ISSN 2047-3338

Performance Evaluation of MIMO and HARQ Techniques for LTE Uplink System

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***Abstract*— In this paper, we carry out a performance evaluation of multiple-input multiple-output (MIMO) and Hybrid automatic repeat request (HARQ) techniques for single-carrier frequency division multiple access (SCFDMA) of the LTE uplink system. Different MIMO schemes such as single-antenna port (SISO or SIMO), transmit diversity (TD) and spatial multiplexing (SM) are described and simulated. In this paper, we propose an advanced soft combining method of HARQ transmissions which is called linear minimum square error soft combining (LMMSE-SC). In this method, the LMMSE equalizer operates jointly the spatial diversity provided by MIMO technique and the temporal diversity provided by the HARQ retransmissions. Simulation results show that the proposed method improves the performance of HARQ with chase combining technique compared to the classical method of combination.**

***Index Terms*— LTE, MIMO, SC-FDMA, MIMO, HARQ and LMMSE**

I. INTRODUCTION

SINCE the beginning of this century, wireless telecommunication have increased dramatically, especially after the introduction of the cellular phone, which now can not only transmit voice, but as well receive e-mail, browse the World Wide Web, and much more… In wireless telecommunication, different standards are used in order to provide connectivity for the user in the rapid grows in the usage of the frequency spectrum. With the fusion of usage in the wireless telecommunication that include the same task as before only was possible in the normal wired communication, such as modem and ADSL, the demand for speed and availability from the daily user have become increasingly real. Thus the LTE is standardized by 3rd Generation Partnership Project (3GPP). With this new technology, a wide range of improvements are brought forward, such as improved connectivity and availability, as well as higher speeds.

The 3GPP Release 8 provides the basis for the LTE standard [2]. It is possible to increase the data throughput and the quality of service with the equipment less complex and optimized. It is possible also to reduce system latencies. This new standard is a continuation of the existing systems (UMTS, HSUPA and HSDPA) to avoid overload networks and thus reduce the cost of deployment.

To increase the spectral efficiency of the LTE system, new access technologies radio have been adopted in this standard. For communications downlink, this is the orthogonal frequency division multiple access technique (OFDMA) is chosen. This method is based on OFDM modulation. This technique is very robust to the selectivity of multipath channels. With the OFDMA technique the peak rate reached is 100Mbps for LTE downlink.

For the uplink communications, the SC- FDMA technique is chosen. This technique is very similar to the OFDM technique, but its main advantage over its competitors is its low peak-to-average power ratio (PAPR). This is the main reason for its adoption for LTE uplink. It is also simple to implement, with good spectral efficiency, and is also robust to selective multipath channels. With this technique access the peak rate reached is 50 Mbps for LTE Uplink.

In addition to OFDM, LTE implements multiple-antenna techniques which can either increase channel capacity (spatial multiplexing) or enhance signal robustness (space frequency/time coding). Together, OFDM and MIMO are two key technologies featured in LTE and constitute major differentiation over 3G systems [8].

In addition to OFDM and MIMO, the HARQ technique is one of the promising error controls of the LTE systems. It is used to reach high data rates. In this technique, when a received packet is erroneous, it is saved at the receiver memory and a negative acknowledgement is sent to the transmitter which in response retransmits the packet. The retransmitted packet is combined with the previously saved one. In this manner the obtained packet after combining is more reliable than the individually transmitted packets. This increases the probability of correct decoding.

In this paper, we present a performance comparison of SC-FDMA for different multiple-antenna schemes such as single-antenna port (SISO or SIMO), transmit diversity (TD) and spatial multiplexing (SM). These techniques have been widely treated in literature [6], [8], [10], [11]. However, we study these schemes used in LTE uplink system normalized by 3GPP, and we evaluate their performance over multipath channel. In this paper, we describe the HARQ standardized for LTE uplink system and we evaluate their performance over multipath channel.

