Design and Performance of LTE 3GPP Baseband Transceiver Based Wavelet Signals for Different Channel Estimation Algorithms

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Abstract

Long Term Evolution (LTE) 3GPP advanced is a mobile communication standard. It was formally submitted as a candidate 4G system. This paper refers to channel estimation based on time-domain channel statistics. Using a general 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 modified Long Term Evolution (LTE) 3GPP baseband transceiver based wavelet signals and improvement 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 and OFDM system based wavelet signals is presented by methods of Matlab simulation results.

Keywords: LTE 3GPP, DWT, SUI, OFDM, MMSE, LS, 16-QAM.

1.Introduction

Long Term Evolution (LTE) is that next step and shall be the basis on which future mobile telecommunications systems shall be built. LTE is the first cellular communication system optimized from the outset to support packet-switched data services, within which packetized voice communications are just one part. The 3rd Generation Partnership Project (3GPP) started work on Long Term Evolution in 2004 with the description of targets shown in (Ericsson, 2009). The specifying associated to LTE are formally identified as the evolved UMTS terrestrial radio access network (E-UTRAN) and the evolved UMTS terrestrial radio access (E-UTRA). These are collectively mentioned by the project name LTE. In December 2008, release 8 of LTE has been approved by 3GPP which will allow network operators to appreciate their deployment plans in implementing this technology. A few motivating factors can be identified in advancing LTE growth; enhancements in wire line capability, the requirement for added wireless capacity, the need for provision of wireless data services at lower costs and the competition to the existing wireless technologies. In adding to the continued progression in wire line technologies, a alike growth is required for technologies to work fluently with defined specifications in the wireless domain. 3GPP technologies should match and go beyond the competition with other wireless technologies which guarantee high data capabilities – including IEEE 802.16. To take maximum advantage of obtainable spectrum, large capacity is an essential requirement. LTE is required to provide superior performance compared to High Speed Packet Access (HSPA) technology according to 3GPP specifications. The 3GPP LTE release 8 specifications defines the basic functionality of a new, high-performance air interface providing high user data rates in combination with low latency based on, OFDM (orthogonal frequency division multiplex (3GPP, 2009). Channel estimation is an important issue in any OFDM-based system for demodulation and decoding. In common, 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 mentioned to reference signals known at both transmitter and receiver, this 2D lattice be able to 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 alignment of pilot positions, and the design of the channel estimator to interpolate between the pilots. The aim in designing channel estimators is to solve this problem with an acceptable tradeoff between complexity and performance (Yushi Shen, 2010). Channel estimation techniques for 3GPP LTE 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. Estimation algorithms:

An estimation algorithm is a branch of statistical signal processing. It deals with problem of estimating parameters based on the measured data. The purpose of the estimation theory is to develop an estimator, preferably an implementable one that can be used in practice. The estimator takes the measurement data as inputs and produces estimated values of the parameters (Mohammed Aboud Kadhim, 2014, S. M. Kay, 1993).

$$Y = xH + N \quad \ldots\ldots (1)$$

$$Y = Ah + N \quad \ldots\ldots (2)$$

H and h are unknown vectors. X and A are the known matrices. Y is the measurement matrix for both. Upon this, there are two estimators mainly used for the problem of channel estimation, namely Least Squares (LS) and Minimum Mean Square Error (MMSE). The dependency between frequency domain Y and time domain channel response h can be interpreted as linear thus the system equation in frequency domain comes to be in mathematical terms, taking the Eq.2 as an example, the channel estimation is to find a solution $\hat{h}$ for the equation $A\hat{h} \approx Y$. What LS mean is to minimize the Euclidean norm squared of the residual $A\hat{h} - Y$, that is (Mohammed Aboud Kadhim, 2014, S. M. Kay, 1993),

$$\|A\hat{h} - Y\|^2 = (A\hat{h} - Y)^H (A\hat{h} - Y) = (A\hat{h})^H (A\hat{h}) - Y^H A\hat{h} - (A\hat{h})^H Y + Y^H Y \ldots\ldots (3)$$

