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Design and Investigation of LTE 3GPP Baseband Transceiver Based Fourier Signals for Different Channel Estimation Algorithms in SUI Channels

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Abstract

3GPP LTE is the evolution of the UMTS in response to ever-increasing demands for high quality multimedia services according to users' expectations. These technologies have been selected for LTE 3GPP. Pilot-assisted channel estimation is a method in which known signals, called pilots, are transmitted along with data to obtain channel knowledge for proper decoding of received signals. This paper refers to channel estimation based on time-domain channel statistics. Using a general channels model for Stanford University Interim (SUI) Channel Models, the aim of the paper is to find out the most suitable channel estimation algorithms for the existing LTE 3GPP Baseband Transceiver 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 SUI channel scenarios. Performance of these algorithms has been measured in terms of Bit Error Rate (BER). The bit error rate for a 16-QAM system is presented by methods of Matlab simulation results.

Keywords: LTE 3GPP, MMSE, LS, OFDM, SUI.

1. Introduction

As compared to previous used cellular technologies like UMTS (universal mobile technology systems) or high speed down-link packet access (HSDPA), the Physical Layer of LTE is designed to deliver high data rate, low latency, packet-optimized radio access technology and improved radio interface capabilities. Wireless broadband internet access and advanced data services will be provided by this technology. LTE physical Layer will provide peak data rate in uplink up to 50 Mb/s and in downlink up to 100 Mb/s with a scalable transmission bandwidth ranging from 1.25 to 20 MHz to accommodate the users with different capacities. For the fulfillments of the above requirements changes should be made in the physical layer (e.g., new coding and modulation schemes and advanced radio access technology). In order to improve the spectral efficiency in downlink direction, Orthogonal Frequency Division Multiplex (OFDM), together with multiple antenna techniques is exploited. In addition, to have a substantial increase in spectral efficiency the link adaption and frequency-domain scheduling are exercised to exploit the channel variation in time/frequency domain. LTE air interface exploits both time division duplex (TDD) and frequency division duplex (FDD) modes to support unpaired and paired spectra (Juan J. Sanchez 2007; Borko Furht and Syed A. Ahson 2009). For more detailed description of LTE physical layer covering uplink and downlink in see (T. Haustein 2007 ; 3GPP TS 36.201 V8.3.0 2009). 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 LTE 3GPP Baseband Transceiver 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. Several channel estimation techniques have been proposed to overcome ICI in OFDM. To facilitate the estimation of the channel in an OFDM system (such as WiMAX, WiFi, and 3.9/4G), known signals or pilots could be inserted in the transmitted OFDM symbol (M. Rumney 2009) . In this paper we present a compared between the Minimum Mean Square Error (MMSE) and Least Square (LS) estimators for LTE 3GPP Baseband Transceiver. The principle of this comparison is to use the information given by the reference signals to estimate the channel frequency response.

2. Channel Estimation Algorithms

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 $\underline{X}$ as follows (C. Lim 2006)

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

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

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

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

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

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 σ_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 (S. Galih 2010)

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

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

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

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

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

And $\widehat{\overline{H}}_{MMSE}$ is calculated as fellow (S. Galih 2010)

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

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 • $\underline{X}$ changes.

3. System model

The system model of LTE 3GPP Baseband Transceiver that used for simulation in this paper is shown in Figure.1. The simulation was applied using Matlab program.