The rest of the article is organized as follows: in Section II, the considered LTE uplink system is described. In section III, we study MIMO technique as well as their schemes. In section IV, the behaviors of the HARQ for the LTE uplink system is described and the new soft combining method is study. The performances evaluation are presented and discussed in Section V. Finally, Section VI concludes the work.

II. LTE UPLINK SYSTEM

A. Physical layer parameters

In the time domain, different time intervals within LTE are expressed as multiples of a basic time unit T_s. The radio frame has a length of 10 ms. Each frame is divided into ten equally sized subframes of 1 ms in length. Scheduling is done on a subframe basis for the uplink. Each subframe consists of two equally sized slots of 0.5 ms in length. Each slot in turn consists of a number of OFDM symbols which can be either seven (normal cyclic prefix) or six (extended cyclic prefix).

In the frequency domain, the number of sub-carriers N ranges from 128 to 2048, depending on channel bandwidth with 1.25MHz to 20 MHz, respectively. The sub-carrier spacing is $\Delta f = 15\ kHz$. The sampling rate is $fs = \Delta f \cdot N$. The uplink transmission structure is similar to the downlink. The smallest unit of resource is the resource element (RE) which consists of one SC-FDMA sub-carrier. A resource block (RB) consists of 12 REs for the duration of a slot (0.5 ms). The minimum allocated bandwidth to a UE is, therefore, 180 kHz. Multiple resource blocks are assigned consecutively in the frequency domain to a UE in the uplink while dispersed, non-consecutive assignment, is done on the downlink.

B. Uplink Physical channels

There are three physical layer channels defined for the uplink in LTE as described below [1].

- *Physical Uplink Shared Channel (PUSCH):* This channel carries user data. It supports QPSK, 16 QAM and 64QAM modulation. Information bits are first channel-coded with a turbo code with coding rate of 1/3 before being adapted by a rate matching process for a final suitable code rate. Adjacent data symbols are mapped to adjacent SC-FDMA symbols in the time domain before being mapped across sub-carriers. After this interleaving process, bits are scrambled before modulation mapping, DFT-spreading, sub-carrier mapping and OFDM modulation.
- *Physical Uplink Control Channel (PUCCH):* Control signaling comprises uplink data transmitted independently of traffic data which include HARQ ACK/NACK, channel quality indicators (CQI), MIMO feedback (rank indicator, RI, precoding matrix indicator, PMI) and scheduling requests for uplink transmission.
- *Physical Random Access Channel (PRACH):* This channel carries the random access preamble a UE sends to access the network in non-synchronized mode and used to allow the UE to synchronize timing with the eNodeB.

The Figure 1 shows the transmitter structure of the LTE uplink system implemented in this paper. This transmitter is normalized by 3GPP in [3].

