# Design and Investigation of CDMA Baseband Transceiver Based Fourier Signals for Different Channel Estimation Algorithms in SUI Channels

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## Abstract

Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) and are the technology used in all third generation cellular communications networks, and it is a promising candidate for the definition of fourth generation standards. This paper refers to channel estimation based on time-domain channel statistics. Using a general model for Stanford University Interim SUI channels model, the aim of the paper is to find out the most suitable channel estimation algorithms for the existing CDMA and modified the bit error rate for this system. Starting with the analysis of channel estimation algorithms, we present the Minimum Mean Square Error (MMSE) and Least Square (LS) estimators and compromising between performances under different channel scenarios. The bit error rate for a 16-QAM system is presented by methods of Matlab simulation results.

**Keywords:** CDMA, OFDM, MMSE, LS, SUI.

## 1. Introduction

The wireless manufacturing has grown extremely in recent years. The radio bandwidth resources are scarce and they are used inefficiently. As more personal services appear and the number of the mobile users increases the state becomes worse. The consumers want more services with the increasing demands for better quality and for cheaper products. The great demand from the customers has compelled to making advances in the communication technology. Code Division Multiple Access (CDMA) system is the third generation mobile communication technique and it has been used especially in the military communication for over sixty years in the USA (Pukrushpan.J.T 2004). In present time it appears in the telecommunication area as an applicable technique. The Telecommunication Industry Association (TIA) has presented the IS-95 cellular standard for CDMA that has more strengthened the position of CDMA. Code division multiple access (CDMA) is a multiple access technique where different users share the same physical medium, that is, the same frequency band, at the same time. In cellular system, digital modulation for communication is widely used due to demand for increased capacity in these networks. Since multiple users require simultaneous access to the communication channel in a digital communication system, a share of the available communication resources must be assigned to each user. The most widely used multiple access technique in digital cellular system is CDMA (Hsu 2012). The main ingredient of CDMA is the spread spectrum technique, which uses high rate signature pulses to enhance the signal bandwidth far beyond what is necessary for a given data rate. In a CDMA system, the different users can be identified and, encouraging separated at the receiver by means of their characteristic individual signature pulses, that is, by their individual codes. Now, the most prominent applications of CDMA are mobile communication systems like CDMA One (IS-95), UMTS or CDMA 2000. To apply CDMA in a mobile radio environment, specific additional methods are required to be implemented in all these systems (Wang 2004). Methods such as power control and soft handover have to be applied to control the interference by other users and to be able to separate the users by their respective codes. Channel estimation is an important issue in any OFDM-based system for demodulation and decoding. In general, an OFDM waveform can be viewed as a two-dimensional (2D) lattice in the time-frequency plane. For pilot-assisted channel estimation techniques, where pilots refer to reference signals known at transmitter and receiver, this 2D lattice can be viewed as being sampled at the pilot positions, and the channel characteristics between pilots are estimated by interpolation. The two basic aspects of OFDM channel estimation are the arrangement of pilot positions, and the design of the channel estimator to interpolate between the pilots. The goal in designing channel estimators is to solve this problem with a satisfactory tradeoff between complexity and performance. Channel estimation techniques for CDMA systems have been widely studied. In (Shen 2006) he summarized and compared these two basic channel estimation strategies. The two fundamental principles behind these algorithms are to reduce the computational complexity by adopting one-dimensional (1D) rather than two-dimensional (2D) channel estimators, and to improve the interpolation accuracy by employing second-order statistics of the fading channel in either the frequency or in the time dimension. In (Savitri Galih 2010) , they present low complexity partial-sampled MMSE channel estimation for compromising between complexity and performance. They reduced MMSE channel estimation complexity by partially sampling the MMSE weight matrix.

## 2. Channel Estimation Methods

The channel estimation techniques for OFDM systems based on pilot arrangement are investigated in this section. The channel estimation based on comb type pilot arrangement is studied through different algorithms for both estimating channel at pilot frequencies and interpolating the channel. The estimation of channel at pilot frequencies is based on LS and LMS. The principal of the channel least square estimator (LS) is minimizing the square distance between the received signals $\overline{Y}$ and the original signal $\underline{\mathrm{X}}$ as follows (C. Lim 2006):

$$\min_{H^T} J(H) = \min_{\mathrm{H^T}} \left\{ \left| \overline{Y} - \underline{\mathrm{X}} . \overline{H} \right|^2 \right\}$$
$$= \min_{\mathrm{H^T}} \left\{ \left( \overline{Y} - \underline{\mathrm{X}} . \overline{H} \right)^{\mathrm{T}} \left( \overline{Y} - \underline{\mathrm{X}} . \overline{H} \right) \right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, $(.)^T$ is the conjugate transpose operator.

