Enhancement LTE-A Using MIMO Technology

Hussein Ali Rasool
Information and Communication Engineering
Al-Nahrain University ,NAJAF, Iraq

Abstract—**MIMO is one of the techniques proposed to 3G and 4G LTE-A systems for its added benefits of higher data rates and low bit error rates. The gist of MIMO working is its ability to increase number of channels; thus increasing diversity gain. Correspondingly, more users are accommodated in one communication system. In this work, different MIMO schemes, performance of various Bandwidth, MU-MIMO scheme , impact of HARQ signaling errors caused by unreliable feedback on the throughput of communication systems like LTE and Channel Quality Indicator (CQI) and Precoding feedback are investigated using MATLAB simulation .**

Keywords–*LTE-A; MIMO; CQI; HARQ; Precoding*

I. INTRODUCTION

With the growing application for of wireless services, and the capacity of 2G networks and 3G is reaching saturation point. Long Term Evolution-Advanced (LTE-A) is a technological advancement proposed by the Third Generation Partnership Project (3GPP) to meet the requirements of Fourth Generation (4G) mobile broadband system with a powerful service carrying capacity and the efficiency of resource use, and lower cost of network construction and operation, and flexible network deployment .

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 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 (RAN) system design are the need to provide higher spectral efficiency, lower delay, and more multi-user flexibility than the currently deployed networks. 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].

In our work we focus on the downlink of Long Term Evolution (LTE). In this system the time-frequency grid (resource grid [2]) spanned by OFDM is divided into several Resource Blocks (RBs). User Equipment (UE) resource allocation is carried out on a Resource Block (RB) or a subband basis (each subband consists of several contiguous RBs). Sophisticated scheduling requires the UEs to feed back for each RB (or subband) the supported Channel Quality Indicator (CQI) value, corresponding to a specific code rate – modulation order combination [4]. The standard specifies different feedback granularity possibilities, ranging from wideband (just a single CQI value for all considered RBs) to bestM feedback (a distinct CQI value for the M best RBs). For our simulations we consider distinct CQI values for every RB. we proposed a link adaption (CQI) feedback scheme based on Mutual Information Effective SNR Mapping (MIESM). MIESM is a well know technique from link level abstraction.

This paper is organized as follows: in Section II we describe the overall structure of the LTE-A system. In Section III we show how the physical layer Modeling of MIMO Fading Channel. Afterwards, we present CQI feedback in Section IV, Section V presents the PMI feedback and Section VI presents Hybrid ARQ as well as some conclusions.

II. SYSTEM MODEL

LTE converts a frequency selective channel into a number of narrowband frequency flat channels, by adopting OFDM. The input-output relation on subcarrier k, assuming MR receive and NT transmit antennas, at sampling time instant n is given by

$$\mathrm{y}_{k,n} = \mathrm{H}_{k,n}\mathrm{W}_i\mathrm{x}_{k,n} + \mathrm{n}_{k,n}, k \in 1,...K, n \in 1,...N. \quad (1)$$

$y_{k,n} \in \mathbb{C}^{MR\times 1}$ is the received symbol vector, $H_{k,n} \in \mathbb{C}^{MR\times NT}$ is the channel matrix experienced on subcarrier k at time instant n, $X_{k,n} \in A^{L\times 1}$ is the transmit symbol vector with A being the utilized symbol alphabet and $n_{k,n} \sim \mathcal{CN}(0, \sigma_n^2 \cdot I)$ is white, complex-valued Gaussian noise with variance σ_n^2 . The channel matrix and noise variance are assumed to be known by the receiver. The dimension of the transmit symbol vector depends on the number of useful spatial transmission layers L. Spatial preprocessing is carried out with the precoding $W_i \in \mathcal{W}$.

Here i denotes the index within the codebook of precoding matrices W, defined in [3]. Depending on the feedback granularity, the precoder Wi will be either constant over only one RB or over the total system bandwidth and subframe duration.

LTE radio resources are structured in slots of length *Tslot* = 0.5 ms. The Transmission Time Interval (TTI) is set to 1 ms, thus containing 2 slots. Each slot can be seen as a time-frequency resource grid composed by several OFDM symbols. Each slot is divided into a number of Physical Resource Blocks (PRBs), each of them consisting of 12 consecutive sub-carriers along 7 consecutive OFDM symbols. Assuming a system bandwidth *BW* = 20 MHz, a total of 1200 data subcarriers (i.e. 100 PRBs) is available for transmission.