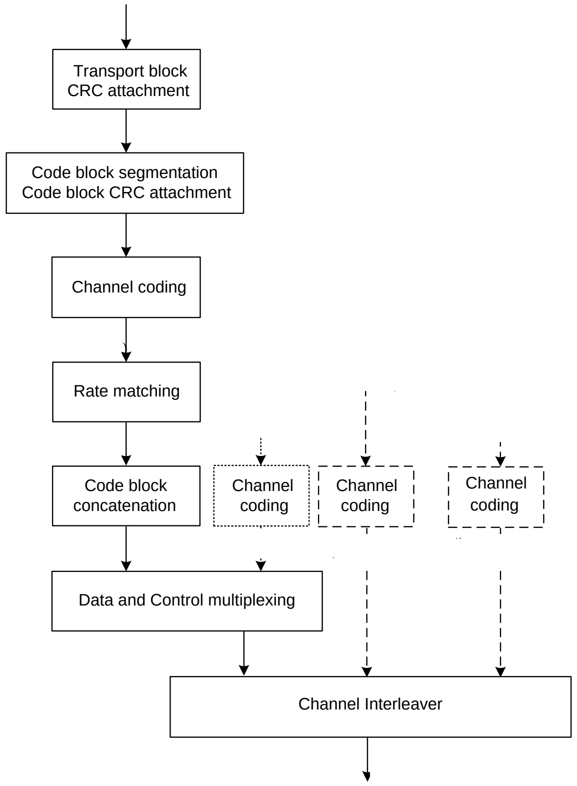

Fig. 1: Transport block processing for Uplink physical channel

III. MIMO IN LTE UPLINK SYSTEM

A key factor to the performance of MIMO is the number of spatial layers of the wireless channel which determines the ability to improve spectral efficiency [4]. Another factor is the number of transmit and receive antennas. The increase in data rate of a MIMO system is linearly proportional with the minimum number of transmit and receive antennas. In uplink, LTE uses three MIMO schemes. These are:

- Single-antenna port: this is analogous to most current wireless systems where a single codeword (i.e. single layer) is transmitted on one antenna and received by either one (SISO) or more antennas (SIMO).
- Transmit diversity: this mode involves the transmission of the same information stream (single layer) on multiple antennas. The information stream is coded differently on each of the antennas using so called SFBC (Space-Frequency Block Codes)[5].
- Spatial multiplexing: in this case tow codewords are transmitted over tow or fore antennas. This scheme is

divided on tow methods open loop spatial multiplexing and closed loop spatial multiplexing [7].

The three MIMO schemes use the same air-interface with different configurations. The Figure 2 shows the air-interface structure of the LTE uplink system used in this paper [1].

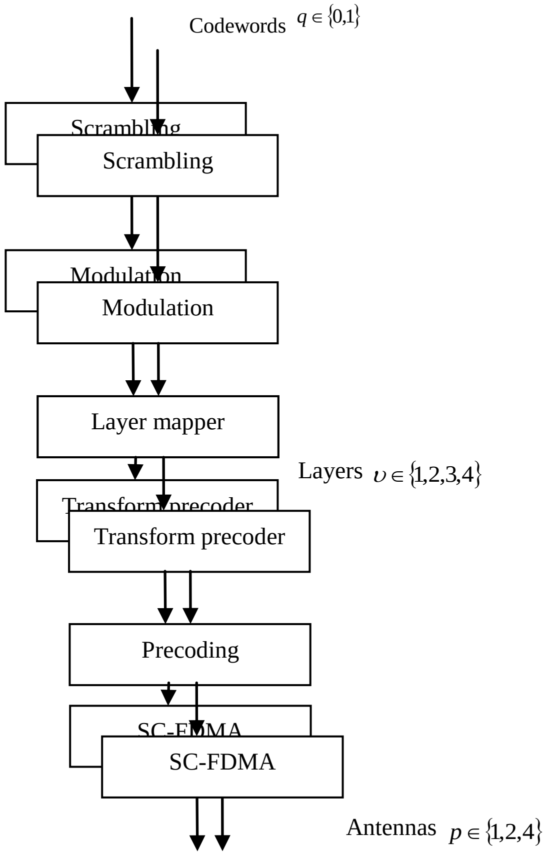

Fig. 2: Overview of uplink physical channel processing

A. *LTE Uplink transmitter*

One subframe is transmitted in up to two codewords, we note q the codewords index where $q \in \{0,1\}$. In the case of single codeword transmission, $q = 0$. For each codeword q, the block of bits $b^{(q)}(0),\ldots,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits transmitted in codeword q on the physical uplink channel in one subframe, shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}(M_{\text{bit}}^{(\text{q})}-1)$.

For each codeword q, the block of scrambled bits $\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}(M_{\text{bit}}^{(\text{q})}-1)$ shall be modulated with one of uplink modulation schemes (QPSK, 16QAM, 64QAM), resulting in a block of complex-valued symbols $d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)}-1)$. [1] specifies the modulation mappings applicable for the physical uplink shared channel.