By differentiating expression (2) with respect to $\overline{H}^T$ and finding the minima, we obtain

$$\frac{\partial}{\partial \overline{H}^T} J(H) = -\underline{\mathrm{X}}^T \overline{Y} + \underline{\mathrm{X}}^T \underline{\mathrm{X}} \overline{H} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Finally, the LS channel estimation is given by (C. Lim 2006):

$$\overline{\overline{H}}_{LS} = \underline{\mathrm{X}}^{-1} \overline{Y} = \left[ \frac{Y_0}{X_0} \quad \frac{Y_1}{X_1} \quad \cdots \quad \frac{Y_{N_C - 1}}{X_{N_C - 1}} \right]^T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In general, LS channel estimation technique for OFDM system has low complexity but it suffers from a high mean square error (C. Lim 2006). The MMSE estimator employs the second-order statistics of the channel conditions to minimize the mean-square error. Denote by $\underline{R}_{hh}$ , $\underline{R}_{HH}$ and • $\underline{R}_{YY}$• the auto-covariance matrix of $\overline{h}$ , $\overline{H}$ and $\overline{Y}$ , respectively, and by $\underline{R}_{hY}$• the cross covariance matrix between $\overline{h}$ ,and $\overline{Y}$ Also denote by $\sigma_N^2$ the noise variance $\left\{ \left| \overline{N} \right|^2 \right\}$ .Assume the channel vector $\overline{h}$ and the noise $\overline{N}$are uncorrelated, this quantity are given by (Savitri Galih 2010):

$$\underline{R}_{HH} = E\left\{ \overline{H}\ \overline{H}^2 \right\} = E\left\{ \left( \underline{\mathrm{F}}\, \overline{h} \right) \left( \underline{\mathrm{F}}\, \overline{h} \right)^H \right\} = \underline{\mathrm{F}}\, \underline{R}_{hh}\, \underline{\mathrm{F}}^H \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\underline{R}_{hY} = E\left\{ \overline{h}\ \overline{Y}^H \right\} = E\left\{ \overline{g}\ \left( \underline{\mathrm{X}}\ \underline{\mathrm{F}}\, \overline{h} + \overline{N} \right)^H \right\} = \underline{R}_{hh}\, \underline{\mathrm{F}}^H \underline{\mathrm{X}}^H \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\underline{R}_{YY} = E\left\{ \overline{Y}\ \overline{Y}^H \right\} = \underline{\mathrm{X}}\, \underline{\mathrm{F}}\, \underline{R}_{hh}\ \underline{\mathrm{F}}^H \underline{\mathrm{X}}^H + \sigma_N^2 \underline{I}_N \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Assume $\underline{R}_{hh}$(thus $\underline{R}_{HH}$ and $\sigma_N^2$ are known at the receiver in advance, the MMSE estimator of $\overline{h}$ is given by(Savitri Galih 2010).

$$\hat{\overline{h}}_{MMSE} = \underline{R}_{hY}\, \underline{R}_{YY}^{-1}\, \overline{Y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

And $\overline{\overline{H}}_{MMSE}$ is calculated as fellow [7]

$$\overline{\overline{H}}_{MMSE} = \underline{\mathrm{F}}\, \hat{\overline{g}}_{MMSE} = \underline{\mathrm{F}} \left[ \left( \underline{\mathrm{F}}^H \underline{\mathrm{X}}^H \right)^{-1} \underline{R}_{gg}^{-1} \sigma_N^2 + \underline{\mathrm{X}}\, \underline{\mathrm{F}} \right]^{-1} \overline{Y}$$
$$= \underline{\mathrm{F}}\, \underline{R}_{gg} \left[ \left( \underline{\mathrm{F}}^H \underline{\mathrm{X}}^H \underline{\mathrm{X}}\, \underline{\mathrm{F}} \right)^{-1} \sigma_N^2 + \underline{R}_{gg} \right] \underline{\mathrm{F}}^{-1} \overline{\overline{H}}_{LS}$$
$$= \underline{R}_{HH} \left[ \underline{R}_{HH} + \sigma_N^2 \left( \underline{\mathrm{X}}\, \underline{\mathrm{X}}^{\mathrm{H}} \right)^{-1} \right]^{-1} \overline{\overline{H}}_{LS} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The MMSE estimator yields much best performance than LS estimators, especially under the low SNR scenarios. A major drawback of the MMSE estimator is its high computational complexity, especially if matrix inversions are needed each time the data in • $\underline{\mathrm{X}}$ changes.

