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Design And Implementation Of Mobile Wimax Baseband Transceiver For Different Channel Estimation Algorithms

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Abstract :

This paper refers to channel estimation based on time-domain channel statistics. Using a general model for International Telecommunication Union (ITU) channel model, the aim of the paper is to find out the most suitable channel estimation algorithms for the existing Mobile WiMAX 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 : ITU, WiMAX, MMSE.

جهاز الإرسال والاستقبال الوامكس المحمول بعدة طرق لقنوات التخمين   تصميم وتنفيذ

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الخلاصة :

هذا البحث يشير الى إحصاءات قنوات التخمين مع الزمن . باستخدام نموذج عام لقنوات الاتحاد الاتصالات الدولية . الهدف من هذا البحث إيجاد أفضل طريقة لقناة التخمين للوامكس المحمول ، وتحسين معدلات الخطأ لهذا النظام ابتدأ من التحليل الرياضي لهذه الطرق، عرض في هذا العمل نموذجان الأول الحد الأدنى متوسط مربع الخطأ والثاني اقل مربع خطا وقد تمت المقارنة بين أداء هذين العمليين بمختلف الظروف البيئية. حساب معدلات الخطى تم لتضمين من نوع 16 كوام ببرنامج المحاكاة ماتلاب.

1. Introduction

IEEE 802.16 is the set of standards governing the design of the wireless interface for a standard-based Metropolitan Area Network (MAN), and to provide conformance and interoperability for the implementation of this standard the Worldwide Interoperability for Microwave Access (WiMAX) group was formed. Today, the standards are fondly referred to as WiMAX. The standard group was chartered to provide business and consumer wireless broadband services on the scale of the MAN [1].Orthogonal frequency division multiple access (OFDMA) has been used in WiMAX systems for wireless metropolitan area network (MAN) communications and broadcasting. And it has been standard-ized in the IEEE 802.16e/D10, which specifies the air interface for fixed broadband wireless access (BWA) systems supporting multimedia services [2].

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 both 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 [3].

Channel estimation techniques for WiMAX systems have been widely studied. In [4] 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 [5], 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 algorithm:

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 [6].

$$Y = xH + N \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

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

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 [6],

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

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

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

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

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

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 [7], the estimated channel impulse response will be given by $(MSE)\ E\left[\left(h - \hat{h}_{MMSE}\right)^2\right]$

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

Where R_{hY}, R_{YY} are the cross covariance matrix between h and Y and the auto covariance matrix of Y with [8],

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

$$\begin{aligned} R_{YY} &= E[YY^H] = E[(Ah+N)(Ah+N)^H] \\ &= E[Ah(Ah)^H + AhN^H + N(Ah)^H + NN^H] \\ &= AR_{hh}A^H + \sigma_n^2 I \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8) \end{aligned}$$

$R_{hh} = E[hh^H]$ 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 [8].

$$\begin{aligned} \hat{h} &= R_{hh}A^H(AR_{hh}A^H + \sigma_n^2 I)^{-1} Y \\ &= R_{hh}(R_{hh} + \sigma_n^2 (A^H A)^{-1})^{-1} A^{\dagger} Y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9) \end{aligned}$$

3. System model :

The system model of Mobile WiMAX IEEE802.16e that used for simulation in this paper is shown in **Figure. (1)**. The simulation was applied using Matlab program R2011a.

