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WIRELESS TRANSMISSION RELIABILITY STUDY FOR LARGE SCALE MIMO SYSTEMS UNDER MINIMUM MEAN SQUARE AND ZERO FORCING EQUALIZATION SCHEMES

by
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Abstract

Future fifth generation (5G) mobile broadband communication systems are expected to provide superior data transmission rates and reliable communication quality. Two main issues that affect wireless transmission reliability are interference and fading effects induced by multipath propagation elements in the radio frequency channel. Nevertheless, both issues can be combated significantly by means of channel equalization in multiple antenna technological settings. In this paper, link reliability in terms bit error rate (BER) is investigated for large scale multiple-input–multiple-output (LS-MIMO) system under minimum mean square (MMSE) and zero forcing (ZF) equalization schemes, employing Matlab simulation platform. The simulation results show that the ZF-based equalizer is good enough to combat noise free channel and remove inter symbol interference, nonetheless the MMSE-based equalizer performs better as the number of antenna increases at the receiver.This can be justified by the fact that MMSE-based equalizer poses the capacity suppress both noise and interference among users in communication channel for enhanced data transmission reliability thereby delivering higher diversity gains at the receivers. However, the performances occurs slowly and then remained unchanged as the antenna number grows beyond 200 owing to saturation.

Keywords*:* *Interference, Fading, Large-scale MIMO, Linear channel equalization, Bit error rate, Transmission reliability.*

Introduction

In the fast developing world of wireless cellular telecommunication systems, a number of technical grounds are gaining widespread acceptance globally. In the midst of these trends is the explosive interest in multi-carrier information broadcasting, and its multimedia mobile broadband applications (Obayagbon and Isabona, 2018). The remarkable development of the multimedia mobile broadband applications, coupled with the ever-increasing number of cellular mobile communication network subscribers in the last years has led to stringent requirements on the transmission quality and reliability that next-generation cellular mobile broadband networks are expected to deliver (Marinello, 2014; Isabona and Azi, 2013). For instance, interference, multipath fading, noise, limitations in bandwidth, signal propagation loss and time variance, among other factors, impact the wireless data transmission reliability (Isabona el al, 2013; Isabona and Babalola, 2013; Isabona and Konyeha, 2013). Also, when the data is communicated at high bit rates through mobile radio communication channels, the channel impulse response can outspread over sundry symbol periods, which results to inter-symbol interference (ISI) (Mindaudu and Miyim, 2012).Thus, ISI is known hazard that severely upsets data transmission speed and error rate performance over mobile radio communication channels, especially at receivers' end A promising method to combating the highlighted problems above is through the deployment of large scale-Multiple-input multiple-output (LS-MIMO) antenna technology, that are capable of using better spatial multiplexing and diversity techniques. The concept behind LS-MIMO is to evenhandedly empower the base-station (BS) with tens, hundreds or thousands of smart antennas while catering for a large number users exploring the available time-frequency resource. One key efficient means to cater for the ISI multipath propagation environment is by employing a filtering method termed equalization (Liu, 2012; Dawar and Sharma, 2014).

In this research work, two linear channel equalization algorithms which includes the minimum-mean-square-error (MMSE) and zero forcing (ZF), are studied extensively through computer simulations to examine their impact on data transmission reliability of large scale MIMO (LS-MIMO) systems. Similar research approach was adopted (Marinello and Abrao, 2014), but in multi-cellular MIMO system settings. In our previous works (Isabona and Srivastava, 2018a; Isabona and Srivastava, 2018b;Isabona and Srivastava, 2018c), the focus were solely on massive MIMOcommunication the downlink single cell scenarios. In this work, the focus is in the uplink, wherein both the single base transmitter and mobile terminals are equipped with large scale multiple antennas.