## 3. System model:

The system model of CDMA that used for simulation in this paper is shown in Figure.1. The simulation was applied using Matlab program.

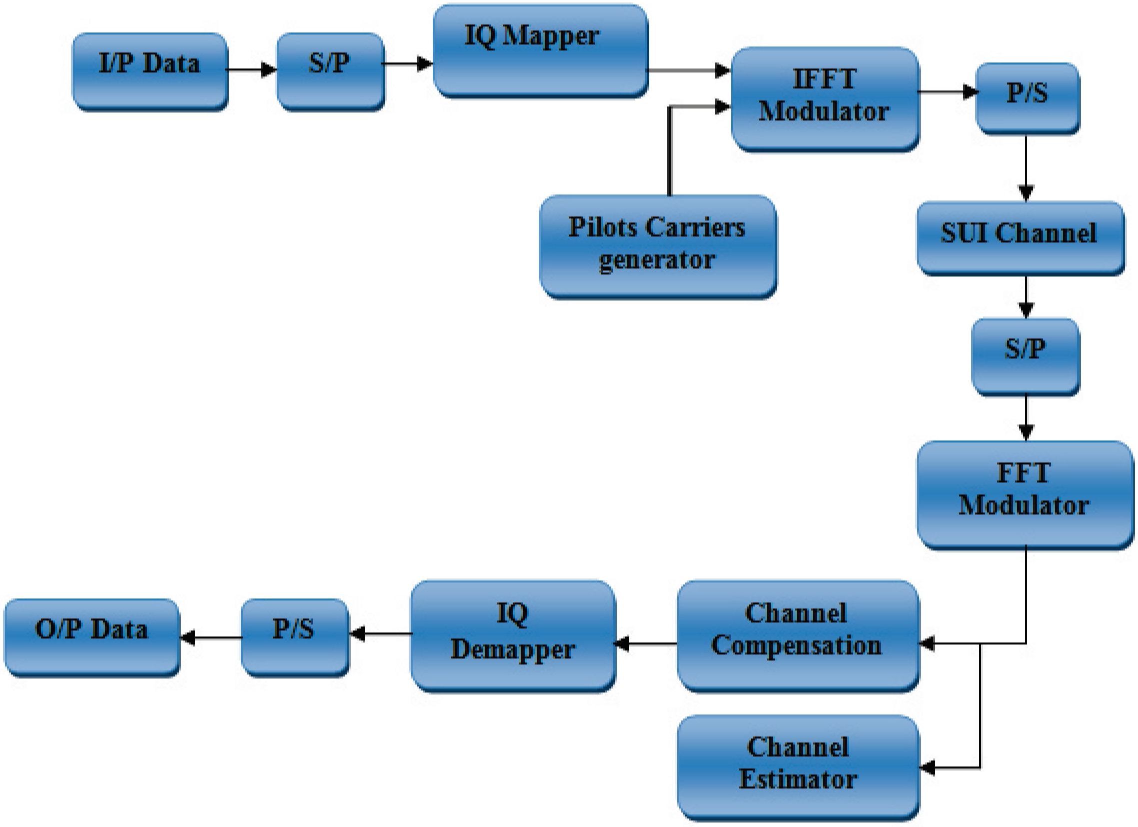

Figure 1. Algorithm of Proposed CDMA Model

The block diagram structure is divided into four main sections: transmitter, receiver, adaptive antenna array algorithm and channel. The transmitter accepts data, and converts it into lower rate sequences via serial to parallel conversion, these lower rate sequences are mapped to give sequences of channel symbols. This process will convert data to corresponding value of M-ary constellation which is complex word, i.e. real and imaginary part. The bandwidth ($B = (1/T_s)$) is divided into N equally spaced subcarriers at frequencies ($k\Delta f$), k=0,1,2,...,N-1 with $\Delta f = B/N$ and, $T_s$ , the sampling interval. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, 16 QAM with constellation $C_{QAM}$ is assumed for the symbol mapping. We assume that half of the virtual carriers are on both ends of the spectral band. Which consists of the OFDM modulator and demodulator. The training frame (pilot sub-carriers frame) are inserted and sent prior to the information frame (H. Schulze and C. Lüders 2005) . This pilot frame is used to provide channel estimation, which is used to compensate for the channel effects on the signal. The spread data symbol is modulate on the orthogonal carriers, an N-point Inverse Fourier Transform IFFT is used, as in conventional OFDM. Zeros are inserted in some bins of the IFFT to compress the transmitted spectrum and reduce the adjacent carriers' interference. The appended zeros to some sub-carriers limit the bandwidth of the system, while the system without the zeros pad has a spectrum that is spread in frequency. The last case is unacceptable in communication systems, since one limitation of communication systems is the width of bandwidth. The addition of zeros to some sub-carriers means not all the sub-carriers are used; only the subset ($N_c$) of total subcarriers ( $N_F$) is used. Therefore, the number of bits in OFDM symbol is equal to $\log_2(M) * N_c$. Orthogonality between carriers is normally destroyed when the transmitted signal is passed through a dispersive channel. When this occurs, the inverse transformation at the receiver cannot recover the data that was transmitted perfectly. Energy from one sub-channel leaks into others, leading to interference. However, it is possible to rescue orthogonality by introducing a cyclic prefix (CP). This CP consists of the