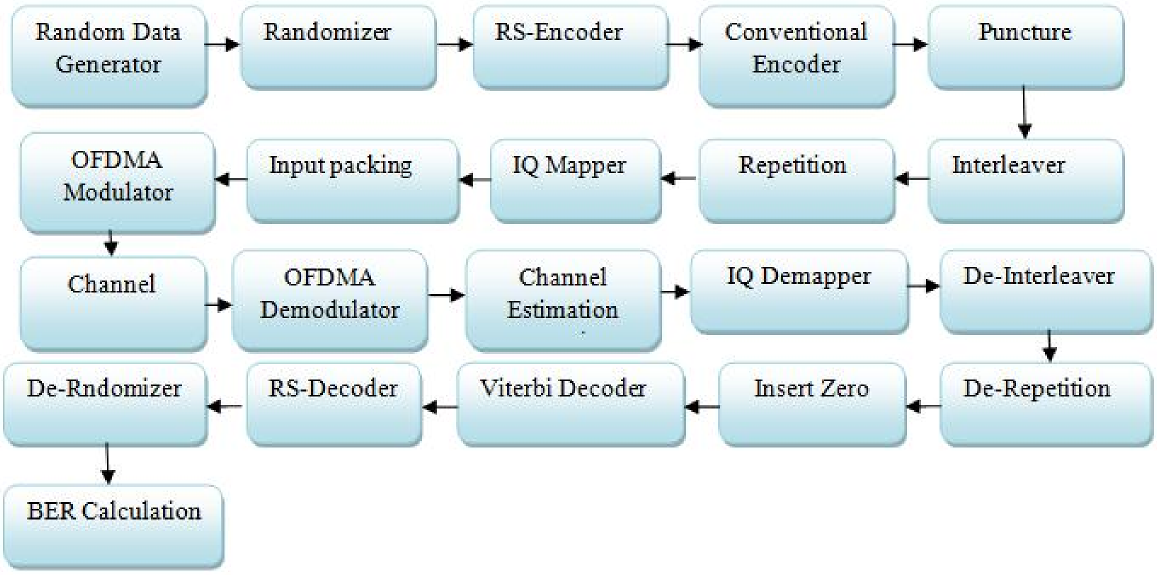

Fig. (1). Algorithm of Proposed Mobile WiMAX IEEE802.16e

The algorithm system is divided into three main sections, namely, transmitter, receiver, and channel. The model has been tested with the channel coding. Data are generated from a random source and consist of a series of ones and zeros. Since the transmission is done block wise, when forward error correction (FEC), the size of the data generated depends on the block size used. Randomized is done to avoid a long run of zeros or ones. The result is ease in carrier recovery at the receiver. The randomized data are encoded when the encoding process comprise of a concatenation of an outer Reed-Solomon (RS) code, and an inner convolutional code (CC) as an FEC scheme. This method that the first data pass in block format through the RS encoder, and then go across the convolutional-encoder. CC is a flexible coding process due to the puncturing of the signal, and it to permit different coding rates. Such encoder is a handle of interleaving to prevent long error bursts using tail biting CC with a different coding rate of (puncturing of codes is provided in the standard) **[9,10]**. Finally, interleaving is done by a two-stage permutation; the first aims to avoid the mapping of adjacent coded bits on adjacent subcarriers, and the second insures that adjacent coded bits are mapped alternately onto more or less significant bits of the constellation, thus avoiding long runs of lowly reliable bits. The training frame (pilot sub-carriers frame) shall be inserted and sent prior to information frame. This pilot frame shall been used to make channel estimation that's used to compensate the channel effects on the signal. After that the, symbol mapping the coded bits are then mapped to shape symbols. The modulation scheme used is 16QAM (1/2) coding rate with gray coding in the constellation map. Anyway, the symbol is normalized so that the average power is unity irrespective of the modulation scheme used. The 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 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 OFDMA symbol is equal to log_2 (M)*N_cOrthogonality between carriers is normally destroyed when the transmitted signal is passed through an ITU channels. 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 1024 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.

4. Simulation and Results

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

Table (1) System parameters

Number of sub-carriers	1024
Number of FFT points	1024
Modulation type	16QAM
Coding rate	1/2
Cyclic prefix	1/8
Channel bandwidth B	8.75MHz
Carrier frequency fc	2.3GHz
N cpc (Number of transmitted bits per symbol)	4
N cbps(number of coded bits per the specified allocation)	768
Number of data bits transmitted	10^6

In this section the simulation of the proposed channel estimation algorithms for the existing in Mobile WiMAX IEEE802.16e and comparing between LS vs. MMSE is executed, beside the BER performance of the system regarded in ITU channel models [11].

4.1 AWGN Channel Performance

In this scenario, the results obtained were encouraging, the system with, channel estimation (LS) and channel estimation (MMSE) can be seen that for BER=10^{-3} the SNR required for channel estimation (LS) is about 9.9 dB while in channel estimation (MMSE) is about 7.8 dB, from **Figure. (2)** it is found that the channel estimation (MMSE) outperforms significantly other system for this channel model.

4.2 AWGN plus Multipath Channel Performance

In this general channel scenario, in the next sections the relevant results are discussed.

4.2.1 Indoor Channel A

In this simulation profile some influential results were obtained, the system with, channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required for channel estimation (LS) is about 14.74 dB while in channel estimation (MMSE) the SNR is about 11.2 dB from, **Figure .(3)** it is found that the channel estimation (MMSE) outperforms significantly other system for this channel model.