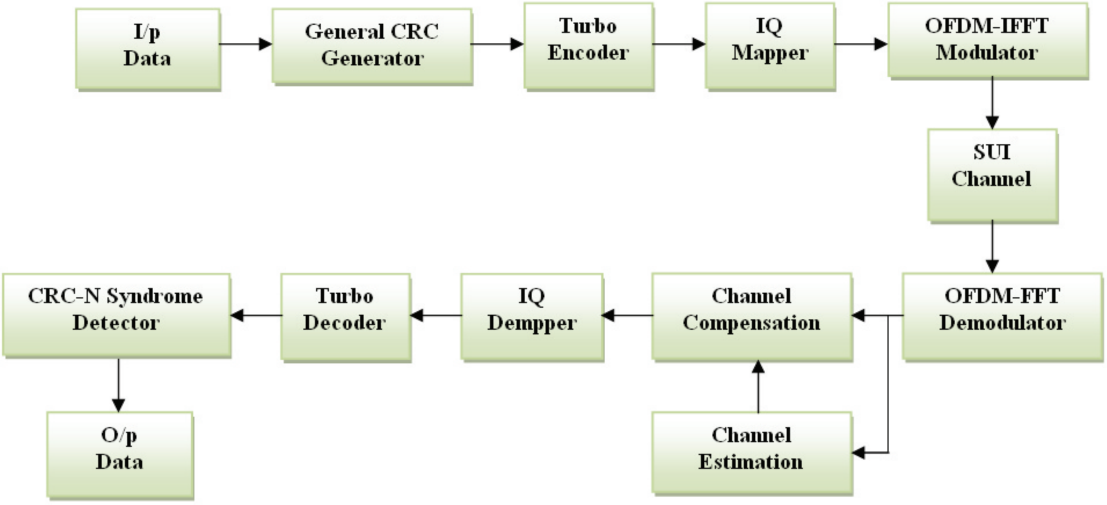

Figure .1.Block Diagram of Proposed LTE Transceiver Structure in SUI Channel

In transmitter the transport channel is the interface between the physical layer and the MAC layer. As the LTE simulator focuses on the physical layer, the initial data is generated in the form of transport blocks .The transmitter in the physical layer starts with the resource data which are in the form of transport blocks (see Figure 1). In each, one transport block will be transferred first to the channel coding part which consists of two CRC encoders and one Turbo encoder. According to (C. Berrou 1993), an encoder of Cyclic Redundancy Check (CRC) is utilized at the beginning of channel coding. There are two CRC schemes for PDSCH: '*gCRC24A*' and '*gCRC24B*'. Both of them possess a 24 parity bits length, but work with different cyclic generator polynomials. The '*gCRC24A*' focuses on a transport block, while the '*gCRC24B*' focuses on the code block. The channel coding scheme for PDSCH adopts Turbo coding, which is a kind of robust channel coding. The performance of Turbo codes can be close to the theoretical Shannon capacity limits. According to (C. Berrou 1993), the scheme of the Turbo encoder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one Turbo code internal interleaver. The theoretical structure of a Turbo encoder in (C. Berrou 1993). As illustrated in Figure 1, the modulation scheme used is the 16 QAM coding rate (1/2) with gray coding in the constellation map. This process converts data to the corresponding value of constellation, which is a complex word (with a real and an imaginary part). The bandwidth ($B = (1/T_s)$) is divided into N equally spaced of groups subcarriers at frequencies ($k\Delta f), k=0,1,2,...,N-1$ with $\Delta f = B/N$ and T_s as the sampling interval. At the transmitter, information bits are classified and mapped into complex symbols. In this system, (QAM) with constellation C_{QAM} is the modulation scheme used to map the bits to symbols 16QAM with (1/2) coding rate To modulate spread data symbol on the orthogonal carriers, an N-point Inverse Fourier Transform IFFT shall be used, as in conventional OFDM. Zeros will be inserted in some bins of the IFFT in order to make the transmitted spectrum compact and reduce the adjacent carriers' interference. The addition of zeros to some sub-carriers means that not all the sub-carriers will be used; only subset (N_c) of total sub-carriers (N_F) will be 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 SUI channels (Daniel S. Baum 2001). However it is possible to rescue orthogonality by introducing a cyclic prefix (CP). This CP comprises of the final v samples of the original K samples to be transmitted, prefixed to the transmitted symbol. The length v is known by the channel's impulse response and is chosen to minimize ISI. If the impulse response of the channel has length lesser than or equal to v, the CP is sufficient to completely eliminate ISI and ICI. If the numbers of group's sub-channels are sufficiently large, the channel power spectral density can be assumed virtually flat within each group's of sub channel. Computation IFFT 256 point for data after that the data convert from parallel to serial these data are fed to the channel model the receiver performs the same operations as the transmitter, but in a reverse order. It also contains operations for synchronization and compensation for the destructive channel.

5. Simulation and Results

The reference model specifies a number of parameters that can be found in Table (1).