final $v$ samples of the original $K$ samples to be transmitted, prefixed to the transmitted symbol. The length $v$ is determined by the channel's impulse response and is selected to minimize ISI. If the impulse response of the channel has a length of less than or equal to $v$, the CP is sufficient to eliminate ISI and ICI. The Fourier based OFDM utilize the complex exponential bases functions. If the number of sub-channels is sufficiently large, the channel power spectral density can be assumed virtually flat within each sub-channel. In these kinds of channels, multicarrier modulation has long been familiar to be optimum when the number of sub-channels is large. The size of sub-channels needed t approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. The computation of FFT and IFFT for 256 point. After which, the data changed from parallel to serial are fed to the channel SUI models (Daniel S. Baum 2001). In This section will introduce the system model of an N subcarrier OFDM system with transmit antenna and receive antennas in the presence of transmit antenna and path correlations. The worst performance of the SUI channels is due to multipath effect, delay spread and Doppler effects. Although the impact of the delay spread and the Doppler effect is low so the major degradation in the performance is due to the multipath effects. The receiver performs the same operations as the transmitter, but in a reverse order. In addition, the receiver includes operations for synchronization, compensation and channel estimation proposed for the destructive SUI channels.

## 4. Simulation Results

In this section the simulation of the proposed adaptive antenna array system in CDMA and comparing without adaptive antenna array system is executed, beside the BER performance of the system regarded in SUI channel models. .

Table (1) System parameters

| | |
|---|---|
| **Channels** | SUI |
| **Cyclic prefix** | 1/8 |
| **Number of sub-carriers** | 256 |
| **Number of FFT points** | 256 |
| **Modulation type** | 16 QAM |

### *4.1 Performance of SUI-1 channel:*

In this scenario, the results obtained were encouraging. With the Minimum Mean Square Error (MMSE) and the Least Square (LS) estimators it can be seen that for BER=$10^{-3}$ the SNR required for (MMSE) is about 16.1 dB while in with (LS) the SNR about 17. 5dB from figure 2 it is found that the using (MMSE) outperforms significantly other system for this channel model. It can be concluded that the With (MMSE) is more significant than the other systems in this channel that have been assumed.

