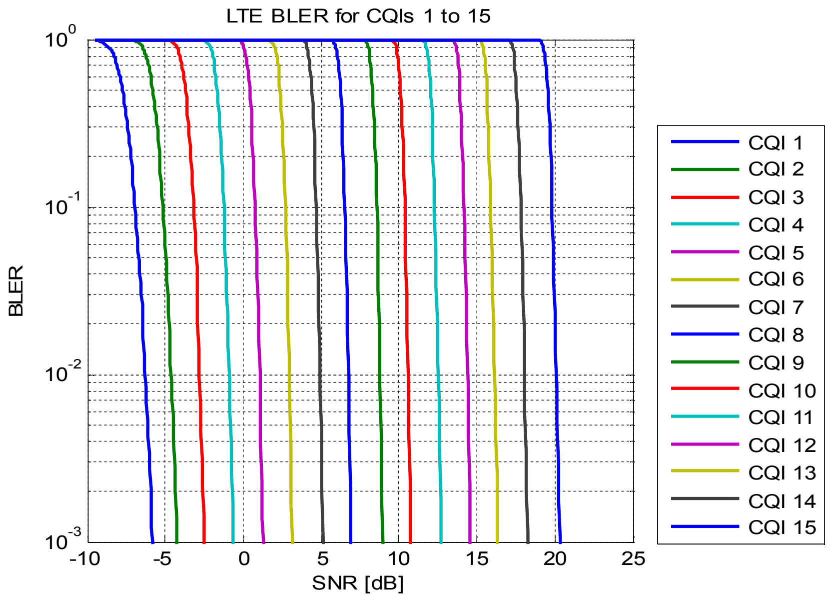


Fig. 2. BLER curves obtained using AWGN for all 15 CQI values.
From CQI 1 (leftmost) to CQI 15 (right most)

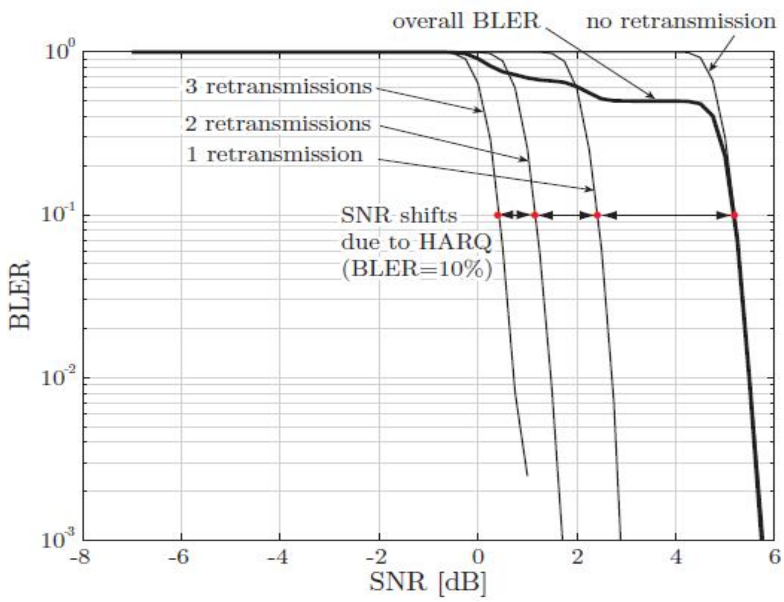


Fig. 3. Resulting BLER at CQI=7 for different number of allowed retransmissions

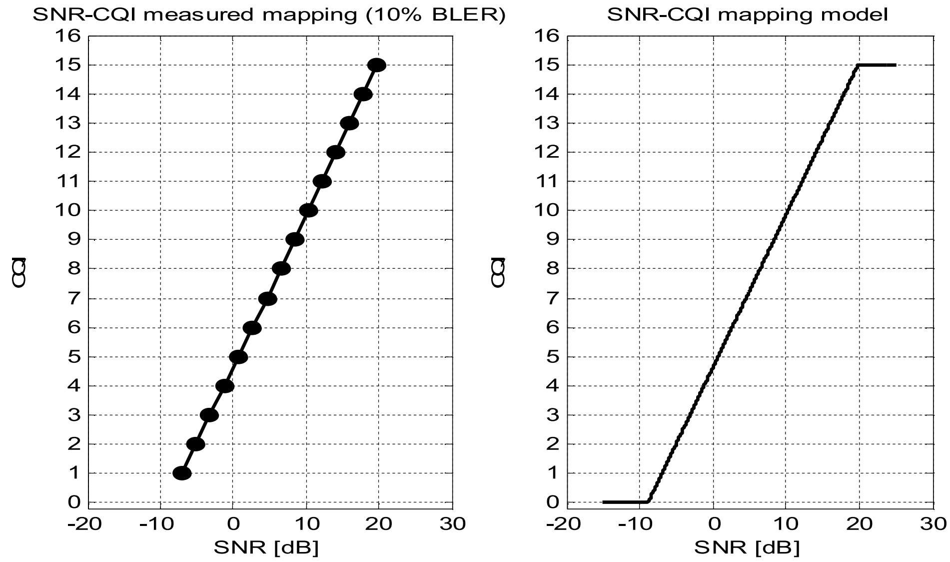


Fig. 4. CQI mapping. BLER=10% points from the BLER curves (left) and SINR-to-CQI mapping function (right)

## Conclusion

This paper presented effective CQI on channel using AWGN and steady many CQIs index for each one according to MCS and how to effective on BLER in the network. Presented steady to Besides the CQI mapping on the physical layer, to obtain the error probability of a received block as a function of the SINR and the MCS. We steady that in LTE, has to ensure a BLER value smaller than 10 % to get best adaptive modulation and coding (MCS).

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