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto up to 4 layers. Complex-valued modulation symbols for codeword q $d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)}-1)$ shall be mapped onto the layers $x(i) = \begin{bmatrix} x^{(0)}(i) & \ldots & x^{(\upsilon-1)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}}-1$ where υ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

For transmission on a single antenna port, a single layer is used, $\upsilon = 1$, and the mapping is defined by

$$x^{(0)}(i) = d^{(0)}(i) \tag{1}$$

with $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$.

For spatial multiplexing, the layer mapping shall be done according to Table 5.3.2A.2-1 in [1]. The number of layers υ is less than or equal to the number of antenna ports P used for transmission of the physical uplink shared channel.

For each layer $\lambda = 0,1,\ldots,\upsilon-1$ the block of complex-valued symbols $x^{(\lambda)}(0),\ldots,x^{(\lambda)}(M_{\text{symb}}^{\text{layer}}-1)$ is divided into $M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one SC-FDMA symbol. Where $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$ is the scheduled bandwidth for uplink transmission, expressed as a number of subcarriers.

Transform precoding shall be applied according to

$$\begin{gathered} y^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} x^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}} \\ k = 0,\ldots,M_{\text{sc}}^{\text{PUSCH}} - 1 \\ l = 0,\ldots,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}} - 1 \end{gathered} \tag{2}$$

resulting in a block of complex-valued symbols $y^{(\lambda)}(0),\ldots,y^{(\lambda)}(M_{\text{symb}}^{\text{layer}}-1)$.

The precoder takes as input a block of vectors $\begin{bmatrix} y^{(0)}(i) & \ldots & y^{(\upsilon-1)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}}-1$ from the transform precoder and generates a block of vectors $\begin{bmatrix} z^{(0)}(i) & \ldots & z^{(P-1)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}}-1$ to be mapped onto resource elements.

For transmission on a single antenna port, precoding is defined by

$$z^{(0)}(i) = y^{(0)}(i) \tag{3}$$

where $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

Precoding for spatial multiplexing is only used in combination with layer mapping for spatial multiplexing. Spatial multiplexing supports $P = 2$ or $P = 4$ antenna ports

where the set of antenna ports used for spatial multiplexing is $p \in \{20,21\}$ or $p \in \{40,41,42,43\}$, respectively.
Precoding for spatial multiplexing is defined by:

$$\begin{bmatrix} z^{(0)}(i) \\ \vdots \\ z^{(P-1)}(i) \end{bmatrix} = W \begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(\upsilon-1)}(i) \end{bmatrix} \quad (4)$$

where $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$ and W is the precoding matrix of size $P \times \upsilon$. The percoding matrix is presented in [1] to the tables 5.3.3A.2-1, 5.3.3A.2-2, 5.3.3A.2-3 and 5.3.3A.2-4

For each antenna port p used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),\ldots,z^{(\tilde{p})}(M_{\text{symb}}^{\text{ap}} - 1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{PUSCH}, and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port p and assigned for transmission of PUSCH.

$$a_{2k'+k_0^{(p)},l}^{(p)} = \begin{cases} \beta_{\text{PUSCH}} z^{(\tilde{p})}(k') & k' = 0,1,\ldots,N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}}/2 - 1 \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

After multiplexing with the other uplink physical signals and physical channels, the SC-FDMA symbol l is generated. The time-continuous signal $s_l^{(p)}(t)$ for antenna port p in SC-FDMA symbol l in an uplink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\lfloor N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}}/2 \rfloor}^{\lceil N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}}/2 \rceil - 1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi(k+1/2)\Delta f(t - N_{\text{CP},l} T_{\text{s}})} \quad (6)$$

for $0 \le t < (N_{\text{CP},l} + N) \times T_{\text{s}}$ where $k^{(-)} = k + \lfloor N_{RB}^{UL} N_{sc}^{RB}/2 \rfloor$, where $a_{k,l}^{(p)}$ is the content of resource element (k,l) on antenna port p and $N_{\text{CP},l}$ is the cyclic prefix length.