Mathematical MIMO System Model

In the MIMO system model, a typical multiuser large-scale MIMO system that possess $N_t$transmit antennas and $N_r$receive-antennas is adopted. The received signal in the jth antenna can be expressed as (Isabona and Obahiagbon, 2018):

$$y_i^K = \sum_{j=1}^{Nt} H_{ij} x_j^k + n_i^k \quad (1)$$

$$\mathbf{y} = \mathbf{H}x + \mathbf{n} \quad (2)$$

The subscript *i* and *j* indicate the *i-th* receiver and *j-th* transmitter respectively. The superscript *k* designates the *kth* transmit-antennas and H_{ij} defines the complex channel, where

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{Nt} \end{bmatrix}, \mathrm{H} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & \cdots & h_{1Nt} \\ h_{21} & h_{22} & h_{23} & \cdots & h_{2Nt} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ h_{Nr1} & h_{Nr2} & h_{Nr3} & \cdots & h_{NrNt} \end{bmatrix}, \ \mathbf{x} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_k \end{bmatrix} and \ n = \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_{Nr} \end{bmatrix} \quad (3)$$

In equation (3) **y**, **H**,x and **n**denote thereceived signal, channel matrix, transmit signal, and the additive white Gaussian noise corresponding to the receive-antenna.

Equalization Schemes

To estimate and cater for the transmitted signal symbols that has been impacted by Inter symbol Interference (ISI) and noise in the MIMO systems communication link, an equalization method is employed (Dilip and Godbole. 2009; Isabona and Obahiagbon, 2018). A brief general overview of the four channel equalization techniques considered at the receiver in this work provided below. The receiver is assumed to possess a perfect knowledge of the channel state. Also, the weights of the equalizing filters are calculated dynamically.

Zero-forcing (ZF) Equalizer

ZF equalizer was first proposed by Robert Lucky and it is a type of linear equalization algorithm employed to inverts the frequency response of the channel in communication systems. That is, the ZF equalizer exploits the inverse of the radio channel to remove signal distortion if there were no noise and bring down the inter symbol before the channel. When perfect CSI is available at the BS, the ZF equalization employs a Pseudo-inverse method of the *Nt*× *Nr* channel matrix, to combat interference by a weight matrix:

$$\mathbf{G}_{ZF} = Pinv(\mathbf{H}) = \left(\mathbf{H}^{H}\mathbf{H}\ \right)^{-1}\mathbf{H}^{H} \tag{4}$$

where***G***is the channel equalization matrix, *Pinv*(*H*) denotes the Pesudo-inverse, the superscript *H* stands for Hermitian conjugation of a matrix and the superscript '-1' stands for the inverse of matrix.

Let

$$\mathbf{G} = [\mathbf{g}_1,...\mathbf{g}_i,...,\mathbf{g}_{Nt}]^T \tag{5}$$

and

$$\mathbf{h} = [\mathbf{h}_1,...\mathbf{h}_i,...,\mathbf{h}_{Nt}] \tag{6}$$

It curtails the interference in the system by inverting the channel effect as:

$$\hat{x} = \mathbf{G}_{\mathbf{zf}}.y \tag{7}$$

Thus, with ZF equalization, the signal quality, $SINR_k$at theuser *k*, can be expressed as:

$$SINR_{k,ZF} = \frac{P_k|\mathbf{G}_k\mathbf{h}_k|^2}{N_0} \tag{8}$$

Minimum mean square error (MMSE) Equalizer

The ZF equalizer is employed to get rid of all linear distortion, nonetheless noise is increased significantly in the process, especially when the channel response possesses a small amplitude. A better equalizer to cater for the total power of the noise channel and also partially remove ISI distortion is the MMSE equalizer (Dawar and Sharma, 2014; Isabona and Obahiagbon, 2018). Aptly, it is a method that attempts to find an equalization matrix *G* minimizing the criterion:

$$E\{(\mathbf{G}.y-x)^H(\mathbf{G}.y-x)\} \tag{9}$$

where,

$E = \{.\}$ denotes the statistical ensemble.