Table 1 System parameters

Transmission Bandwidth	**2.5 MHz**
Sub-frame duration	**0.5ms**
Sub-carrier spacing	**15KHz**
Sampling Frequency	**3.84MHz**
FFT Size	**256**
OFDM symbol per slot (short/long CP	**7/6**
CP length (µsec/samples)	**SHORT (4.69/18) x 6 (5.21/20) x 1 LONG (16.67/64)**
Modulation type	**16QAM**
Channel coding	**Turbo**
Channel type	**SUI Channel**
Receiver decoder type	**Soft sphere detection (SSD)**
Number of iterations	**1000**

In this section the simulation of the proposed channel estimation algorithms for the existing in LTE 3GPP Baseband Transceiver and comparing between LS vs. MMSE is executed, beside the BER performance of the system regarded in SUI channel models.

4.1 Performance of LTE Transceiver in SUI-1 Channel

In this scenario, the results obtained were encouraging. When using channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required for (MMSE) is about 11.88 dB while in (LS) the SNR about 13.13 dB from Figure 2 it is found that the when 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

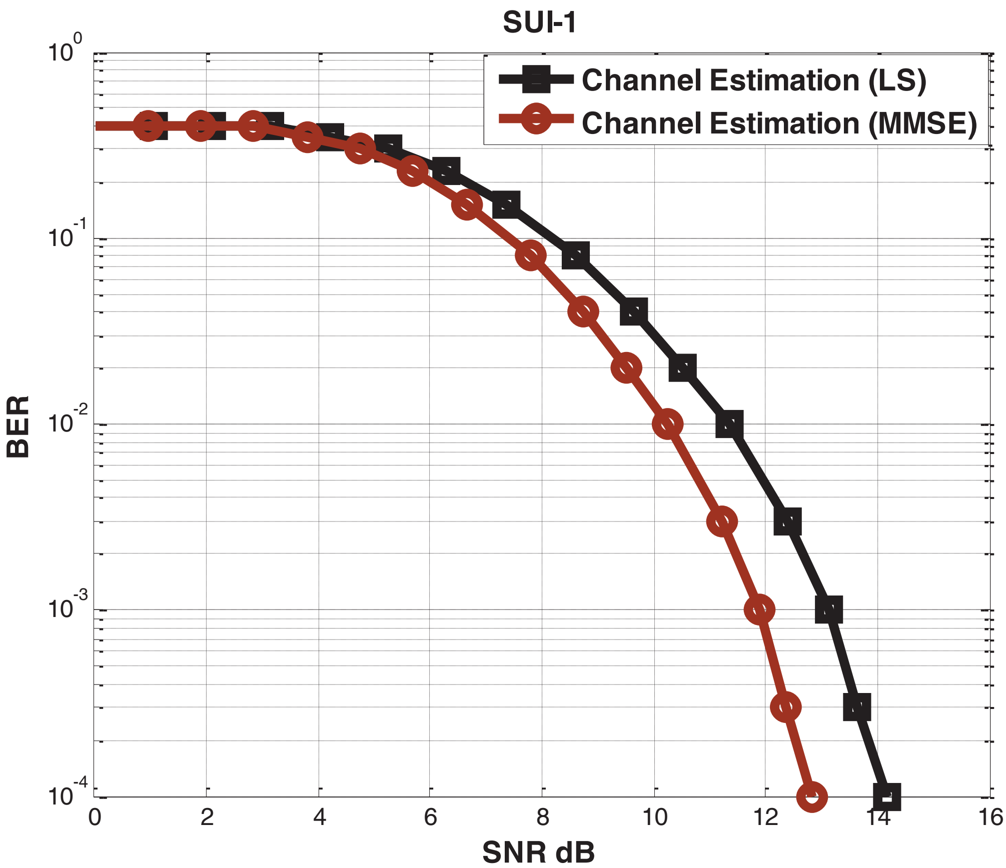

Figure 2. BER performance of proposed model in SUI-1 channel

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4.2 Performance of LTE Transceiver in SUI-2 Channel

In this simulation profile some influential results were obtained. With channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required for (MMSE) is about 16.25 dB while in (LS) the SNR about 17.5 dB from Figure 3 it is found that the when 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.