B. LTE Uplink receiver

The signal is received by more than one antenna at the receiver end. The time-continuous received signal $r_l^{(i)}(t)$ for received antenna port i in SC-FDMA symbol l in an uplink slot is defined by

$$r_l^{(i)}(t) = \sum_{p=0}^{P-1} \sum_{k=-\lfloor N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}}/2 \rfloor}^{\lceil N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}}/2 \rceil - 1} a_{k^{(-)},l}^{(p)} \int_{Ts} h^{(p)}(t-\tau) \cdot e^{j2\pi(k+1/2)\Delta f(\tau - N_{\text{CP},l} T_{\text{s}})} dt \quad (7)$$

where $h^{(p)}(t)$ is the channel transfer function between the transmit antenna p and the receive antenna i.
We can write the received signal as:

$$R = \overline{H} S + N \quad (8)$$

where $\overline{H}$ is the channel matrix between the P transmit antennas and i^{th} receive antenna and N is a vector of complex white Gaussian noise samples which has the power spectral density σ. The matrix $\overline{H}$ is expressed by :

$$\overline{H} = \begin{bmatrix} \overline{H_1} \\ \overline{H_2} \\ \vdots \\ \overline{H_P} \end{bmatrix} \quad (9)$$

Where $\overline{H}_p$ is the channel matrix between the p^{th} transmit antenna and i^{th} receive antenna. The $\overline{H}_p$ is Toeplitz matrix expressed by :

$$\overline{H_p} = \begin{bmatrix} h_{pth-1}^{(p)} & \cdots & h_0^{(p)} & 0 & \cdots & 0 \\ 0 & h_{pth-1}^{(p)} & & h_0^{(p)} & \ddots & \vdots \\ \vdots & \ddots & \ddots & & \ddots & 0 \\ 0 & \cdots & 0 & h_{pth-1}^{(p)} & & h_{pth-1}^{(p)} \end{bmatrix} \quad (10)$$

Where *pth* denotes the multipath channel length and h_j $(0 \le j \le pth - 1)$ are the complex paths coefficients.

The LTE uplink receiver uses an LMMSE detector. This detector can be expressed as

$$\overline{U} = \overline{H}^H (\overline{H}\,\overline{H}^H + SNR.\overline{I})^{-1} \quad (11)$$

where $\overline{U}$ is the LMMSE receive processing matrix, *SNR* is the signal to noise ratio and $\overline{I}$ is identity matrix.

IV. HARQ AND RATE MATCHING FOR LTE UPLINK SYSTEM

The HARQ technique combines ARQ protocols with a turbo encoder which materializes the forward error correction (FEC) in order to provide increased throughput in packet transmissions. The ARQ protocol used is N process stop-and-wait (N-SAW) protocol which is an improved version of the protocol stop-and-wait (SAW). In this paper, several parallel N-SAW HARQ processes are used at the physical layer. The number of the processes is 8. It is selected in order to leave enough time to decode the packet and to transmit the HARQ ACK/NACK signals.

The HARQ technique is based on the rate matching functionality. It adapts the bits number of the input packet at the bits number which can carry on the PUSCH physical channel. This bits adaptation is done by the rate matching pattern algorithm normalized by 3GPP in [3]. It is based on the redundancy versions (RV) parameter which is transmitted by eNodeB in the PHICH physical channel. This parameter is used for compute the punctured or repeated bit index.

LTE uses synchronous HARQ transmission on the uplink. This means that the eNodeB knows exactly which HARQ process and RV the UE will transmit ahead of time. Synchronous HARQ can be used because the UE transmits the same HARQ process every eighth subframe. Because retransmissions of a HARQ process are associated with previous transmissions based on the eight-subframe delay, the scheduling in the uplink is not quite as flexible as that in the downlink.