The MMSE weight matrix is given as:

$$\mathbf{G}_{MMSE} = \left(No\mathbf{I}_{Nr} + \sum_{i\neq k}^{Nt} Pi\mathbf{h}_{\mathbf{i}}\mathbf{h}_{\mathbf{i}}^{*}\right)^{-1} h_{\mathrm{k}} \tag{10}$$

It curtails the interference in the system by inverting the channel effect as:

$$\hat{x} = \mathbf{G}_{MMSE}.y \tag{11}$$

The achieving output $SINR_K$, at theuser *k*, can be expressed as (Isabona and Obahiagbon, 2018):

$$SINR_{k,MMSE} = P_k\mathbf{h}_k^{*}\left(No\mathbf{I}_{Nr} + \sum_{i\neq k}^{Nt} Pi\mathbf{h}_{\mathbf{i}}\mathbf{h}_{\mathbf{i}}^{*}\right)^{-1} h_{\mathrm{k}} \tag{12}$$

Simulation Setup, Results and Analysis

This section present simulation parameters as revealed in table 1 and results to verify the various models obtained in Section 2 for ZF and MMSE equalization schemes. We provide simulation results obtained using Matlab 2015a software considering perfect CSI, in single-cell scenarios.

Simulation Setup

This subsection present parameters we exploited for BER simulation performance under MIMO ZF and MMSE equalizers. Table 1 below reveals the simulation parameters:

Table 1: Simulation parameters

Parameter	Value
No. of receive antennas, N_r	varied
No. of transmit antennas, N_t	varied
Channel	Rayleigh flat fading channel
SNR	1-20dB
Noise	Gaussian Noise
Symbols	1000000
Modulation	16-QAM

Results and Analysis

Figs. 1 to 2 present the BER performances as a function of growing antenna dimensions in a single-cell systems setting. It can be seen from the figures that MMSE and ZF performance improves as the antenna numbers grows at the transmitters. However, the performances occurs slowly and then remained unchanged as the antenna number grows above 200 due to saturation.

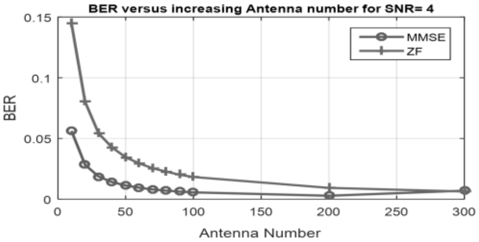

Figure 1: BER versus increasing Antenna number for MMSE and ZF with SNR =4dB

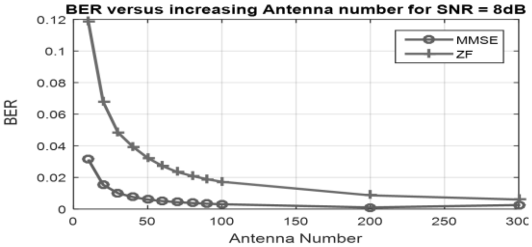

Figure 2: BER versus increasing Antenna number for MMSE and ZF with SNR =8dB

Figs. 4 to 6 reveals that BER performance robustly get betteras the SNR quality improves, and one can see that MMSE outperform ZF, especially at larger antenna number. This can be attributed to MMSE capacity to combat with more interference, noise and channel fading conditions.