The minimum is found at the zero of the derivative with respect to $\hat{h}$ **,** then

$$2A^H A\hat{h} - 2A^H Y = 0 \Rightarrow A^H A\hat{h} = A^H Y \ldots\ldots (4)$$

Therefore, $\hat{h}$ will be given by

$$\hat{h} = (A^H A)^{-1} A^H Y \quad \ldots\ldots (5)$$

Under the condition that the A has full column rank. The term $(A^T A)^{-1} A^H$ is called pseudo-inverse of matrix A sometimes denoted by $A^{\dagger}$. MMSE estimator aims to approach optimal result by exploit the statistical dependence between the measured data and the estimated parameter. Eq.1 is chosen to be an example, where h is to be estimated. On purpose of minimizing the Mean Square Error according to (Mohammed Aboud Kadhim, 2014, Z. Cheng, 2002) , the estimated channel impulse response will be given by $(MSE)\ E\left[\left(h - \hat{h}_{MMSE}\right)^2\right]$

$$\hat{h} = R_{hY} R_{YY}^{\ -1} Y \quad \ldots\ldots (6)$$

Where R_{hY}, R_{YY} are the cross covariance matrix between h and Y and the auto covariance matrix of Y with (Mohammed Aboud Kadhim, 2014, Z. Cheng, 2002),

$$R_{hY} = E[hY^H] = E[h(Ah + N)^H] = R_{hh} A^H \ldots\ldots (7)$$

$$R_{YY} = E[YY^H] = E[(Ah + N)(Ah + N)^H]$$

$$= E[Ah(Ah)^H + AhN^H + N(Ah)^H + NN^H]$$

$$= AR_{hh}A^H + \sigma_n^2 I \quad \ldots\ldots (8)$$

$R_{hh} = E[hh^H]$ is the auto-covariance matrix of h and σ_n^2 denotes the noise variance $E|n_k|^2$ These two quantities are assumed to be known at the estimator then Eq.4 can be rewritten as (Mohammed Aboud Kadhim, 2014, Z. Cheng, 2002).

$$\hat{h} = R_{hh} A^H (AR_{hh}A^H + \sigma_n^2 I)^{-1} Y$$

$$= R_{hh}(R_{hh} + \sigma_n^2 (A^H A)^{-1})^{-1} A^{\dagger} Y \ldots\ldots (9)$$

3. System model:

The system model of LTE 3GPP baseband transceiver based wavelet signals that used for simulation in this paper is shown in Figure.1. The simulation was applied using Matlab program. The LTE transceiver structure is divided into three main sections: transmitter, channel, and receiver:

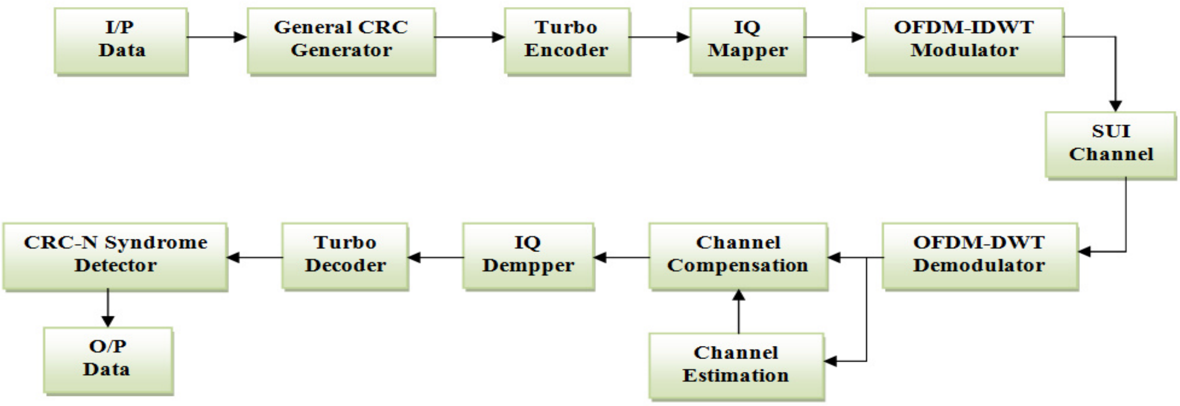

Figure.1. Algorithm of Proposed LTE 3GPP Baseband Transceiver Based Wavelet Signals