At the receiver side, the HARQ transmissions are separately received in time by more than one antenna. The resulting received signal at the j^{th} HARQ transmission can be formulated into vector as:

$$R^{(j)} = \overline{H^{(j)}}S + N^{(j)} \qquad (12)$$

where $\overline{H}^{(j)}$ is the channel matrix of the j^{th} HARQ transmission between the transmit antennas and receive antennas and $N^{(j)}$ is a vector of complex white Gaussian noise samples of the j^{th} HARQ transmission.

The received data code blocks at the j^{th} HARQ transmission are combined with the stored erroneous received data code blocks of the previous HARQ transmission at the input of the channel decoder. In this paper, the receiver uses maximum ratio combining (MRC) to combine the received code blocks.

We note $\hat{b}_k^{(j,c)}$ the k^{th} bit of the c^{th} code block received at j^{th} HARQ transmission, after maximum ratio combining, the combined bit is expressed by:

$$\hat{b}_k^{(j,c)} = \sum_{i=0}^{j} b_k^{(i,c)} \qquad (13)$$

A. The LMMSE soft combining

In this work, we propose a new method to combine the HARQ transmissions. This method is used only when HARQ is configured with Chase Combining scheme [12], [13], [14].

At the receiver, the HARQ transmissions are received separately in different times. These different retransmissions are combined at the input of the LMMSE equalizer for forming a single received packet.

At the j^{th} retransmission, the resulting vector which combine the j^{th} received vector $R^{(j)}$ with the received vectors of all previously HARQ transmissions $R^{(i)}$ (where $i \in \{1, \cdots, j-1\}$), is writing in a matrix form as following:

$$\begin{bmatrix} R^{(1)} \\ R^{(2)} \\ \vdots \\ R^{(j)} \end{bmatrix} = \begin{bmatrix} \overline{H^{(1)}} \\ \overline{H^{(2)}} \\ \vdots \\ \overline{H}^{(j)} \end{bmatrix} S + \begin{bmatrix} N^{(1)} \\ N^{(2)} \\ \vdots \\ N^{(j)} \end{bmatrix} \qquad (14)$$

Where $R^{(i)}$, $H^{(i)}$ and $N^{(i)}$ (where $i \in \{1, \cdots, j\}$) are respectively the received vector, the channel matrix and the noise vector at the i^{th} HARQ transmission.

As shown in (14), each HARQ transmission can be viewed as a source of virtual received antennas, i.e. the delay diversity will translate into space diversity which is exploited by the LMMSE equalizer given by:

$$\overline{U}^{(j)} = \begin{bmatrix} \overline{H^{(1)}} \\ \overline{H^{(2)}} \\ \vdots \\ \overline{H}^{(j)} \end{bmatrix}^H \left(\begin{bmatrix} \overline{H^{(1)}} \\ \overline{H^{(2)}} \\ \vdots \\ \overline{H}^{(j)} \end{bmatrix} \begin{bmatrix} \overline{H^{(1)}} \\ \overline{H^{(2)}} \\ \vdots \\ \overline{H}^{(j)} \end{bmatrix}^H + SNR.\bar{I} \right)^{-1} \qquad (15)$$

V. SIMULATION RESULTS

A. Simulation parameters

For simulating the radio link performance of the LTE uplink with MIMO and HARQ techniques, we implemented the LTE uplink simulator which consists of the normalized transceiver described in section II, MIMO precoding described in section III and HARQ technique described in section IV. The MIMO channels are a multi-path channel which uses the profile of ITU-Pedestrian A with a speed of 3Km/h. The simulations were run using the radio link parameters summarized in Table 1.