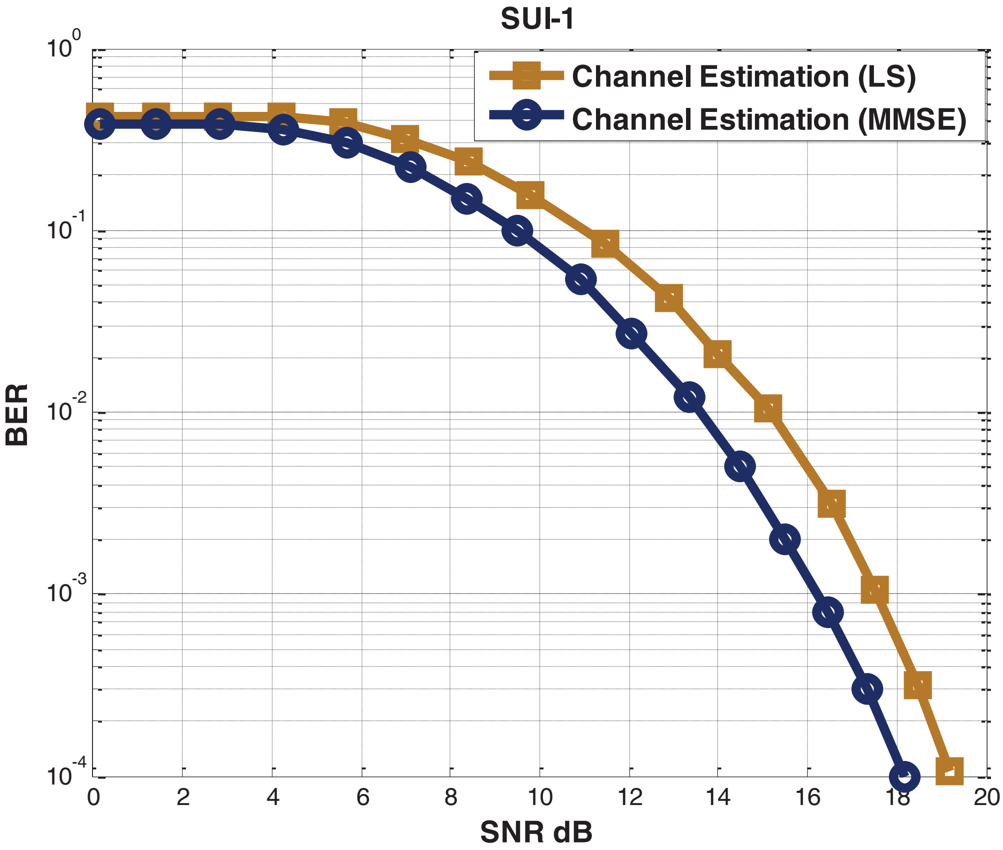

Figure 2. BER performance of proposed model in SUI-1 channel

*4.2 Performance of SUI-2 channel:*

In this simulation profile some influential results were obtained. the Minimum Mean Square Error (MMSE) and the Least Square (LS) estimators it can be seen that for BER=$10^{-3}$ the SNR required for the system with (MMSE) is about 21 dB while in with (LS) the SNR about 22. 5 dB from Figure 3 it is found that the system with (MMSE) outperforms significantly other system for this channel model.

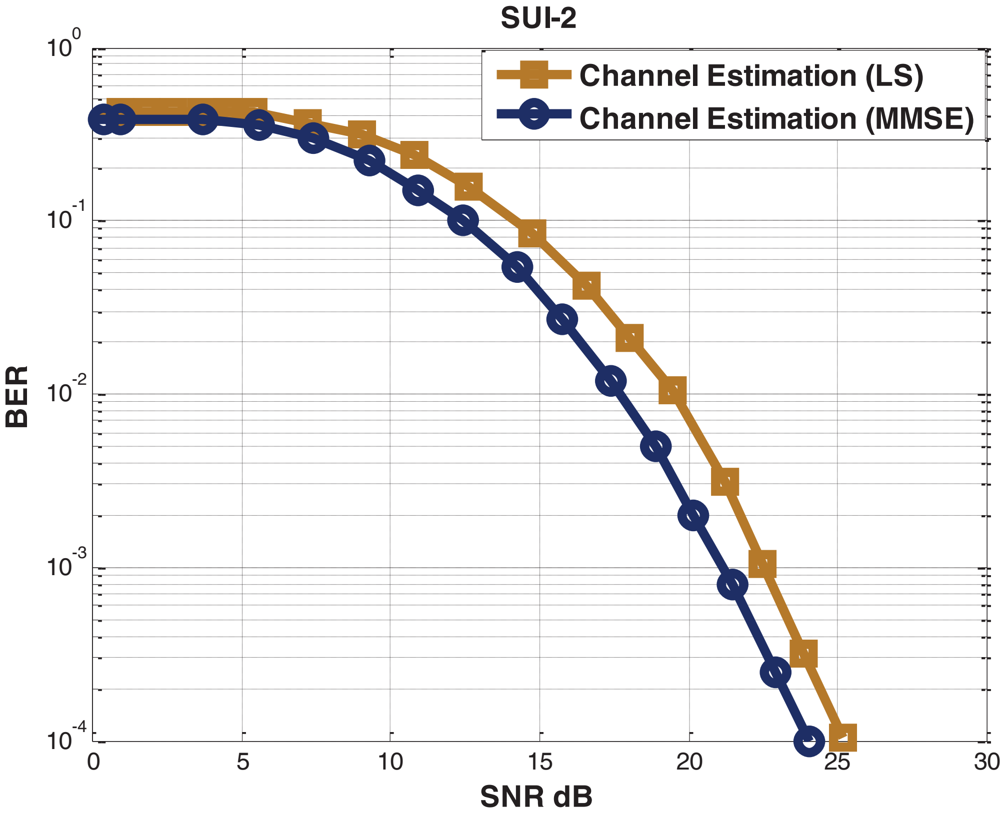

Figure 3. BER performance of proposed model in SUI-2 channel

*4.3 Performance of SUI-3 channel:*

In this simulation profile some influential results were obtained. the Minimum Mean Square Error (MMSE) and the Least Square (LS) estimators it can be seen that for BER=$10^{-3}$ the SNR required for the system with (MMSE) is about 21 dB while in with (LS) the SNR about 22. 5 dB from Figure 3 it is found that the system with (MMSE) outperforms significantly other system for this channel model.