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 subcarriers at frequencies (kΔf), k=0,1,2,...,N-1 with Δf=B/N and, T_s , the sampling interval. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, QPSK with constellation C_{QPSK} is assumed for the symbol mapping. N_c is the number of sub-carriers carrying data. N is the multicarrier size. Which consists of the OFDM modulator and demodulator. The training frame (pilot sub-carriers frame) are inserted and sent prior to the information frame. This pilot frame is used to create channel estimation, which is used to compensate for the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse multi-wavelet transform IDWT is used, as in conventional OFDM. Zeros are inserted in some bins of the IDWT to compress the transmitted spectrum and reduce the adjacent carriers' interference. The added 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 chosen 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 efficiency of the transceiver is reduced by a factor of$\frac{K}{K+V}$; thus, it is desirable to make the v as small or K as large as possible. Therefore, the drawbacks of the CP are the loss of data throughput as precious bandwidth is wasted on repeated data. For this reason, finding another structure for FFT-OFDM as DWT-OFDM to mitigate these drawbacks is necessary. The Fourier based OFDM uses the complex exponential bases functions and it's replaced by orthonormal wavelets in order to reduce the level of interference. It is found that the Haar-based orthonormal wavelets are capable of reducing the ISI and ICI, which are caused by the loss in orthogonality between the carriers. The computation of DWT and IDWT for 256 point. After this, the data converted from the parallel to the serial form are fed to the SUI channels more information about SUI channels in (Daniel S. Baum, 2001). The receiver performs the same operations as the transmitter, but in a reverse order. In addition, wavelet OFDM includes operations for synchronization and compensation for the destructive SUI channels.

4. Simulation Results

In this section the simulation of the proposed LTE 3GPP baseband transceiver based wavelet signals and comparing when using the channel estimation (LS) and the channel estimation (MMSE) is executed, beside the BER performance of the system regarded in SUI channel models.

Table (1) System parameters

Transmission Bandwidth	**2.5 MHz**
Sub-frame duration	**0.5ms**
Sub-carrier spacing	**15KHz**
Sampling Frequency	**3.84MHz**
DWT Size	**256**
Modulation type	**16QAM**
Channel coding	**Turbo**
Channel type	**SUI Channel**
Channel estimation	**Perfect**
Receiver decoder type	**Soft sphere detection (SSD)**
Number of iterations	**1000**

4.1 Performance of 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 4.56 dB while in (LS) the SNR about 5.6 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