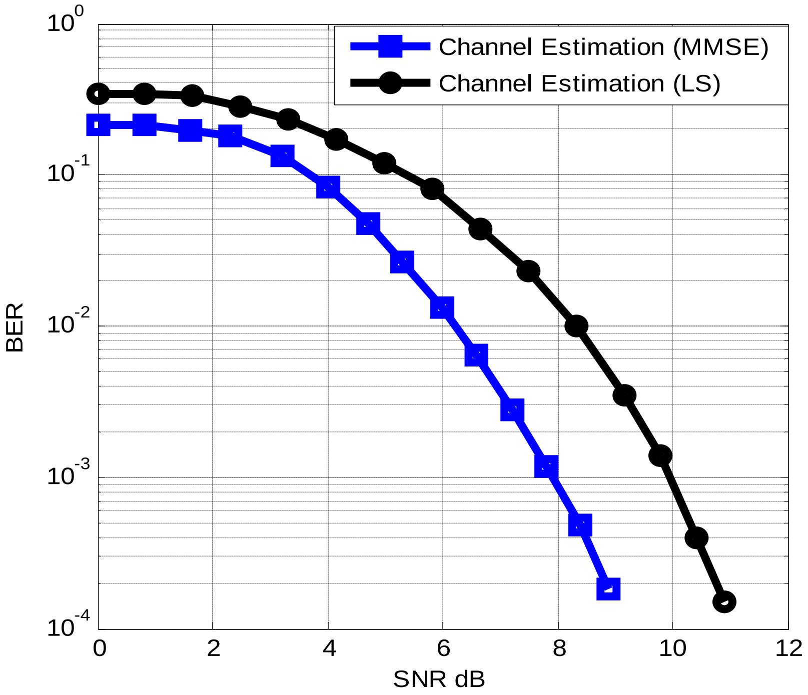

Fig .(2). BER performance of Mobile WiMAX in AWGN channel

4.2.2 Indoor Channel B

In this channel, the results are depicted in **Figure .(4)** it can be seen that for BER=10^{-3} the SNR required for the system with channel estimation (LS) is about 21.1 dB, while in channel estimation (MMSE) the SNR is about 17.15 dB, from Figure.4 it is found that the channel estimation (MMSE) outperforms significantly than others systems for this channel model.

4.2.3 Pedestrian Channel A

In the pedestrian profile, two different situations were regarded: a stationary and a moving person.

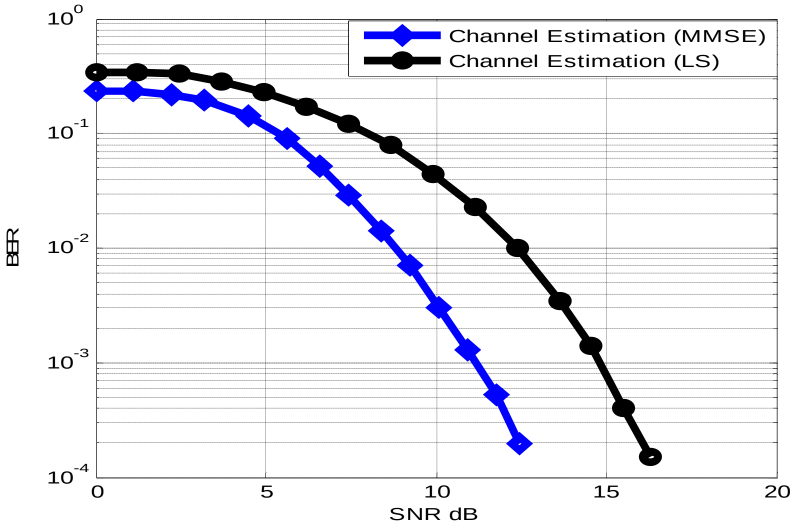

Fig. (3). BER performance of Mobile WiMAX in AWGN plus Multipath Indoor A

4.2.3.1 Pedestrian Channel A (a stationary person):

Using similar methodology as in the previous section, simulations for this channel the result depicted in **Figure .(5)**.