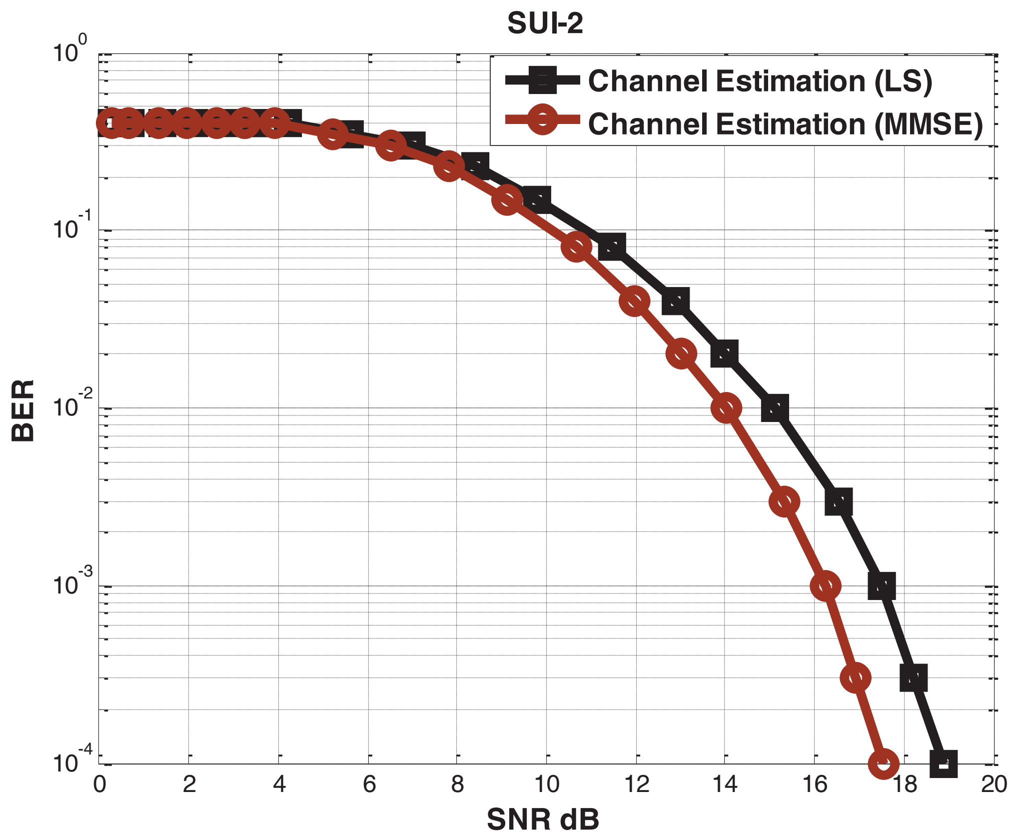

Figure 3. BER performance of proposed model in SUI-2 channel

4.3 Performance of LTE Transceiver in SUI-3 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 LTE 3GPP baseband transceiver based wavelet signals when using (MMSE) is about 21.25 dB, while when using (LS) the SNR about 22.5 dB, from Figure 4 it is found that the transceiver when using (MMSE) outperforms significantly than other systems for this channel model.