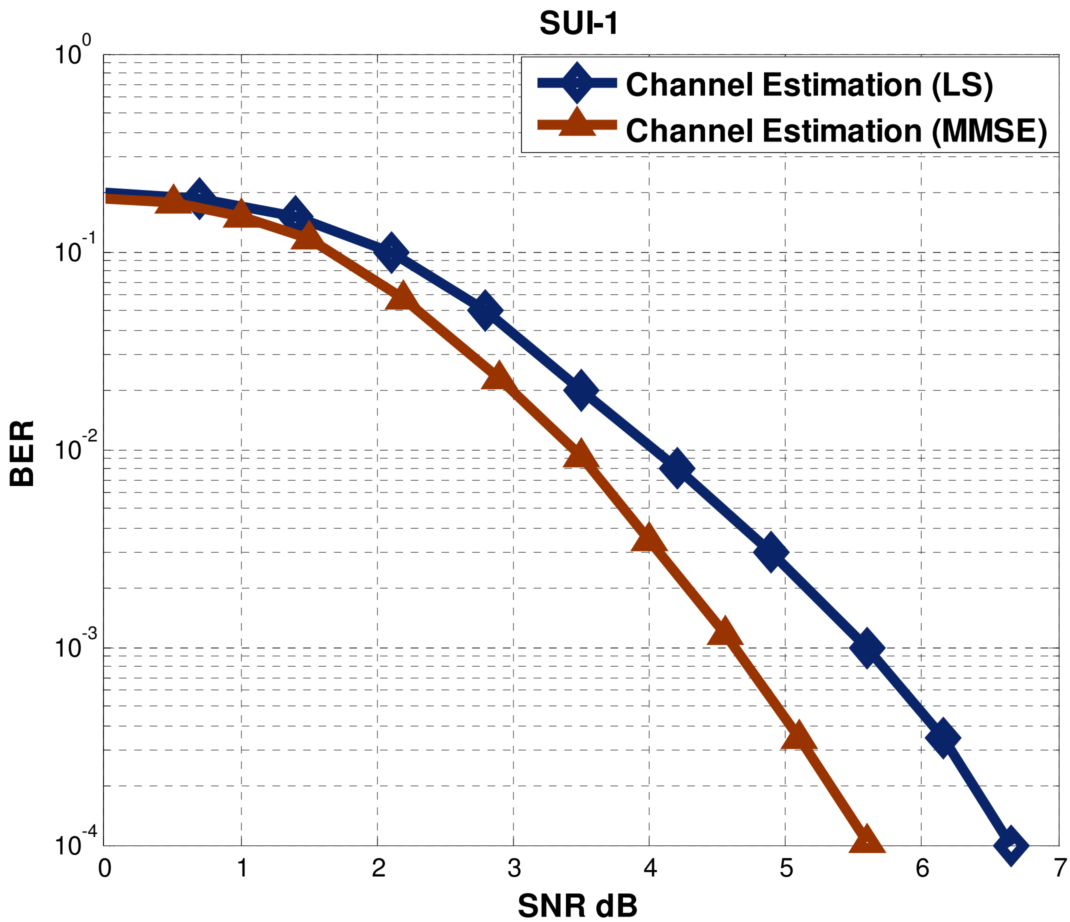

Figure .2. BER performance of proposed model in SUI-1 channel

4.2 Performance of 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 6.76 dB while in

(LS) the SNR about 7.8 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.