Table 1: Simulation parameters

CQI	9
Carrier frequency	2.0 GHz
Symbol rate	4.096 million symbols/sec
Transmission bandwidth	5 MHz
modulation	16 QAM
Data rate	9.175
Number of Resource Blocks	25
FFT block size	512
Cyclic Prefix (CP) length	4.7 µsec
Channel model	ITU-Pedestrian A
Number of received antenna	2
Moving speed	3 km/h
Data modulation	QPSK and 16QAM
Channel coding	Turbo code with R = 0.56 and soft-decision decoding
Equalizer	LMMSE
Channel Estimation	Perfect channel estimation
AMC	No

B. Simulation Results and Discussion

In order to observe the performance of the MIMO technique, the simulations were carried out for the CQI 9 of LTE uplink. The predefined CQI 9 parameters (modulation and coding rate) used in this work are shown in Table 1.

The BLock Error Rate (BLER) results of the physical uplink shared channel of LTE uplink system with MIMO technique are investigated in Fig. 4. The number of received antenna is fixed to 2 and an independent multipath channel for each antenna transmission is used. We see that considerable gain is achieved when we use spatial multiplexing and Transmit diversity. For Transmit diversity, we see a performance enhancement almost 2dB at a BLER=10^{-3} compared with a single transmit antenna. As shown in the Fig. 3, the Spatial multiplexing technique improves the link performance. For this technique, we see a performance enhancement almost 4dB at a BLER=10^{-3} compared with a

Transmit diversity. Hence, the LMMSE equalizer exploits the spatial diversities which are offered by the multiple antennas.

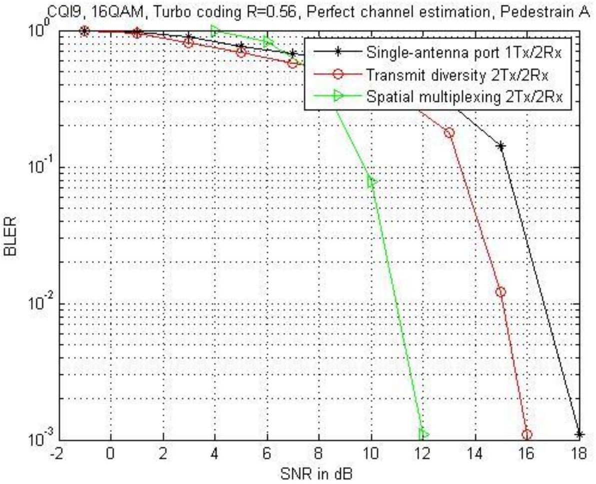

Fig. 3: Performance of transmit diversity and spatial multiplexing compared with a single transmit antenna

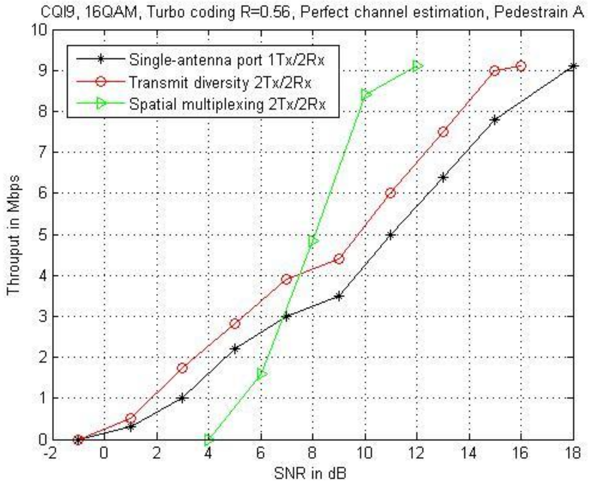

Fig. 4: Throughput performance of transmit diversity and spatial multiplexing compared with a single transmit antenna

The throughput result of LTE uplink is shown in Fig. 4. We observe that the throughput is significantly improved when we use spatial multiplexing technique. From the results above, it is clear that the using of these techniques can introduce performance benefits compared to single transmit antenna, especially at high SNR.

