IOP Conf. Series: Materials Science and Engineering **78** (2015) 012017 doi:10.1088/1757-899X/78/1/012017

# Performance Analysis for LTE Wireless Communication

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**Abstract**. Long Term Evolution (LTE) is the new upgrade path for carrier with both GSM/UMTS networks and CDMA2000 networks. The LTE is targeting to become the first global mobile phone standard regardless of the different LTE frequencies and bands use in other countries barrier. Adaptive Modulation and Coding (AMC) is used to increase the network capacity or downlink data rates. Various modulation types are discussed such as Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM). Spatial multiplexing techniques for 4×4 MIMO antenna configurations are considered. This paper has outlined various estimation techniques to increase the throughput of the LTE network by simulating the estimation techniques with various parameters in the LTE downlink mode 4 (spatial multiplexing). Three techniques i.e. channel estimation technique, estimation of channel models and MIMO receiver algorithm are simulated to provide the ideal LTE wireless communication system.

## 1. Introduction

The increase in broad band multi-media services including voice over internet protocol (VoIP), mobile TV, audio and video messaging and internet access demand a larger wireless cellular network with better reliability. In addition, telecommunication operators are constrained with limited frequency spectrums purchased from the government. Thus the need arises to search for a feasible network which can increase the throughput without purchasing additional bandwidth and at providing good service quality.

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. 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 [1].

In 2008 the International Telecommunication Union specified requirements for 4G standards and named it the International Mobile Telecommunication Advanced which was expected to provide transmission rates of up to 1 Gbps.

This paper analyzed LTE mode 4 (Closed-Loop Spatial Multiplexing) configurations of channel estimation techniques, channel models and multiple-input multiple-output (MIMO) receiver algorithms gives a lower bit error rate (BER) as to comprehend these needs that have arisen for the telecommunication operators [2]-[4].

## 2. MIMO

MIMO use multiple antennas for both transmitting and receiving antennas. The advantages of MIMO communication, which exploits the physical channel between many transmit and receive antennas, are currently receiving significant attention [5]-[6].

Figure 1 shows a MIMO system consists of 'n' receive antennas and 'm' transmit antennas. The connections from each antenna are designated as

$$H = \begin{bmatrix} h_{11} & h_{12} & .. & h_{1m} \\ h_{21} & h_{22} & .. & h_{2m} \\ .. & .. & .. & .. \\ h_{n1} & h_{n2} & .. & h_{nm} \end{bmatrix} \tag{1}$$

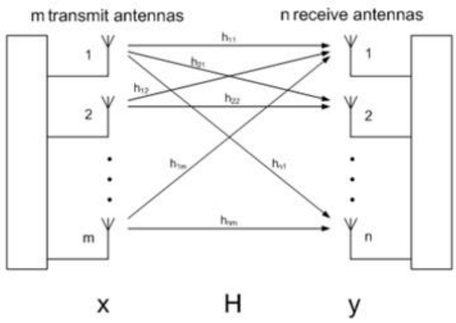


**Figure 1.** MIMO system.

Denote the receive vector '**y**', transmit vector '**x**' and noise '**n**'. We have

$$\mathbf{y} = \mathbf{Hx} + \mathbf{n} \tag{2}$$

### *2.1. Channel modes*

*2.1.1. Flat fading.* A transmitted signal undergoes flat fading, or sometimes called as narrowband channels, when the signal bandwidth (BW) is less than the channel coherence bandwidth. In flat fading, though the spectrum of the transmitted signal is preserved, the received signal varies in amplitude and encounters deep fades of 20 to 30 dB. Instantaneous amplitudes of these received signals follow Rayleigh distribution.

*2.1.2. Frequency selective.* For Frequency selective fading or wide band channel, the signal bandwidth is greater than the channel coherence bandwidth. In frequency selective fading, time dispersion causes inters-symbol interference at the receiver making the multiple versions of the received signal attenuate and delay in time to a different degree.

*2.1.3. LTE specific channels.* There are three different multipath fading channels for LTE specific channels made by the Third Generation Partnership Project (3GPP). Namely,

- Extended Pedestrian A (EPA)

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- Extended Vehicular A (EVA)
- Extended Typical Urban (ETA)

*2.2. MIMO receivers*
Receiver use equalizer to produce the best estimate of the transmitted symbols. Three algorithms are considered i.e.