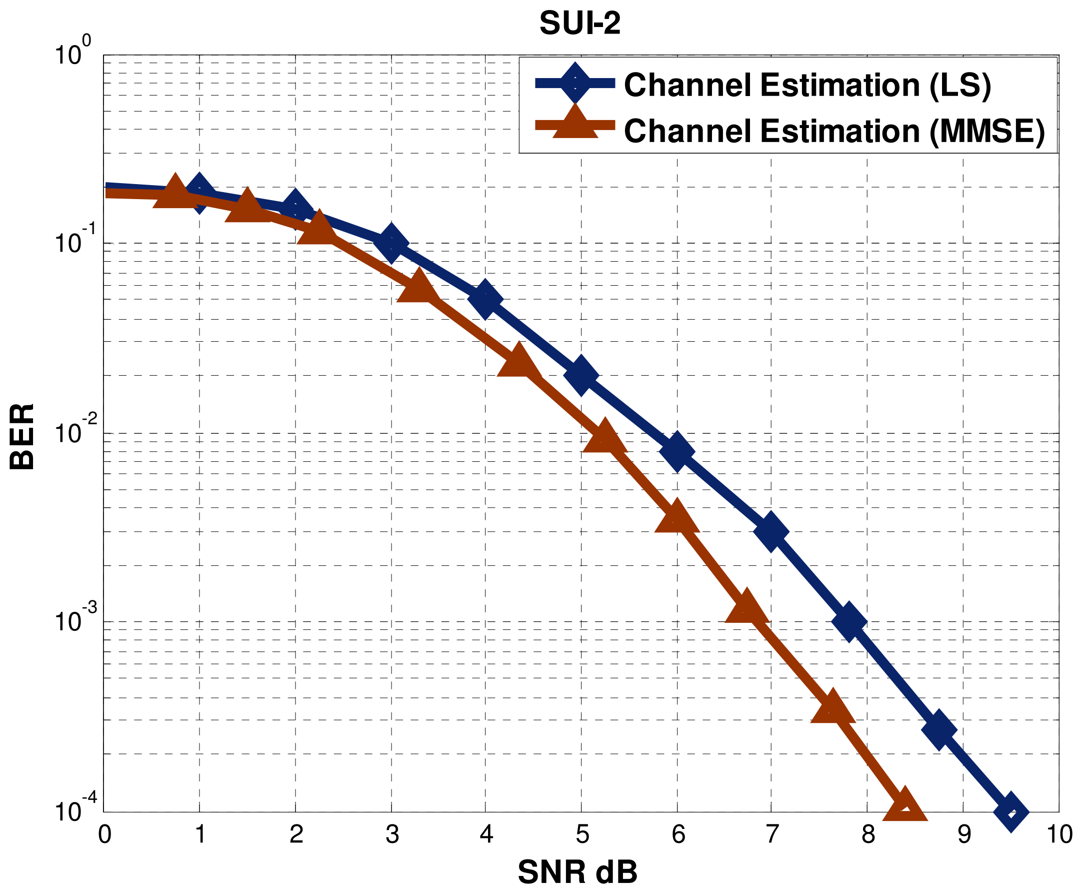

Figure .3. BER performance of proposed model in SUI-2 channel

4.3 Performance of 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 10.45 dB, while when using (LS) the SNR about 11.7 dB, from Figure 4 it is found that the transceiver when using (MMSE) outperforms significantly than other systems for this channel model.