The Fig. 5 and Fig. 6 show the BLER and the throughput performances of the LTE uplink system with the spatial multiplexing scheme and the HARQ technique with a soft packet combining. The maximum number of HARQ transmissions is fixed to 2. We see that considerable gain is achieved after the first and the second retransmission. This figure shows that the HARQ technique improves the performance of LTE uplink system by almost 3.5dB at a BLER=10^{-3} after the first HARQ transmission and by almost 5.5dB at a BLER=10^{-3} after the second HARQ transmission. .

Simulation results show also that the HARQ with LMMSE soft combining performances is better than the HARQ with MRC scheme. We can see that the proposed method improves the performance of HARQ technique compared to the classical method. This enhancement is almost 0.7dB at BLER=10^{-3}after one HARQ transmission. This enhancement is due to the translation of temporal diversity given by the HARQ technique into spatial diversity. This diversity is exploited by the LMMSE equalizer to improve system performances. Then each HARQ transmission can be viewed as a source of virtual received antennas.

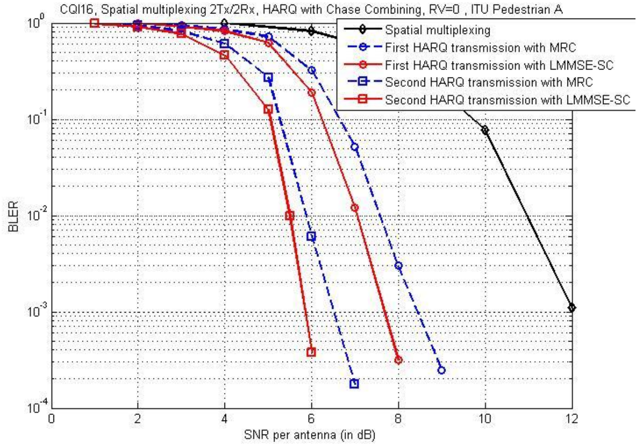

Fig. 5: Performance of LTE uplink with HARQ and spatial multiplexing techniques

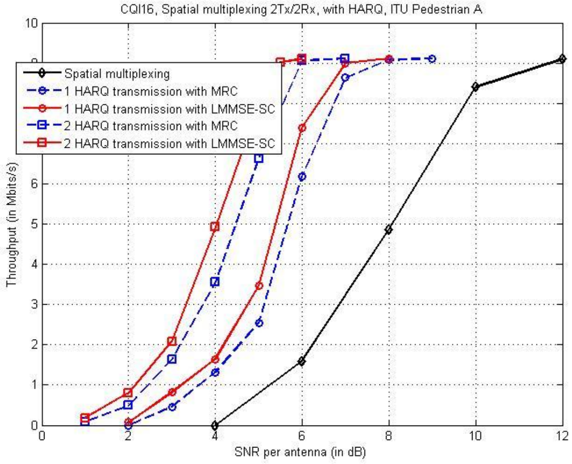

Fig. 6: Throughput performance of LTE uplink system with HARQ and spatial multiplexing techniques

VI. CONCLUSION

In this paper, we evaluated the performance of the multiple antennas and HARQ techniques in a LTE Uplink system in a multipath environment. The use of these techniques was enabling wireless systems to increase throughput and spectral efficiency. In this paper, we showed that considerable BLER and throughput gain is offered by the use of spatial multiplexing and HARQ techniques. In the case of CQI 9, we achieved almost 5.5dB gain of SNR for a BLER value equal to 10^{-3} after tow HARQ transmission. This is due to the spatial diversities and the precoding offered by the spatial multiplexing and the temporal diversity offered by the HARQ technique. To improve the performances of the LTE uplink system, we propose an advanced soft combining method of HARQ transmissions which is called LMMSE soft combining (LMMSE-SC). Simulation results show that the proposed method improves the performance of HARQ technique compared to the classical method of combination. This enhancement is due the linear minimum square error (LMMSE) equalizer which operates jointly the spatial diversity provided by MIMO technique and the temporal diversity provided by the HARQ retransmissions.

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