- Zero Forcing (ZF) equalizer
- Minimum Mean Square Error (MMSE) equalizer
- Sphere Decoder (SD) equalizer

*2.2.1. ZF equaliser.* The ZF receiver inverses the MIMO channel matrix. The major drawback of the ZF receiver is noise enhancement. Although the ZF receiver eliminates the interference, performance becomes poor when the channel of the signal of interest is almost collinear to the interference subspace, or in other words when the channel matrix is almost rank deficient.

*2.2.2. MMSE equaliser.* The MMSE receiver minimises the average estimation error on the transmitted symbols. The average is taken over the transmitted symbols and the noise : the mean square error (MSE) is $E_{\mathbf{x},\mathbf{n}}\|\hat{\mathbf{x}}-\mathbf{x}\|^2$, where $\hat{\mathbf{x}}$ is estimated symbol and $\mathbf{x}$ is the transmitted symbol. The ZF receiver also minimises the output MSE but under the constraint of complete inter symbol interference (ISI) elimination.

*2.2.3. SD equaliser.* SD receiver finds the transmitted signal vector with minimum maximum likelihood (ML) metric, that is, to find the ML solution vector. However it considers only a small set of vectors within a given sphere rather than all possible transmitted signal vectors. SD adjusts the sphere radius until there exists a single vector (ML solution vector) within a sphere. It increases the radius when there exists no vector within a sphere, and decreases the radius when there exists multiple vectors within the sphere.

## 3. OFDM
Orthogonal Frequency Division Multiplexing (OFDM) is a radical and revolutionary technology as it forms the basis for 4G technology. The basic concept of OFDM is to send samples concurrently using multiple orthogonal sub-channels rather than sending a sample signal using the entire bandwidth. The main advantage of OFDM is that because of the use of many sub-channels, only some of the sub-channels are affected by interference or multi-path effect [7]-[8].

*3.1. OFDM*
In OFDM a single channel utilizes multiple overlapping sub-carriers as shown in Figure 2. However, because these overlapping sub-carriers are orthogonal to each other, the sub-carriers will not interfere with each other. OFDM system can maximize spectral efficiencies.

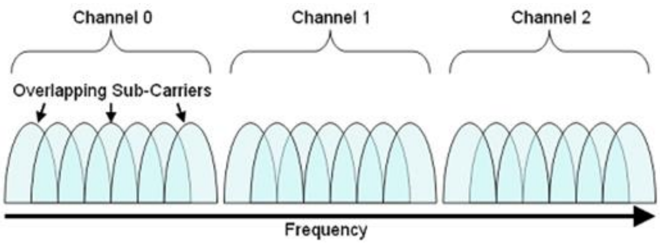

**Figure 2.** OFDM channel

### *3.2. Cyclic prefix*

To completely eliminate the Inter Symbol Interference (ISI), cyclic prefix (CP) is introduced into the OFDM. CP is a repetition of the last samples of the data portion that is appended at the beginning of the data payload. As long as the CP duration is longer than the channel delay spread the ISI will be completely eliminated.

## 4. LTE physical layer

Designed to meet the present-day needs for high-speed media and data transfer, the 3GPP Long Term Evolution, or more commonly known LTE, symbolizes a major advance in cellular technology. It also includes multimedia unicast and broadcast services in addition to high-capacity voice support.

The LTE physical layer (PHY) acts as a highly efficient means for transmission of both data and control information between mobile user equipment (UE) and an enhanced base station (eNodeB). The technologies employed by the LTE PHY include OFDM and MIMO

Furthermore, it uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). The function of OFDMA is to direct data to or from multiple users for a number of symbolic periods on a subcarrier-by-subcarrier basis.

### *4.1. Transmission Modes in LTE downlink*

*4.1.1. Mode 1 (SIMO).* There is a single transmit antenna and multiple receiver antennas. Thus Mode 1 of LTE has only one transmit antenna.

*4.1.2. Mode 2 (transmit diversity).* The default MIMO mode, transmit diversity, sends the same data via various antennas. As Each antenna stream is using different frequency resources and different coding it provides a stronger transmission and causes the SNR to improve. Transmit diversity is used as a fall-back option in LTE for some transmission modes. For example, when spatial multiplexing (SM) cannot be applied, Control channels, such as physical broadcast channel (PBCH) and physical downlink control channel (PDCCH), is also transmitted using transmit diversity. A frequency-based version of the Alamouti codes space frequency block code (SFBC) is used for two antennas; whereas a combination of SFBC and frequency switched transmit diversity (FSTD) is used in the case of four antennas.