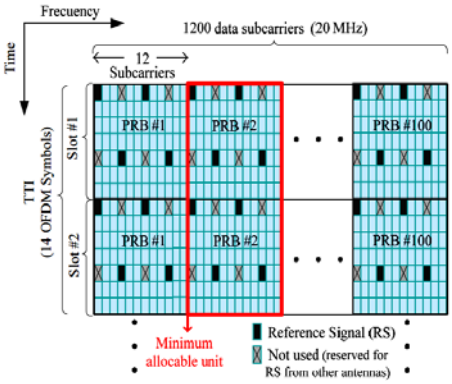

FIGURE 1. LTE PHYSICAL RESOURCES STRUCTURE

For standard LTE, an RB comprises 12 subcarriers at a 15 kHz spacing, and for eMBMS with the optional 7.5 kHz subcarrier spacing an RB comprises 24 subcarriers for 0.5 ms. The maximum number of RBs supported by each transmission bandwidth is given in Table 1

TABLE 1. LTE BANDWIDTH AND RESOURCE CONFIGURATION

Channel bandwidth BWChannel [MHz]	1.4	3	5	10	15	20
Number of Resource Blocks (N_{RB})	6	15	25	50	75	100
Number of occupied subcarriers	72	180	300	600	900	1200
IFFF/FFT Size	128	256	512	1024	1536	2048
Subcarrier Spacing	15kHz / 7.5 kHz					

The modulation schemes supported in the LTE DL and UL over each subcarrier are QPSK, 16QAM and 64QAM. LTE applies Adaptive Modulation and Coding (AMC) and variable coding rates inside each subcarrier combined to the retransmission protocol H-ARQ (Hybrid Automatic Repeat Request).

The channel coding scheme for transport blocks in LTE is Turbo Coding with a coding rate of R=1/3, two 8-state constituent encoders and a contention-free quadratic permutation polynomial (QPP) turbo code internal interleaver. Trellis termination is used for the turbo coding. Before the turbo coding, transport blocks are segmented into byte aligned segments with a maximum information block size of 6144 bits. Error detection is supported by the use of 24 bit CRC.

The linear receiver is typically chosen according to a zero forcing orminimum mean square error design criterion [3]. The input signal vector is normalized to unit power.

III. MODELING OF MIMO FADING CHANNEL

For a MIMO communication system, shown in Figure (2), with *MT* transmit and *MR* receive antennas, each of the receive antennas detects all of the transmitted signals. This allows the SISO channel to be represented as a *MT*×*MR* matrix For frequency-flat fading over the bandwidth of interest, the *MT*×*MR* MIMO channel matrix at a given time instant may be represented as [4]:

$$H = \begin{bmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,M_T} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,M_T} \\ \vdots & \vdots & \ddots & \vdots \\ h_{M_R,1} & h_{M_R,2} & \cdots & h_{M_R,M_T} \end{bmatrix} \tag{2}$$

Where is $h_{i,j}$ the SISO channel gain between the i^{th} receive and j^{th} transmit antenna pair. the i^{th} column of column of *H* is often referred to as the spatial signature of the j^{th} transmit antenna across the receive. antenna array. as As t for the case of SISO channels, the individual channel gains comprising the MIMO channel are commonly modeled as zero-mean AWGN. Consequently, the amplitudes of $h_{i,j}$ are Rayleigh distributed random variables. Hence, the received signal can be represented as in the following equation .

$$y = \sqrt{\frac{E_s}{M_T}} Hs + z \tag{3}$$

Where *y* is the *MR*×1 received signal vector, *s* is the *MT*×1 transmitted signal vector, is the AWGN, and the factor √ ensures that the total transmitted energy is *Es*. The MIMO channel in Figure (2) is assumed to be a rich scattering environment. Each transmit receive antenna pair can be treated as parallel sub channels (i.e., SISO channel). Since the data is being transmitted over parallel channels, one channel for each antenna pair, the channel capacity increases in proportion to the number of transmits-receive pairs [4].