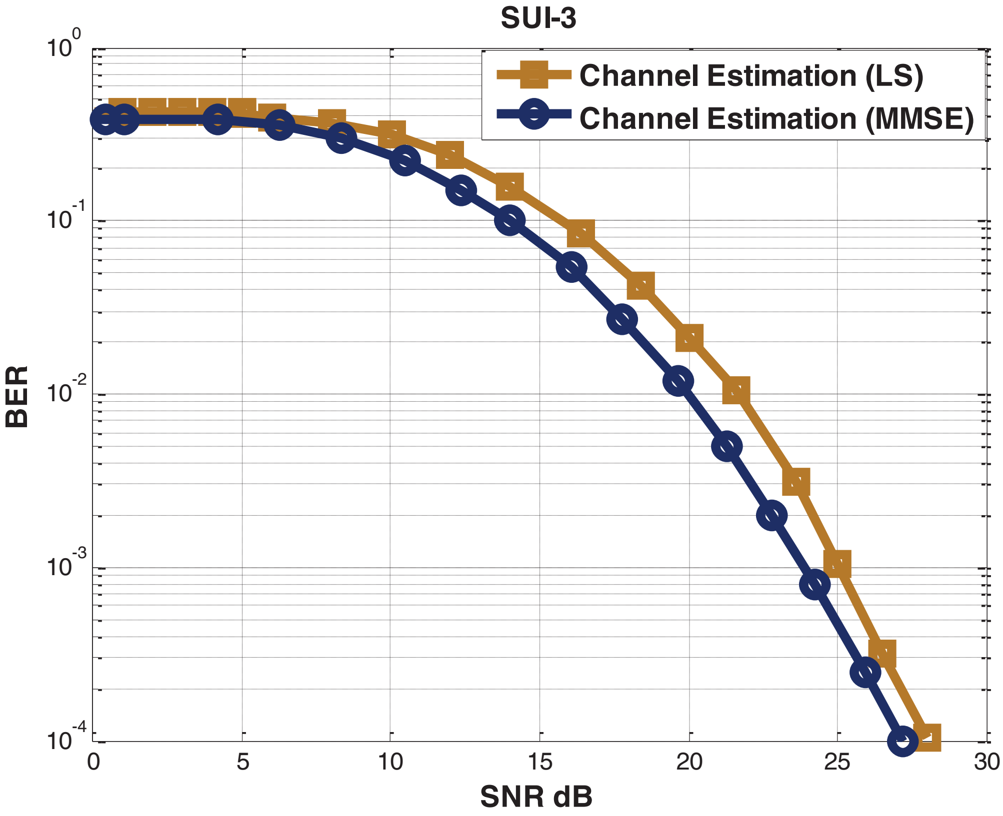

Figure 4. BER performance of proposed model in SUI-3 channel

### *4.4 Performance of SUI-4 channel:*

In the SUI-3 channel, the results are depicted in Figure 4 it can be seen that for BER=10$^{-3}$ the SNR required for the CDMA model with the Minimum Mean Square Error (MMSE) is about 24 dB, while in with the Least Square (LS) estimators the SNR about 25 dB, From Figure 4 it is found that the CDMA with (MMSE) outperforms significantly than other systems for this channel model