*4.1.3. Mode 3 (open-loop spatial multiplexing).* To attain higher date rates, this mode supports spatial multiplexing of two to four layers that are multiplexed to two to four antennas, respectively. Less user equipment (UE) feedback is required for it regarding the channel situation as precoding matrix indicator is excluded. It is used when channel rapidly changes or when there is missing channel information. An example of this can be UEs moving with high velocity. Furthermore, there is a specific delay in supplying the signal to every antenna known as the cyclic delay diversity ( CDD). This in turn artificially creates a frequency diversity.

*4.1.4. Mode 4 (closed-loop spatial multiplexing).* This mode supports spatial multiplexing with up to four layers that are multiplexed to up to four antennas respectively. This is in order to attain higher data rates. To allow channel estimation at the receiver, cell-specific reference signals (RS) is transmitted by the base station and distributed over various resource elements (RE) and timeslots. A response regarding the channel situation is then sent by the UE. This includes information about which precoding is ideal from the defined codebook.

## 5. Performance Analysis

### *5.1. Examining effects for channel estimation techniques*
The channel estimation techniques are

- Ideal Channel Estimation
- Channel Estimation on interpolation
- Channel estimation based on averaging over each slot
- Channel estimation based on averaging over each subframe

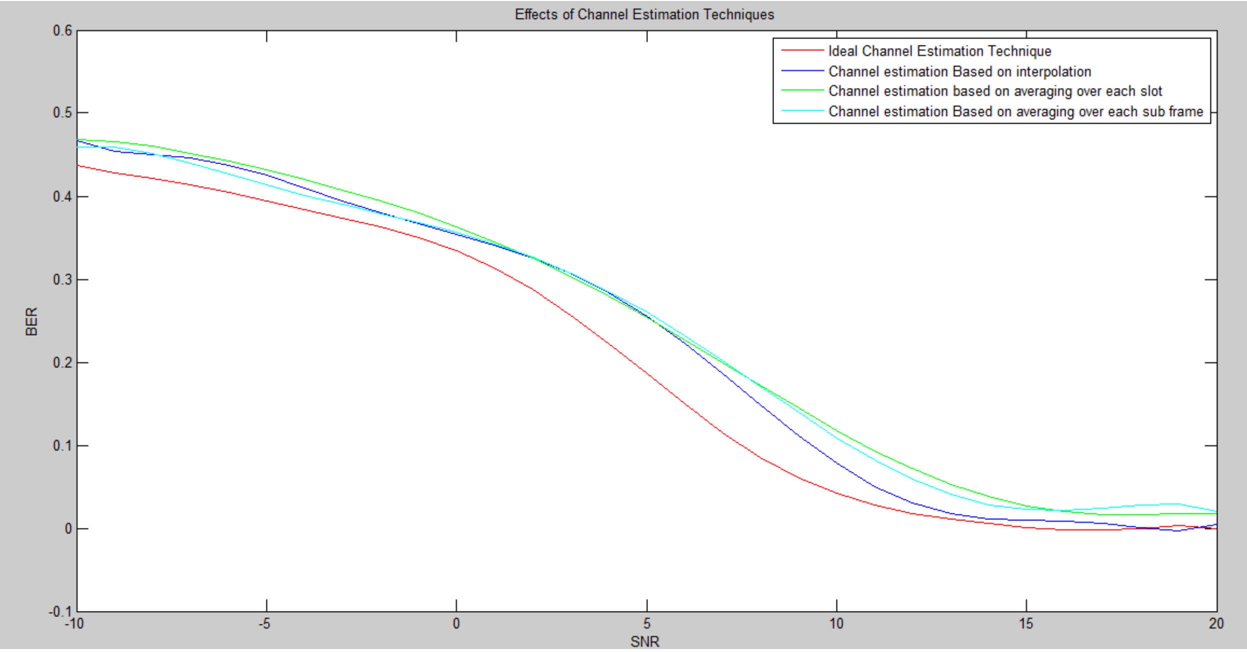


**Figure 3.** BER vs SNR for channel estimation techniques

**Table 1.** Channel estimation technique parameters.

| Parameter | Value |
|---|---|
| Transmission Mode | 4 |
| Number of transmit antenna | 2 |
| Number of receiver antenna | 2 |
| Channel Bandwidth | 10 MHz |
| Modulation Scheme | 16QAM |
| Channel Model | frequency selective |

Figure 3 shows the ideal channel estimation technique provides the best BER performance. As the variations within slots and subframes are allowed by interpolation it has a higher performance in an MMSE error-minimization context. Though the averaging methods don’t improve the BER performance much it provides a continuity needed for better perceptual results.