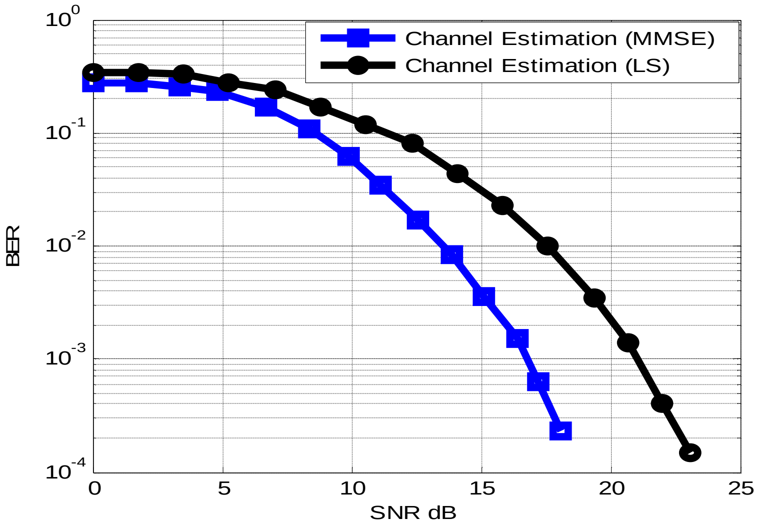

Fig. (4) BER performance of Mobile WiMAX in AWGN & Multipath Indoor B

It can be seen that for BER=10^{-3} the SNR required for the system with channel estimation (LS) is about 15.75 dB while in channel estimation (MMSE) the SNR is about 13.75 dB. Also from Figure 5 it is found that the channel estimation (MMSE) outperforms significantly than others systems for this channel model.

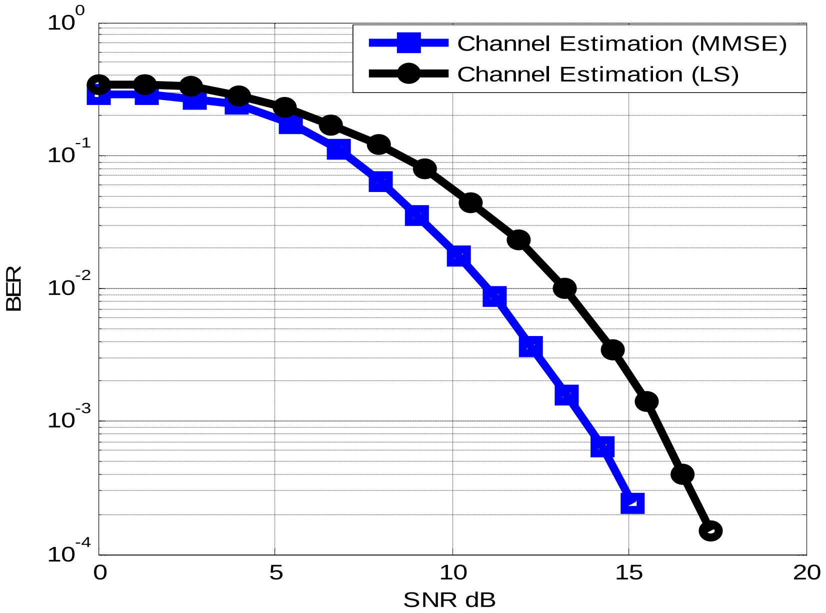

Fig .(5) . BER performance of Mobile WiMAX in AWGN & Multipath Stopped Pedestrian A

4.2.3.2 Pedestrian Channel A (a moving person):

In this model, the results obtained were encouraging. The system with , channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required is about 18.2 dB for channel estimation (LS) while in channel estimation (MMSE) the SNR is about 16.3 dB from Figure 6 it is found that the channel estimation (MMSE) best significantly other system for this channel model.

4.2.4 Pedestrian Channel B

Using such as methodology as in the previous section, simulations for both a stationary and a moving pedestrians were carried out:

4.2.4.1 Pedestrian Channel B (a stationary person):

In this state, the results obtained were hopeful. The system with channel estimation (LS) and channel estimation (MMSE) it can be seen that for BER=10^{-3} the SNR required for channel estimation (LS) is about 26.2 dB while in channel estimation (MMSE) the SNR is about 24 dB from **Figure .(7)** it is found that the channel estimation (MMSE) is better significantly other system for this channel model