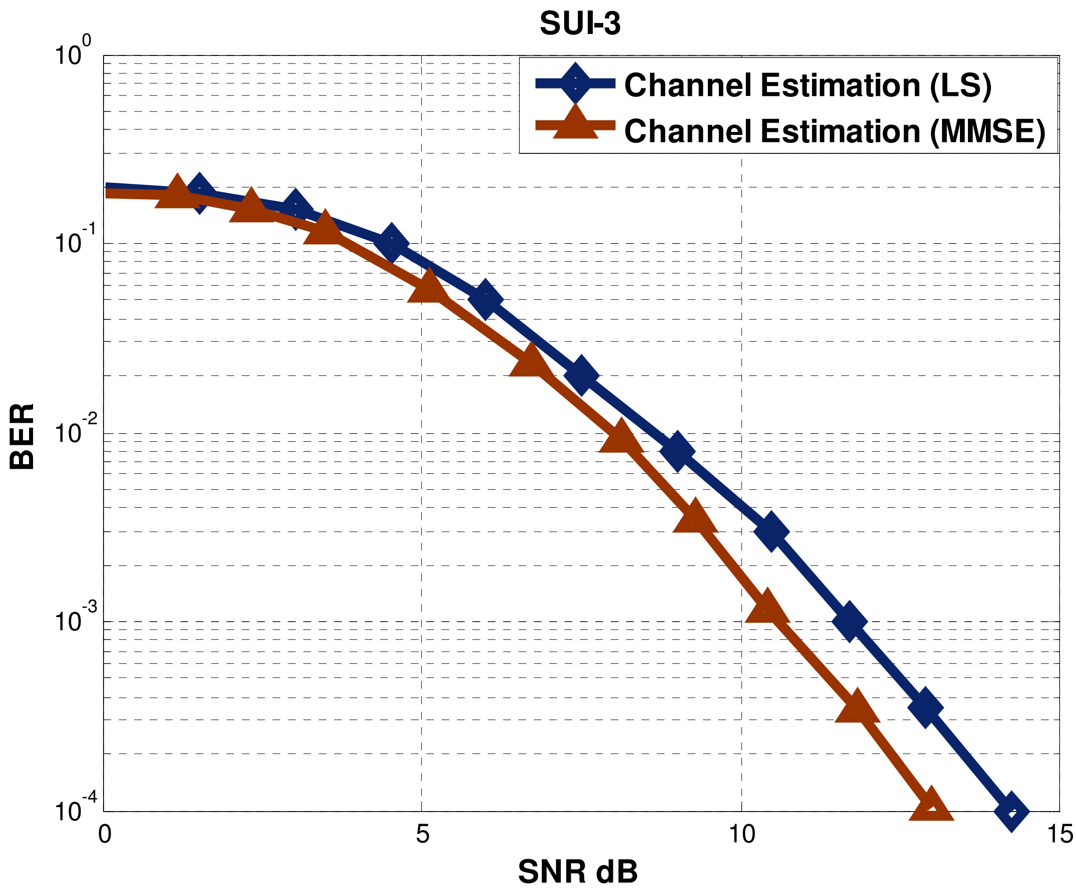

Figure .4. BER performance of proposed model in SUI-3channel

4.4 Performance of 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 14.5dB, while when using (LS) the SNR about 15.6dB. 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.

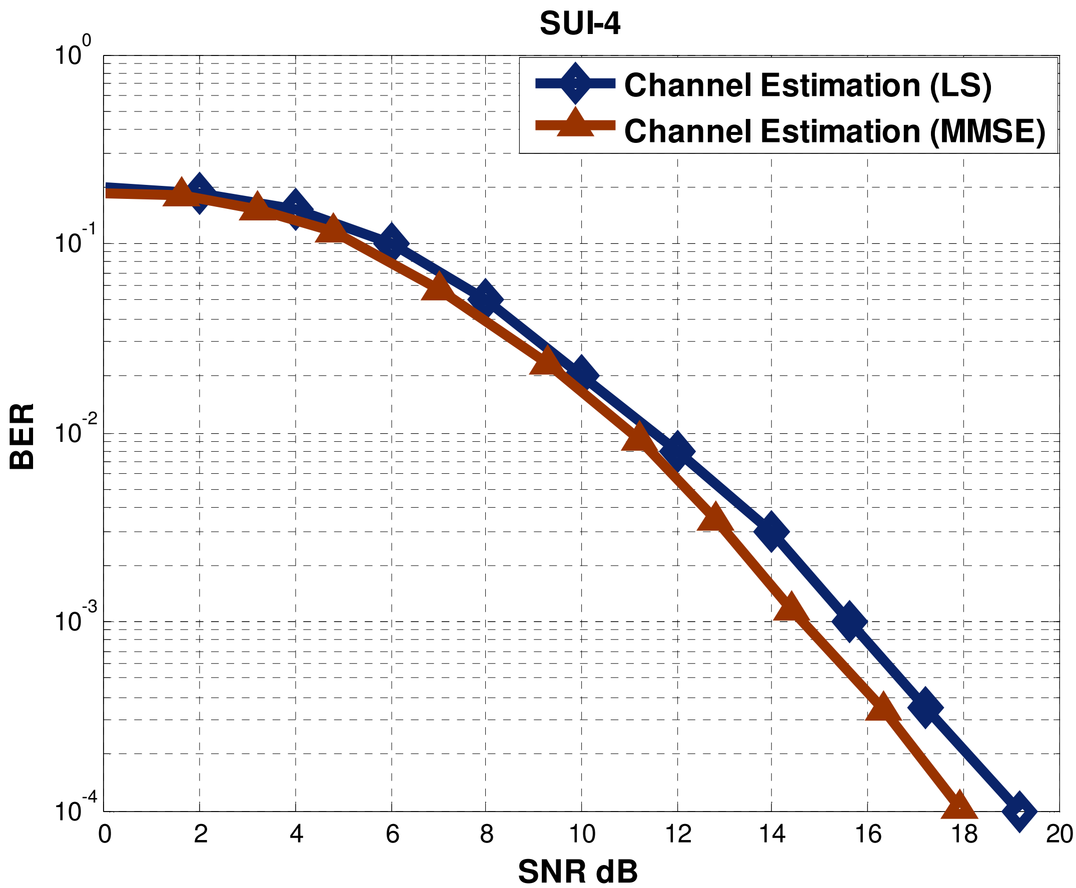

Figure .5. BER performance of proposed model in SUI-4channel

4.5 Performance of 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 18.33 dB while when using (LS) the SNR about 19.5 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.