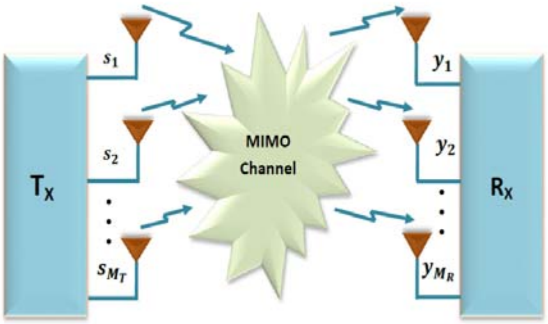

FIGURE 2. BLOCK DIAGRAM OF A MIMO SYSTEM WITH *MT* TRANSMIT ANTENNAS AND *MR* RECEIVE ANTENNAS

IV. CQI FEEDBACK

LTE uses the same modulation order and code rate (corresponding to a CQI value) for all resources allocated to a UE. Nevertheless, RB dependent CQI feedback is supported to give the scheduler the opportunity to schedule users on favorable resources. There are transmissions modes defined in [5] that allow for independent codeword's per spatial layer, but also for a single codeword for several layers. All these possibilities must be captured by a reasonable feedback strategy.

Our feedback strategy is based on averaging the post equalization SINR over all resources of interest. This can include SINRs corresponding to single or multiple RBs per layer but also to RBs of different layers.

In our work we have considered the EESM and MIESM methods. Mathematically the mapping is given by:

$$\mathrm{SNR_{eff}} = \beta f^{-1}\left(\frac{1}{R}\sum_{r=1}^{R} f\left(\frac{\mathrm{SINR}_r}{\beta}\right)\right), \qquad (4)$$

Where R corresponds to the number of resources of interest. For EESM the function f corresponds to an exponential, for MIESM it is given by the Bit Interleaved Coded Modulation (BICM) capacity [6]. Both methods require the calibration of the CQI dependent _ value that adjusts the mapping to the different code rates and modulation alphabets.

V. PMI FEEDBACK

The basic idea is to choose the precoder that maximizes the mutual information for a specific subcarrier- (1 . . .K) and temporal-range (1 . . .N) of interest (which is at least a single RB and can be up to the full system bandwidth and subframe duration). Denoting Ik,n the mutual information of the resource element (k, n) we obtain :

$$\mathbf{W}_j = \arg\max_{\mathbf{W}_i \in \mathcal{W}} \sum_{k=1}^{K}\sum_{n=1}^{N} I_{k,n}(\mathbf{W}_i) \qquad (5)$$

Therefore we will now use the post-equalization mutual information which is given in terms of the post-equalization SINRk,n,l as

$$I_{k,n} = \sum_{l=1}^{L} \log_2(1 + \mathrm{SINR}_{k,n,l}) \qquad (6)$$

In bits per channel use, with L denoting the number of spatial transmission layers.

The feedback strategy for the PMI values involves two steps (assuming different PMIs on every RB):

1) Calculate the post-equalization mutual information (6) for all possible preorders from WL .
2) Find the combination of precoders that maximizes the sum mutual information over all resource blocks. The PMIs by the codebook indices of the preorders.

Hence, the UE has to report the eNodeB with this channel feedback, which the eNodeB will use as extra information, the final AMC does not need to follow the configuration in the table. In LTE the channel feedback reporting is always fully controlled by the eNodeB and the UE cannot send any channel state feedback reports without eNodeB knowing it beforehand. A simple representation of this communication is done in figure 3

.

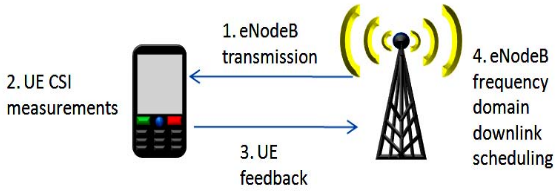

FIGURE 3.CHANNEL STATE INFORMATION (CSI) REPORTING PROCEDURE

VI. HYBRID ARQ

The usual approach to handle transmissions errors is to use Automatic Repeat Request (ARQ). In an ARQ scheme the receiver uses an error-detecting code, typically a Cyclic Redundancy Check (CRC), to detect if the received packet is in error or not. If no error is detected in the received data packet, the received data is declared error-free and the transmitter is notified by sending a positive acknowledgment (ACK). On the other hand, if an error is detected, the receiver discards the received data and notifies the transmitter via a return channel by sending a negative acknowledgment (NAK). In response to a NAK, the transmitter retransmits the same information.