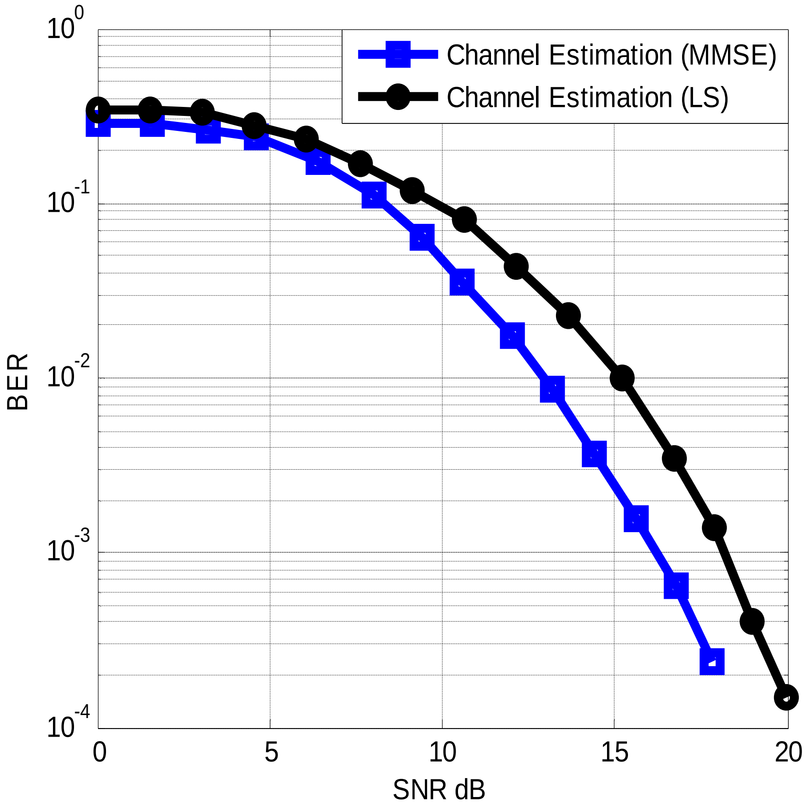

Fig .(6). BER performance of Mobile WiMAX in AWGN & Multipath moving Pedestrian A

4.2.4.2 Pedestrian Channel B (a moving person):

In this scenario, the results obtained were encouraging. it can be seen that for BER=10^{-3} the SNR required with channel estimation (LS) system performed is about 36.2 dB, while in the channel estimation (MMSE) system showed a performance 33.2 dB better than the channel estimation (LS) system. These results are presented in **Figure .(8)**.

4.2.5 Vehicular Channel A

In this channel was proposed for communication links under mobility, i.e., vehicular use. However, simulations under these conditions were performed to get a sense of the effects and to eventually reflect on solutions to combat the negative consequences. In this section the performance of the link under the user-channel vehicular A profile with 60 km *h* is addressed the results obtained for the user-channel vehicular A.

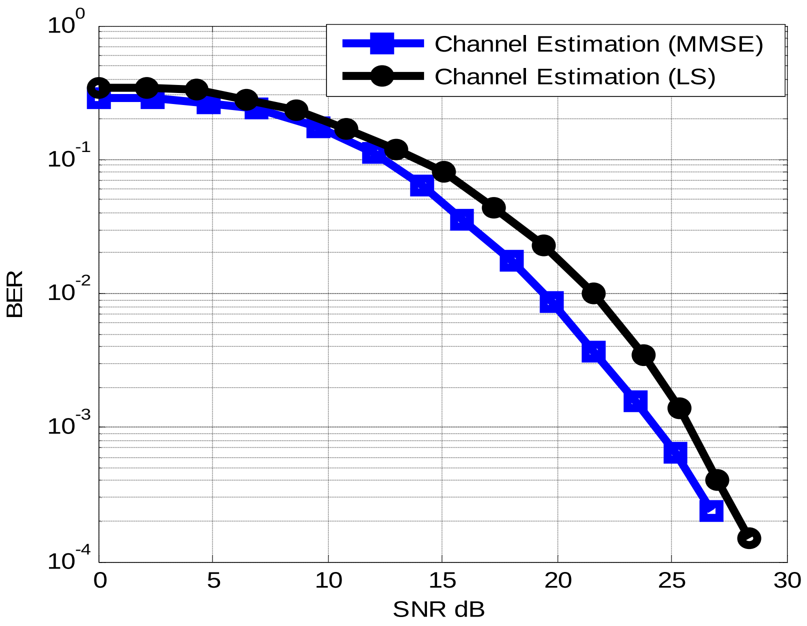

Fig .(7). BER performance of Mobile WiMAX in AWGN & Multipath Stationary Pedestrian B