The best channel estimation is Ideal channel Estimation, followed by Estimation based on Interpolation and then averaging over each slot and finally averaging over each sub frame.

### *5.2. Examining effects of channel models*

**Table 2.** Effects of channel model parameters.

| Parameter | Value |
|---|---|
| Transmission Mode | 4 |
| Number of transmit antenna | 2 |
| Number of receiver antenna | 2 |
| Channel Bandwidth | 10 MHz |
| Modulation Scheme | 16QAM |
| Channel estimation technique | Ideal channel estimation |
| MIMO Receiver | MMSE |

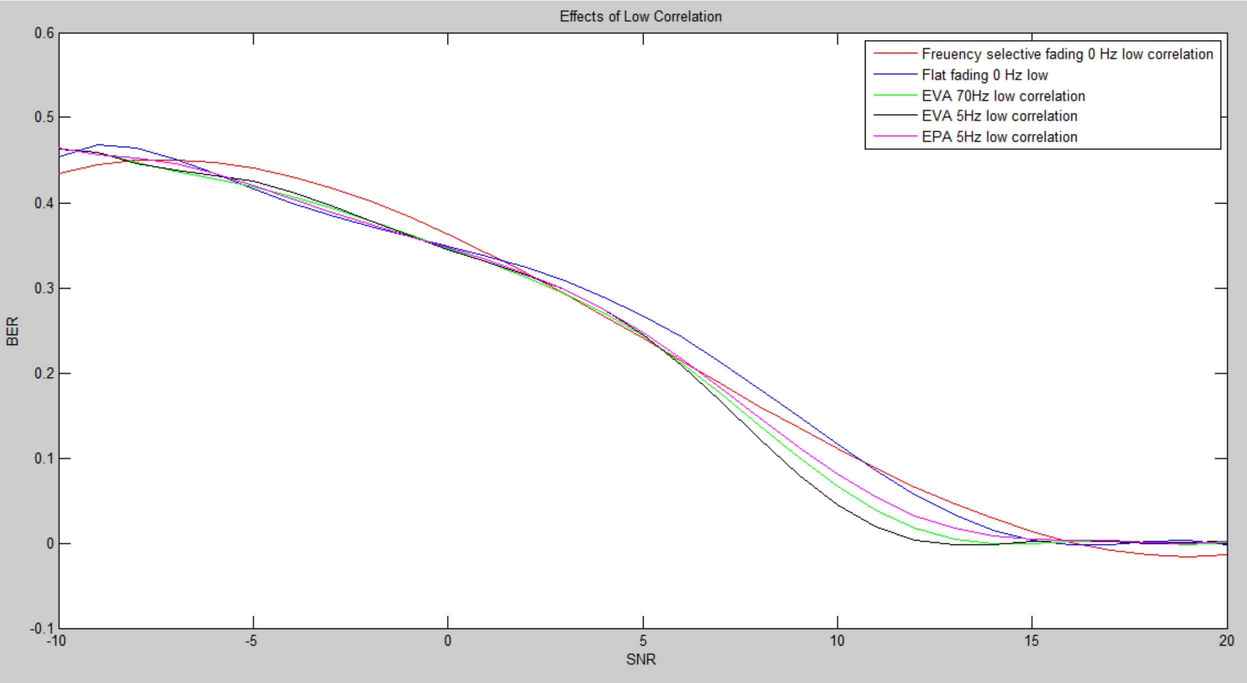


**Figure 4.** BER vs SNR for low correlated channels

Figure 4 shows there is not much difference in all the graphs until around SNR 7dB. At SNR 12 dB, As such the best to worst type of channel models can be listed as follows from the graph;

- EVA of a maximum Doppler shift of 5 Hz
- EVA of a maximum Doppler shift of 70 Hz
- EPA of a maximum Doppler shift of 5 Hz
- Flat Fading channel of a Maximum Doppler shift of 0 Hz
- Frequency Selective Fading channel of a maximum Doppler shift of 0 Hz

As noise profile increase, the performance becomes consistently reduced. Higher mobility as indicated by higher Doppler shift also reduce performance.