In a physical layer HARQ operation the receiver also stores the packets with failed CRC checks and combines the received packet when a retransmission is received. The HARQ operation in LTE supports both soft combining and the use of incremental redundancy [7]. The use of soft combining means that retransmission has exactly the same rate matching parameters as the original transmission and thus exactly the same symbols are transmitted. For incremental redundancy, the retransmission may have different rate matching parameters like the original transmission.

VII. SIMULATION RESULTS

A. This section presents simulation results obtained with a standard compliant LTE-A physical layer.

TABLE 2. SIMULATION OF DIFFERENT BANDWITH

Parameter	Value
Number of UEs	1
HARQ Retransmissions	0
Channel type	flat Rayleigh uncorrelated
Filtering	Block Fading
Receiver type	Soft Sphere Decoder
Simulation length	2000
Transmit modes	2 transmit, 2 receive (2 × 2)

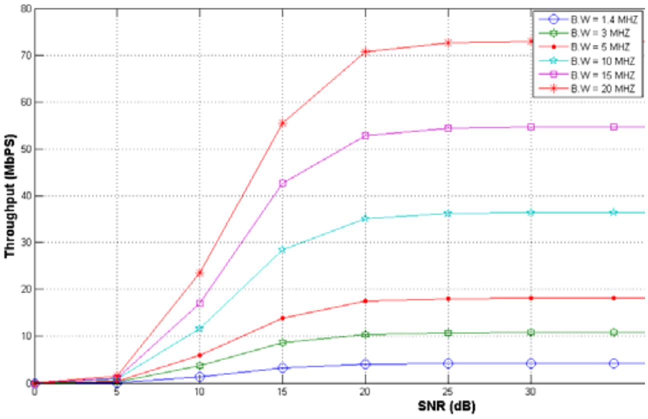

FIGURE 4.SIMULATION OF DIFFERENT BANDWIDTH

B. In this part , many types of Multiantenna techniques will be introduced, at MIMO techniques, Zero Forcing (ZF), Minimum-Mean-Squared-Error (MMSE), Soft Sphere Decoder Code (SSD) .

B.1 *Zero Forcing*

The most simple, but also the least efficient decoding technique is matrix inversion. As matrix inversion exists only for square matrices, there is a more general expression known as, pseudo-inverse matrix, which can be used for square and non-square matrices. The interference is removed by multiplying the received signal *y* given in Eq. (8) with the pseudo inverse of the channel matrix. Hence, the ZF combiner weight *GZF* is given by :

$$G_{ZF} = \sqrt{\frac{M_T}{E_s}} H^P = \sqrt{\frac{M_T}{E_s}} (H^H H)^{-1} H^H \qquad \ldots(7)$$

Where *HP=(HHH)-1HH*, is a pseudo inverse of the channel matrix, *H* is the channel matrix, and *HH* is the complex conjugate transpose of the channel *H* .

$$\tilde{s} = G_{ZF} y = G_{ZF}\left(\sqrt{\frac{E_s}{M_T}} Hs + z\right) = s + G_{ZF} z \qquad (8)$$

B.2 *Minimum-Mean-Squared-Error Technique*

A logical alternative to the zero forcing receivers is the MMSE receiver, which attempts to strike a balance between spatial interference suppression and noise enhancement by minimizing the expected value of the mean square error between the transmitted vector *s* and a linear combination of the received vector *GMMSE y* :

$$\min \ E\{(s - G_{MMSE} y)^2\} \qquad (9)$$

$$G_{MMSE} = \sqrt{\frac{M_T}{E_s}} \left(H^H H + \frac{N_o}{E_s} I_{MT}\right)^{-1} H^H \qquad (10)$$