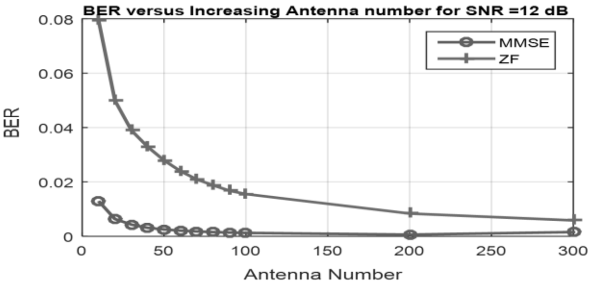

Figure 3: BER versus increasing Antenna number for MMSE and ZF with SNR =12dB

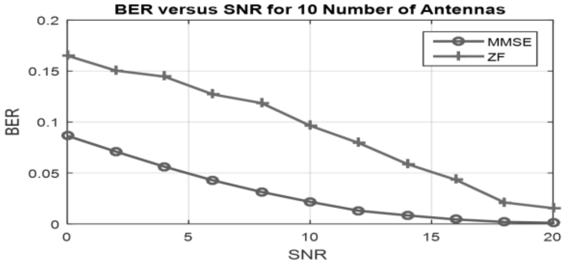

Figure 4: BER a function SNR for MMSE and ZF with 10 Antenna Number

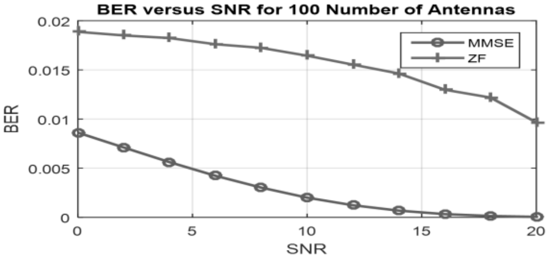

Figure 5: BER a function SNR for MMSE and ZF with 100 Antenna Number

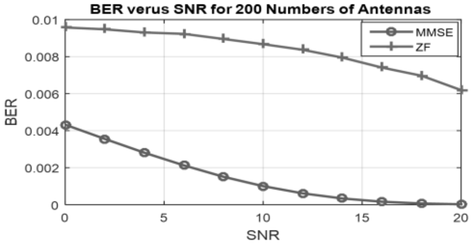

Figure 6: BER a function SNR for MMSE and ZF with 200 Antenna Number

The excellent impacting transmission reliability capability of LS-MIMO as function of SNR can been seen in Figs.7 and 8 for both equalization schemes. Again, the MMSE ability to cope with both interference and noise effects over ZF is also clearly seen from the plotted BER performance graphs.

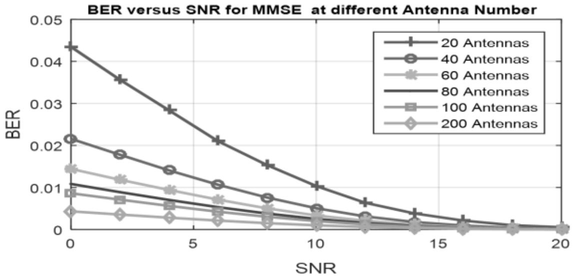

Figure 7: BER a function SNR for MMSE with different Antenna Number

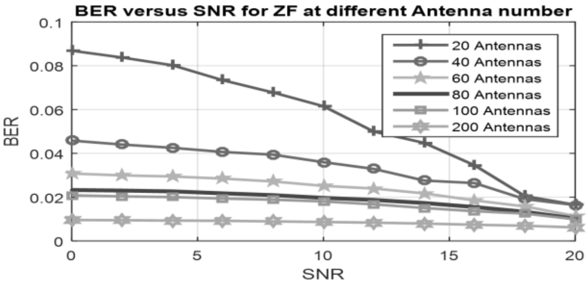

Figure 8: BER a function SNR for ZF with different Antenna Number

Conclusion

In this work, the excellent resultant impact of large-scale MIMO antenna systems link transmission reliability in terms of BER quality, under MMSE and ZF equalization schemes have been demonstrated via Matlab computer simulations. Specifically, it is clearly revealed from the simulation results that the ZF-based equalizer is good enough to combat noise free channel and remove inter symbol interference, nonetheless the MMSE-based equalizer performs better as the number of antenna increases at the receiver.This can be justified by the fact that MMSE-based equalizer poses the capacity suppress both noise and interference among users for enhanced data transmission reliability thereby delivering higher performance gains at the receivers.

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