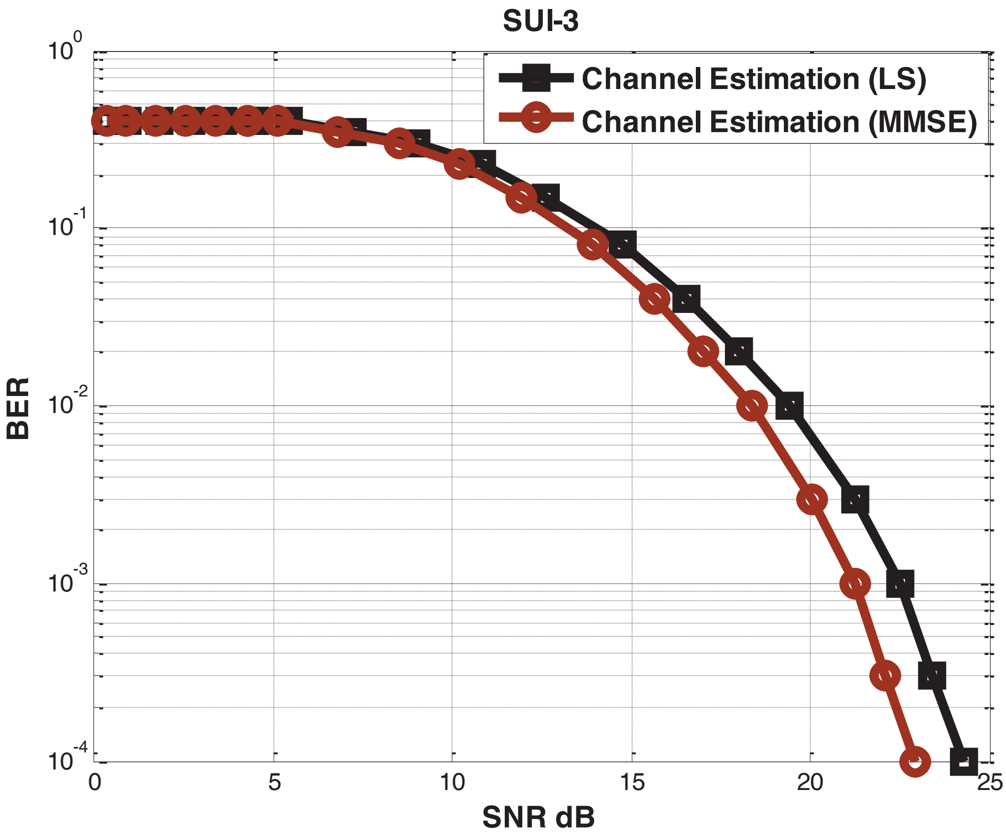

Figure 4. BER performance of proposed model in SUI-3 channel

4.4 Performance of LTE Transceiver in SUI-4 Channel

Using similar methodology as in the previous section, simulations for SUI-4 channel The result depicted in Figure 5 it can be seen that for BER=10^{-3} the SNR required for the system when using (MMSE) is about 25.75dB, while when using (LS) the SNR about 27.5dB. Also from Figure 5 it is found that the LTE 3GPP baseband transceiver based wavelet signals when using (MMSE) outperforms significantly than other systems for this channel model.