Where *Es* is the transmitted energy, *No* is the noise energy and *IMT* is an *MT*×*MT* identity matrix. An estimated received vector˜ is therefore given by :

$$\tilde{s} = G_{MMSE} y = s + G_{MMSE} z \qquad (11)$$

B.3 *Soft Sphere Decoder Code*

Consider a MIMO system with MT transmit and $M_{R \geq M_T}$ receive antennas. The coded bit-stream is mapped to MT - dimensional transmit vector symbols $s \in O^{MT}$. The individual coded bits are denoted by $x_{j,b}$, where the indices j and b refer to the b^{th} bit in the binary label of the j^{th} entry of s, respectively. The resulting complex baseband input-output relation is given by

$$\mathbf{y} = \mathbf{Hs} + \mathbf{n} \qquad (12)$$

Where H denotes the MR × MT channel matrix and n is an i.e. proper complex Gaussian distributed MR-dimensional noise vector with variance No per complex entry.

TABLE 3. SIMULATION OF MIMO DEDICTION TEQNIQUES

Parameter	**Value**
Number of UEs	1
HARQ Retransmissions	0
Channel type	flat Rayleigh uncorrelated
Filtering	Block Fading
Receiver type	Soft Sphere Decoder Zero Forcing Minimum-Mean-Squared-Error Technique
Simulation length	2000
Transmit modes	2 transmit, 2 receive (2 × 2)

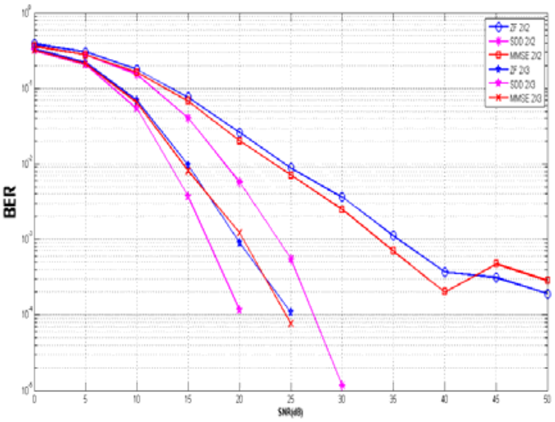

FIGURE 5. SIMULATION OF MIMO DEDICTION TEQNIQUES

Performance Comparison for MIMO Techniques:

- ZF has worst performance followed by MMSE and SSD.
- SSD_has the better BER performance by MMSE and ZF .

Performance improvement in BER performance will be increased when $M_R > Mt$.

C. *MUMIMO PERFORMANCE*

LTE-A parameters like TABLE 2 BUT, in receiver detection using SDD, bandwidth 10 MHZ and QPSK modulation are simulated. Performance of LTE-A for multi-user MIMO in degraded in the throughput when number of users increased.

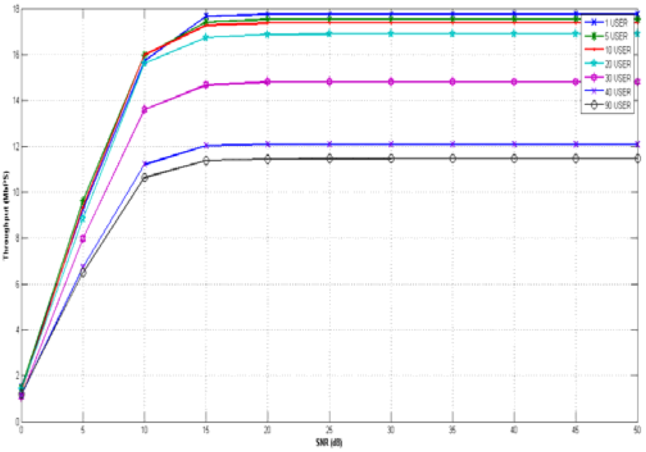

FIGURE 6. SIMULATION OF MU_MIMO

D. HARQ RETRANSMATION SIMULATION

Hybrid Automatic Repeat request (HARQ) schemes are employed [7] to reduce the effect of channel degradations on the system performance. Additional transmissions are requested by the receiver based on a cyclic redundancy check (CRC). The corresponding signaling is carried out over a feedback channel by means of acknowledgments (ACK) and negative acknowledgments (NACK). In the first case the transmitter Proceeds with the transmission of new frames while in the latter case incremental redundancy versions (RVs) of the same frame are transmitted which can be exploited at the receiver as additional soft information.LTE-A parameters like TABLE 2 BUT, in receiver detection using SDD, bandwidth 5 MHZ , QPSK modulation and AWGN channel are simulated in this part .