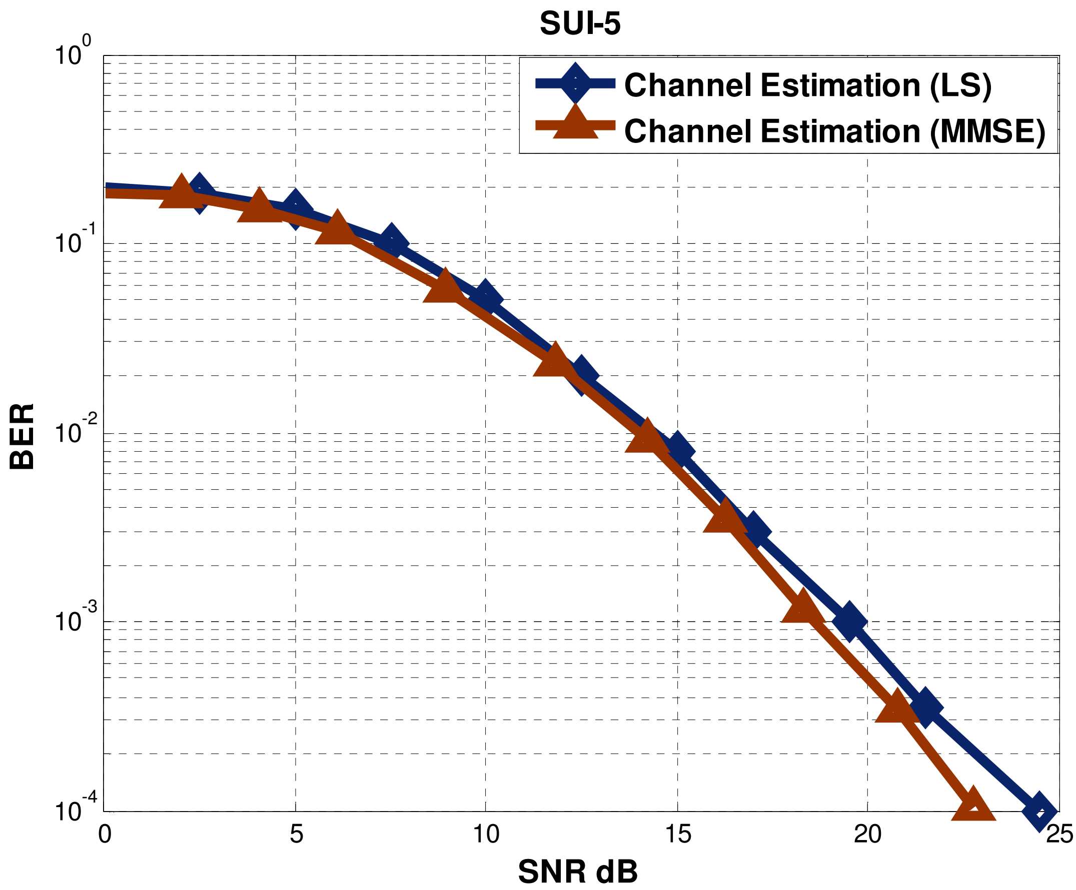

Figure .6. BER performance of proposed model in SUI-5channel

4.6 Performance of 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 23.1 dB while when using (LS) the SNR about 24.8 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