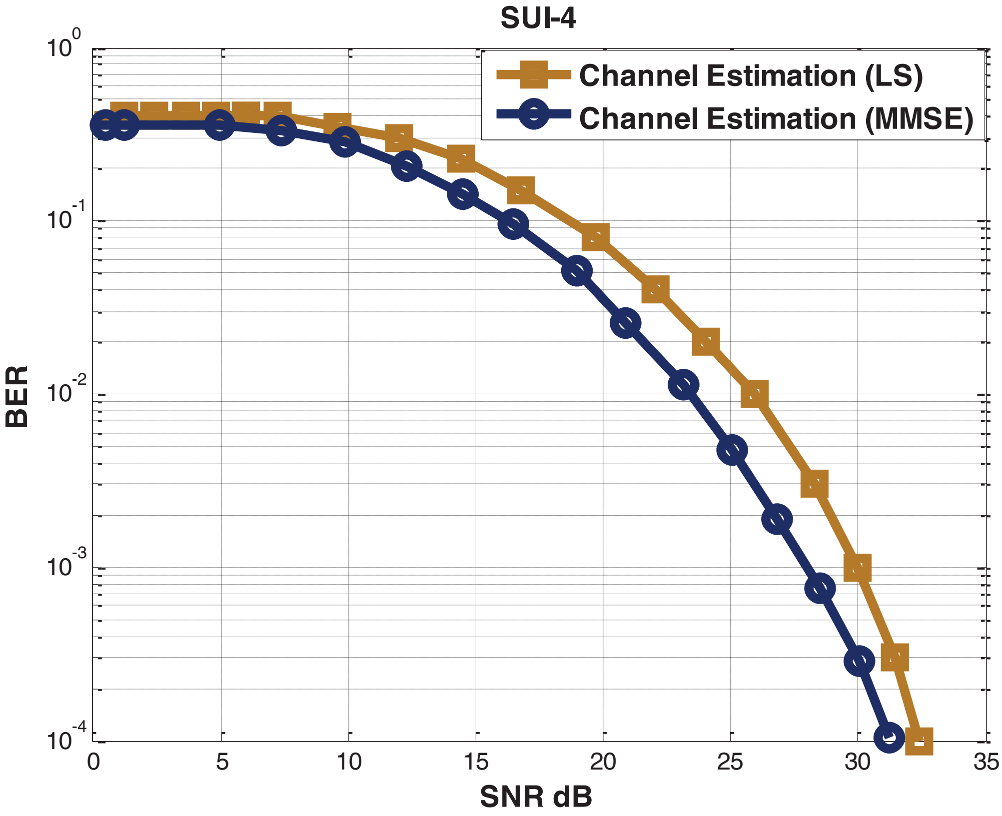

Figure 5. BER performance of proposed model in SUI-4 channel

*4.5 Performance of SUI-5 channel:*

In this model, the results obtained were encouraging. The system With the Minimum Mean Square Error (MMSE) and with the Least Square (LS) estimators it can be seen that for BER=$10^{-3}$ the SNR required for with (MMSE) is about 33 dB while in with (LS) the SNR about 36.65 dB From Figure 6, it is found that the CDMA with (MMSE) is best than other system for this channel model.

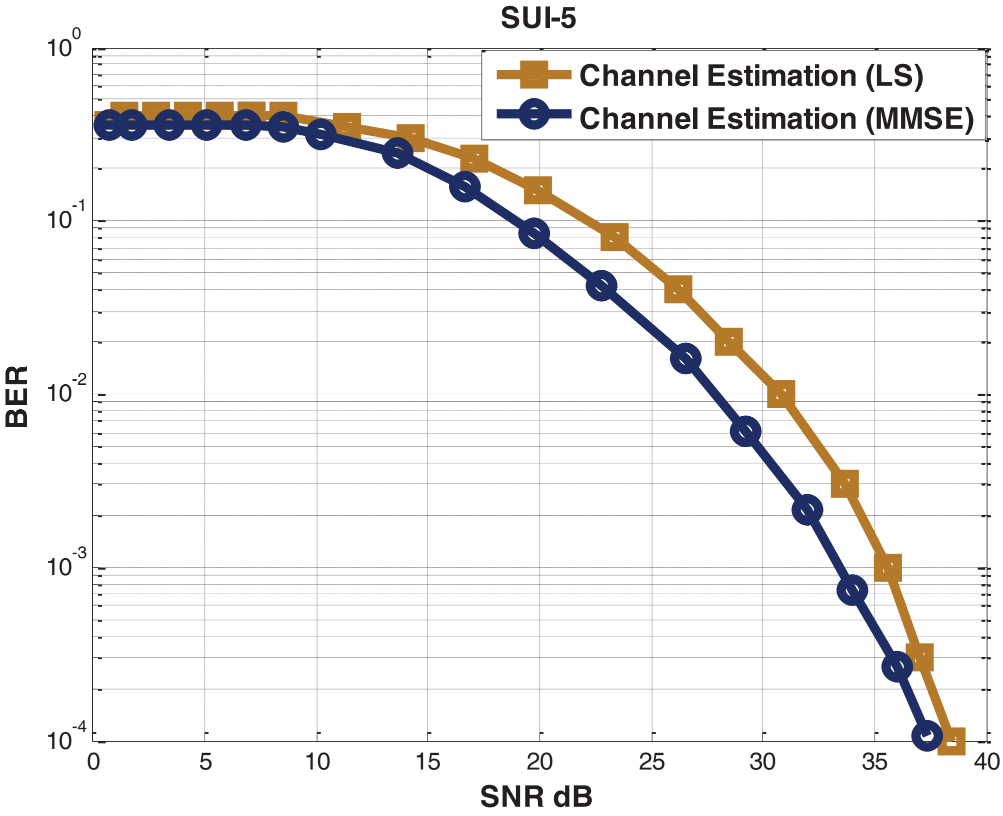

Figure 6. BER performance of proposed model in SUI-5 channel

*4.6 Performance of SUI-6 channel:*

In this state, the results obtained were hopeful. With the Minimum Mean Square Error (MMSE) and with the Least Square (LS) estimators it can be seen that for BER=$10^{-3}$ the SNR required for the system with (MMSE) is about 42.6 dB while in with (LS) the SNR about 46.25 dB From Figure 7 it is found that the CDMA with (MMSE) is better than other system for this channel model