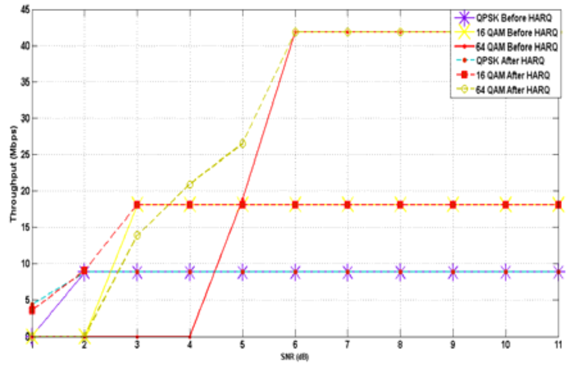

FIGURE 7. SIMULATION OF HARQ RETRANSMATION

E. SIMULATION for all 15 CQI values.

LTE-A parameters like TABLE 2 BUT, in receiver detection using SDD, bandwidth 5 MHZ, 15 CQI values are simulated in this SCEINARIO.

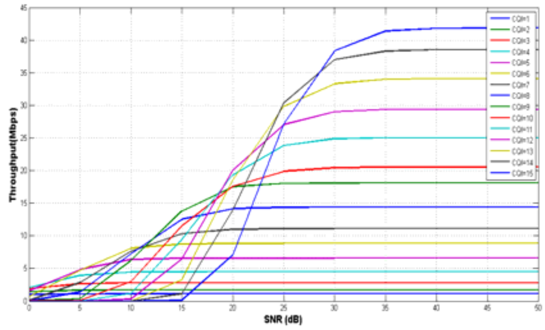

FIGURE 8. SIMULATION FOR ALL CQI VALUES IN TERM THROUGHPUT.

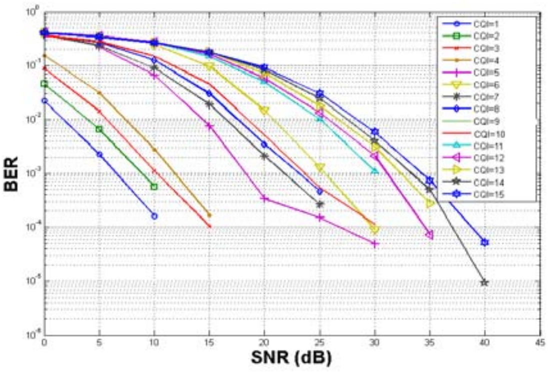

FIGURE 9. SIMULATION FOR ALL CQI VALUES IN TERM BER.

F. SIMULATION for PMI AND CQI FEEDBACK

Simulations are carried out for a 2 × 2 antenna system. A block fading channel model is assumed; that is, the channel is constant during one subframe duration and is fading independently between sub frames. The feedback is sent to the transmitter with a delay of 0, meaning that the feedback values are calculated before the actual transmission. Antennas are assumed to be spatially uncorrelated. Simulations are carried out with a single UE occupying the full system bandwidth.

TABLE 4 SIMULATIONS OF MIMO PMI AND CQI FEEDBACK

Parameter	Value
System bandwidth	5 MHz
Number of UEs	1
HARQ Retransmissions	0
Channel type	flat Rayleigh uncorrelated
Filtering	Block Fading
Receiver type	Soft Sphere Decoder
Simulation length	2000
Transmit modes	2 transmit, 2 receive (2 × 2)
Feedback delay	0 TTI
Channel estimator	perfect channel knowledge

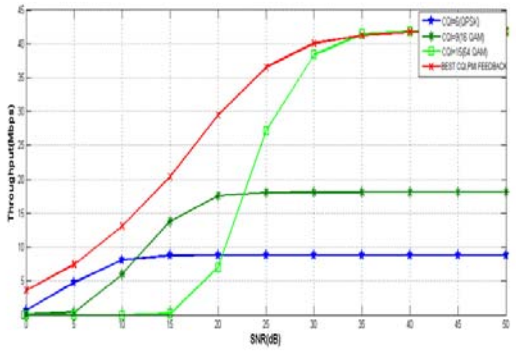

FIGURE 10. SIMULATION FOR PMI , CQI FEEDBACK AND THREE TYPE OF MODULATION IN TERM BER.