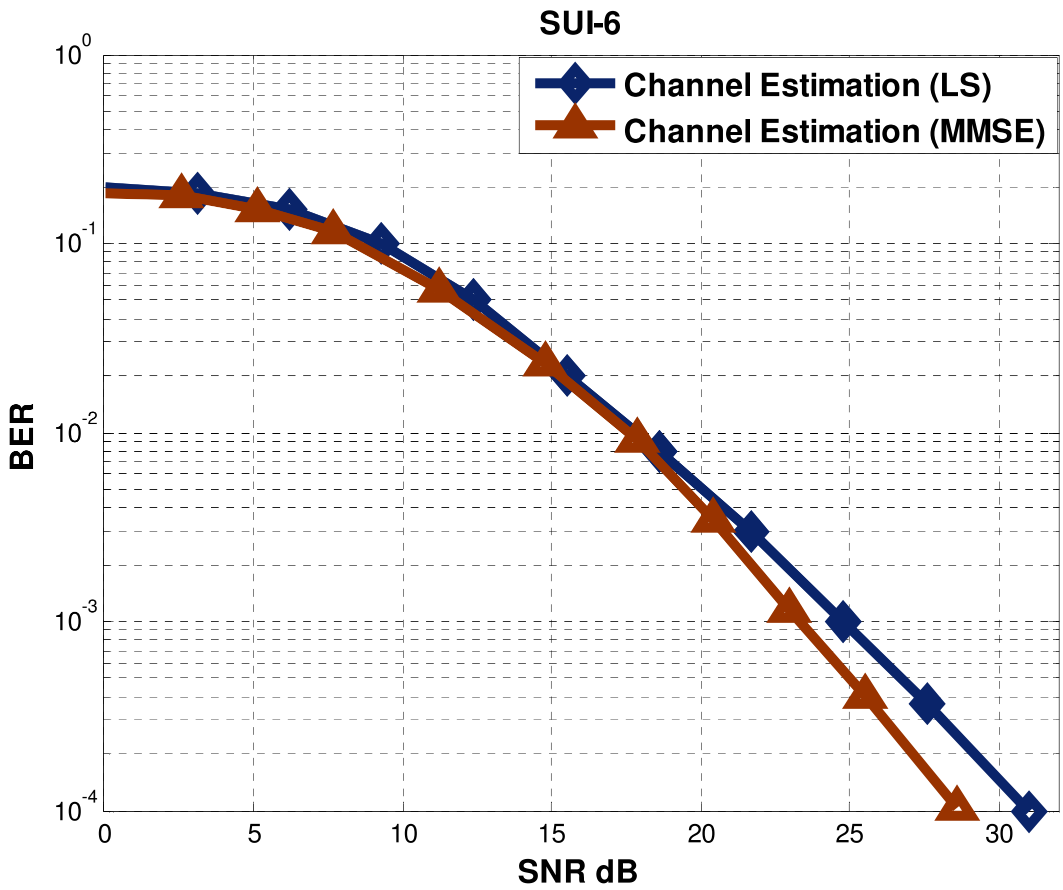

Figure .7. BER performance of proposed model in SUI-6 channel

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	5.6	7.8	11.7	15.6	19.5	24.8
MMSE dB	4.56	6.76	10.45	14.5	18.33	23.1

A number of important results can be taken from Table (2); In this simulation, in most scenarios, when using channel estimation (LS) and channel estimation (MMSE), 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 LTE 3GPP baseband transceiver based wavelet signals when using the channel estimation (MMSE) proved its effectiveness in combating the multipath effect other than when using channel estimation (LS) on the SUI fading channels.

5. Conclusions

The major contribution of this paper was the implementation of the LTE 3GPP baseband transceiver based wavelet signals with channel estimation (MMSE) and (LS) was proposed simulate and tested. 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) designed method.

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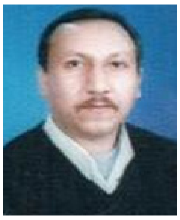

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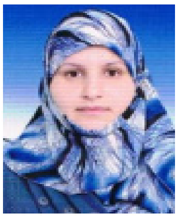
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