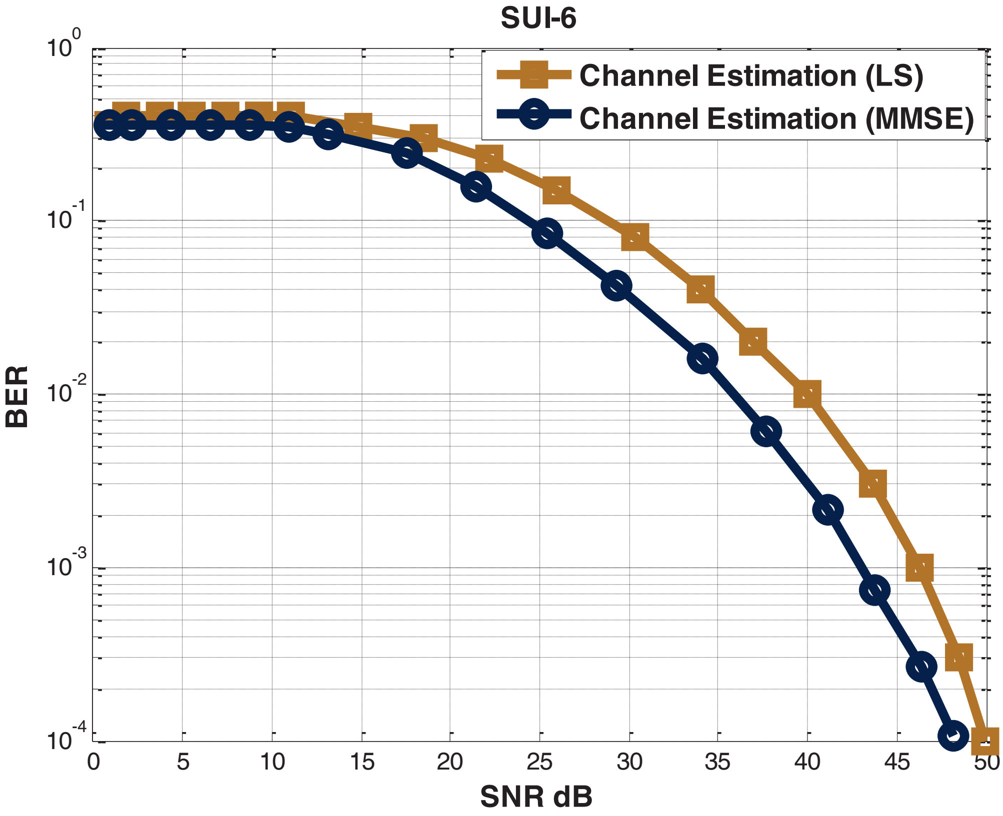

Figure 7. BER performance of proposed model in SUI-6 channel

*Table (2) Comparison between results*

| Channel for BER= $10^{-3}$ | SUI-1 dB | SUI-2 dB | SUI-3 dB | SUI-4 dB | SUI-5 dB | SUI-6 dB |
|---|---|---|---|---|---|---|
| **Channel Estimation (LS) dB** | 17.5 | 22.5 | 25 | 30 | 35.63 | 46.25 |
| **Channel Estimation (MMSE) dB** | 16.1 | 21 | 24 | 28 | 33 | 42.6 |

A number of important results can be taken from Table (2); In this simulation, in most scenarios, the CDMA system with (MMSE) was better than the CDMA system with (LS) , user-channel characteristics under which wireless communications is tested or used have important impact on the systems overall performance. It became clear that SUI channels with larger delay spread are a bigger challenge to any system. The system with (MMSE) proved its effectiveness in combating the multipath effect on the SUI fading channels.

## 5. Conclusions

This paper concentrated on two channel estimation approach for CDMA. Simulations provided proved that proposed design using Channel Estimation (MMSE) achieves much lower bit error rates and better performance than Channel Estimation (LS). Proposed systems design is robust for SUI channels. From obtained results in Table (2) it can be concluded, that SNR can be successfully increased and reduced the bit errors rate (BER) when using proposed Channel Estimation (MMSE).

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