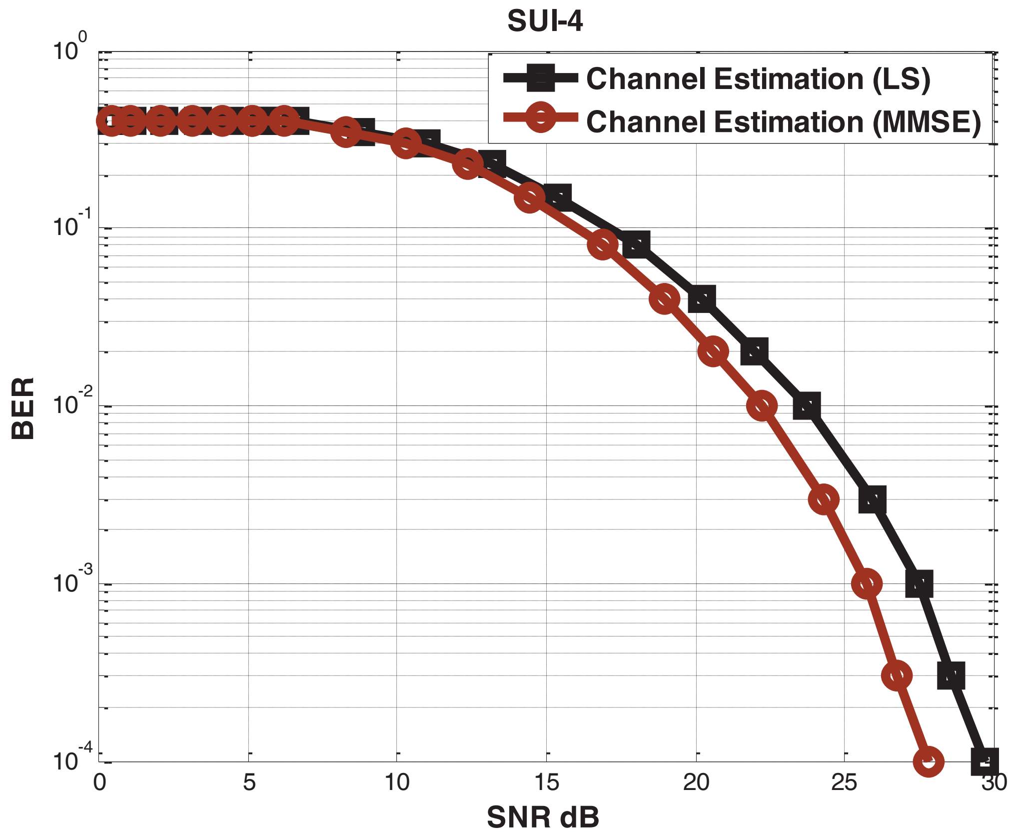

Figure 5. BER performance of proposed model in SUI-4 channel

4.5 Performance of LTE Transceiver in SUI-5 Channel

In this model, the results obtained were encouraging. The system When using channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required for when using (MMSE) is about 30.63 dB while when using (LS) the SNR about 32.5 dB from Figure 6, it is found that the LTE 3GPP baseband transceiver based wavelet signals when using (MMSE) is best than other system for this channel model.

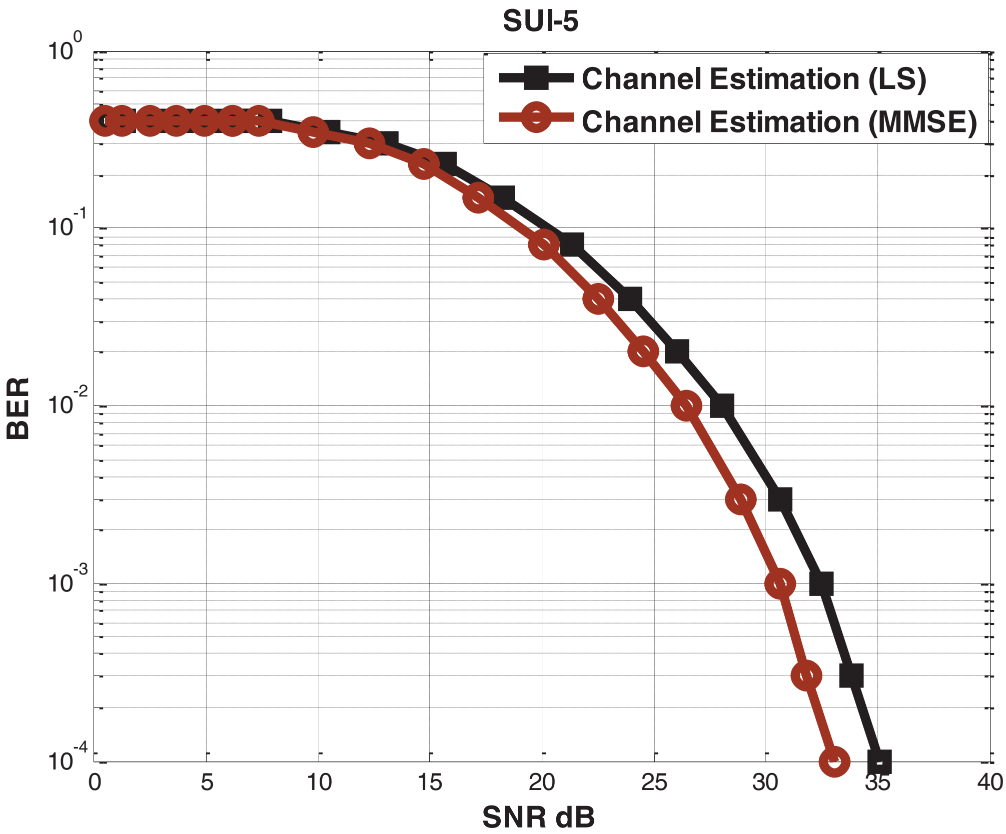

Figure 6. BER performance of proposed model in SUI-5 channel

4.6 Performance of LTE Transceiver in SUI-6 Channel

In this state, the results obtained were hopeful. The system When using channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required for the system when using (MMSE) is about 35.88 dB while when using (LS) the SNR about 37.75 dB from Figure 7 it is found that the LTE 3GPP baseband transceiver based wavelet signals when using (MMSE) is better than other system for this channel model