Figure 10 shows simulated throughput versus transmit energy to noise power spectral density (SNR) obtained for this setup. The RED line with cross markers corresponds to choice of PMI and CQI feedback that maximizes throughput. This choice is obtained by simulating every channel and noise realization with all possible combinations of PMI and CQI values and storing the result of the best combination. The blue star marked, Alhaciche star and green square marked lines correspond to QPSK,16 QAM AND 64 QAM respectively , when applying MIESM SINR averaging.

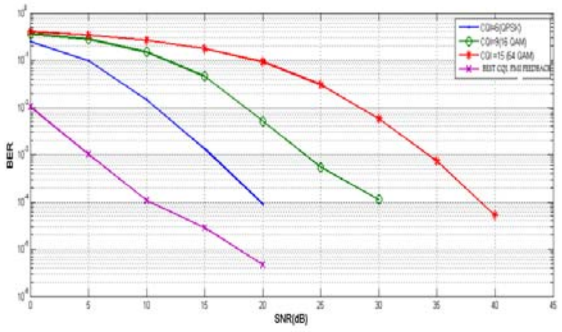

FIGURE 11. SIMULATION FOR PMI , CQI FEEDBACK AND THREE TYPE OF MODULATION IN TERM BER,

VIII. CONCLUSION

In this paper we present simulated for different BANDWITH and an optimal PMI and CQI feedback method for 3GPP LTE-A. These feedback values are used for spatial preprocessing and link adaption at the transmitter (eNodeB). We show that our method performs close to optimal (in terms of throughput and ber) for 2x2 antenna configurations The UE sends PMI, 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). We also investigate the influence of HARQ RETRANSMATION and see that the performance of LTE-A different in SNR values. We also investigate the Performance Comparison for MIMO Techniques:

- ZF has worst performance followed by MMSE and SSD.
- SSD has the better BER performance by MMSE and ZF.

Performance improvement in BER performance will be increased when $M_R > Mt$.

ACKNOWLEDGEMENT

For help and guidance in various stages of this entire work, the Institute of Communications and Radio- Frequency Engineering, Vienna University of Technology. Hussein Ali Rasool A.lihibi.

REFERENCES

[1] Mohammad T. Kawser, Nafiz Imtiaz Bin Hamid, Md. Nayeemul Hasan, M. Shah Alam, and M. Musfiqur Rahman" Downlink SNR to CQI Mapping for Different Multiple Antenna Techniques in LTE" IN *International Journal of Information and Electronic Engineering, Vol. 2, No. 5, September 2012.*

[2] 3GPP, "Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 8)," September 2009. [Online]. Available: http://www.3gpp.org/ftp/Specs/html-info/36211.htm

[3] Stefan Schwarz, Christian Mehlf ¨uhrer and Markus Rupp" Calculation of the Spatial Preprocessing and Link Adaption Feedback for 3GPP UMTS/LTE" Institute of Communications and Radio-Frequency Engineering, Vienna University of Technology , Gusshausstrasse 25/389, A-1040 Vienna, Austria .

[4] Hassan Hadi Saleh , Asst. Prof. Dr. Soukaena Hassan Hashim "Enhancing Wireless Communication For Multi Input Multi Output(MIMO) Using Orthogonal Frequency Division Multiplexing(OFDM) Technology" Informatics Institute for Postgraduate Studies at Iraqi Commission for Computers and Informatics .

[5] 3GPP, "Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 8)," September 2009. [Online]. Available:http://www.3gpp.org/ftp/Specs/html-info/36211.htm:

[6] G. Caire, G. Taricco, and E. Biglieri, "Capacity of bit-interleaved channels," Electron. Lett., vol. 32, issue 12, pp. 1060–1061, June 1996 .

[7] Albert Serra Pagès"A Long Term Evolution Link Level Simulator"Universitat Politècnica de Catalunya February, 2009.