Above 15 dB, Flat Fading channel of a Maximum Doppler shift of 0 Hz outperform all others.

### *5.3. Examining effects of MIMO receiver algorithms*

To examine the effects of MIMO receiver Algorithms, the MIMO receiver algorithms are compared i.e. ZF, MMSE and SD.

**Table 3.** MIMO receiver algorithm parameters.

| Parameter | Value |
|---|---|
| Transmission Mode | 4 |
| Number of transmit antenna | 2 |
| Number of receiver antenna | 2 |
| Channel Bandwidth | 10 MHz |
| Modulation Scheme | 16QAM |
| Channel estimation technique | Ideal channel estimation |

As the ideal channel estimation technique is the best estimation technique, Ideal channel estimation technique is used as a simulation parameter for channel estimation technique in this simulation. Figure 5 shows that SD has the best performance followed by MMSE and ZF.

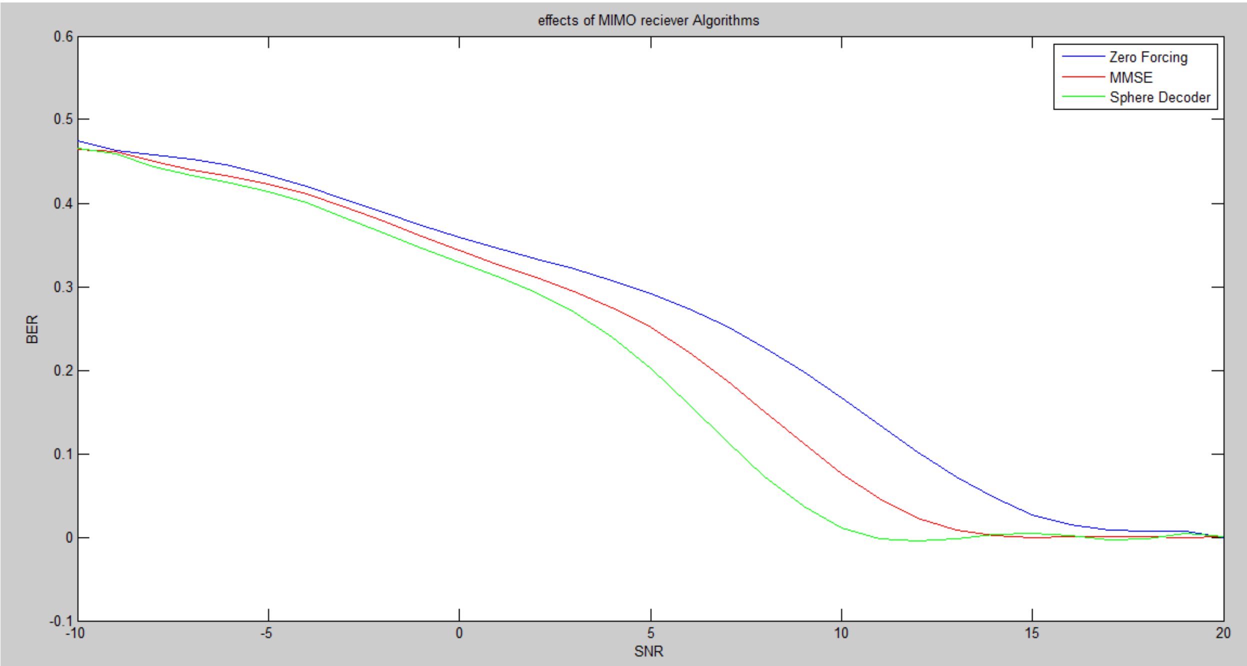


**Figure 5.** MIMO receiver algorithms comparison.

Though the SD outperforms MMSE and ZF, SD has higher computational complexity. Therefore Trade-off between performance and complexity decides the choice between SD and MMSE.

## 6. Conclusion

LTE was introduced to meet the demands of the users to download and upload packet data faster than its predecessor 3G. This paper has outlined various estimation techniques to increase the throughput of the LTE network by simulating the estimation techniques with various parameters in the LTE downlink Mode 4 (closed-loop spatial multiplexing).

Three techniques are used in this paper, channel estimation technique, estimation of channel models and MIMO receiver algorithm simulations. LTE physical layer is simulated to select ideal combination. The ideal combination is Ideal Channel Estimation Technique, Low correlated EVA with low Doppler shift and SD.

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