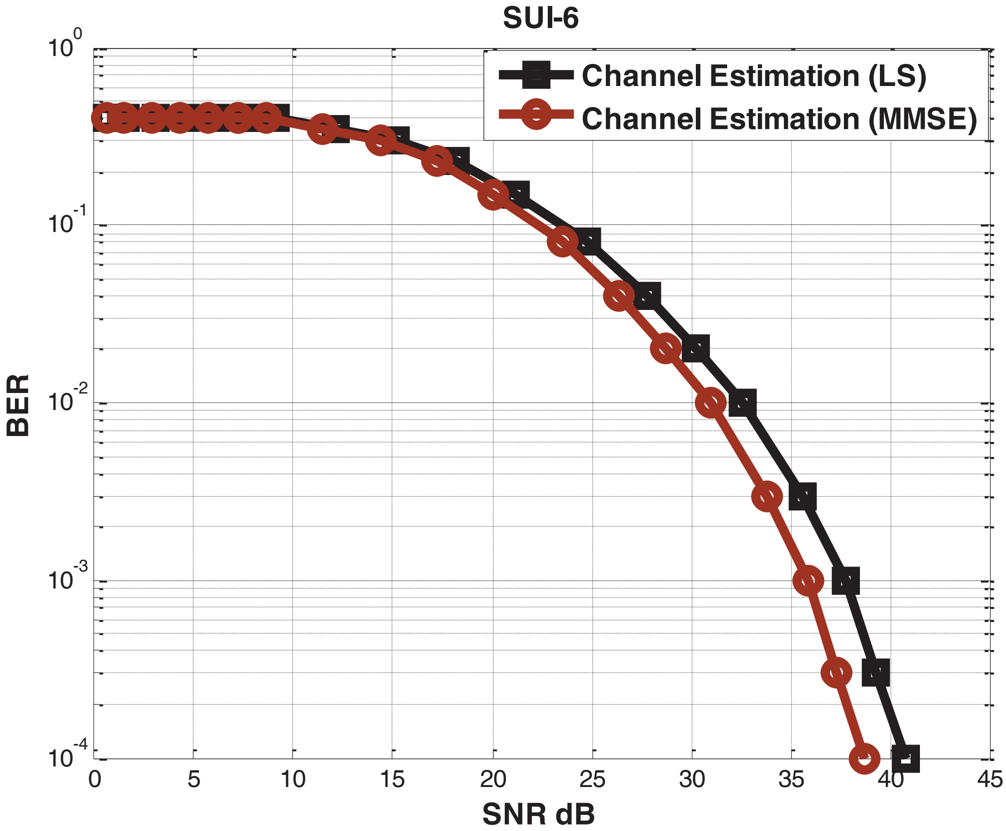

Figure 7. BER performance of proposed model in SUI-6 channel

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
LS dB	13.13	17.5	22.5	27.5	32.5	37.75
MMSE dB	11.88	16.25	21.25	25.75	30.63	35.88

A number of important results can be taken from Table (2); In this simulation, in most scenarios, the LTE 3GPP Baseband Transceiver with the channel estimation (MMSE) was better than the LTE 3GPP Baseband Transceiver with the channel estimation (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 channel estimation (MMSE) proved its effectiveness in combating the multipath effect on the SUI fading channels.

5. Conclusions

The reason of this paper is to evaluate the best channel estimation schemes for LTE 3GPP Baseband Transceiver .We have focused on the task of channel estimation for OFDM based LTE 3GPP Baseband Transceiver. The results for both, (MMSE) and (LS) channel estimation have been presented. The results have been presented by means of Matlab simulations. 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 using proposed Channel Estimation (MMSE) method and performance is superior to LS estimates for higher modulation schemes and large delay spreads.

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