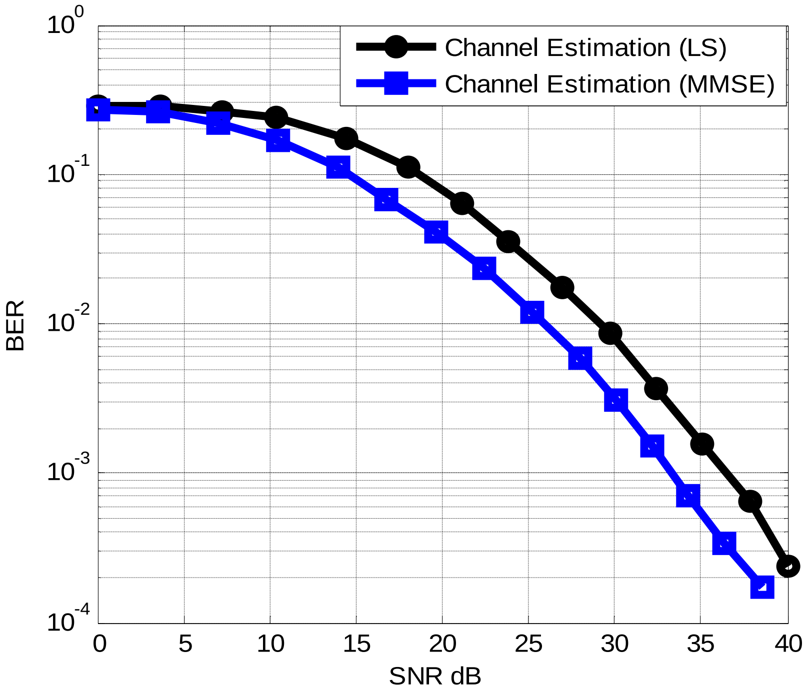

Fig .(8). BER performance of Mobile WiMAX in AWGN & Multipath a moving person Pedestrian B

As shown in Figure 9 with channel estimation (LS) system clearly poor performance and it can be seen that for BER=10^{-3} the SNR required with channel estimation (MMSE) system performed is about 37.7dB.

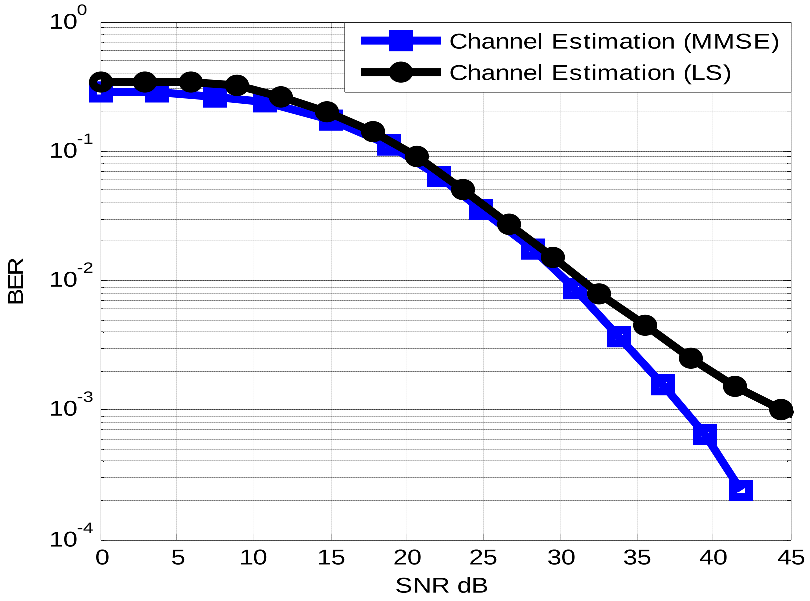

Fig .(9). BER performance of Mobile WiMAX in AWGN & Multipath a Vehicular Channel A

4.2.6 Vehicular Channel B

In this section, we present the results obtained under the user-channel vehicular B profile with speed 120km h. It is clear that all systems performed poorly since none of them can combat the multipath and Doppler spread combined effect of this kind of channel these results are presented in **Figure .(10)** .

Important results can be taken from **Table (2)**; in this simulation, in most scenarios, by using the channel estimation (MMSE) system was better than the channel estimation (LS). The channel estimation (MMSE) system proved its effectiveness in combating the multipath effect on the channels.

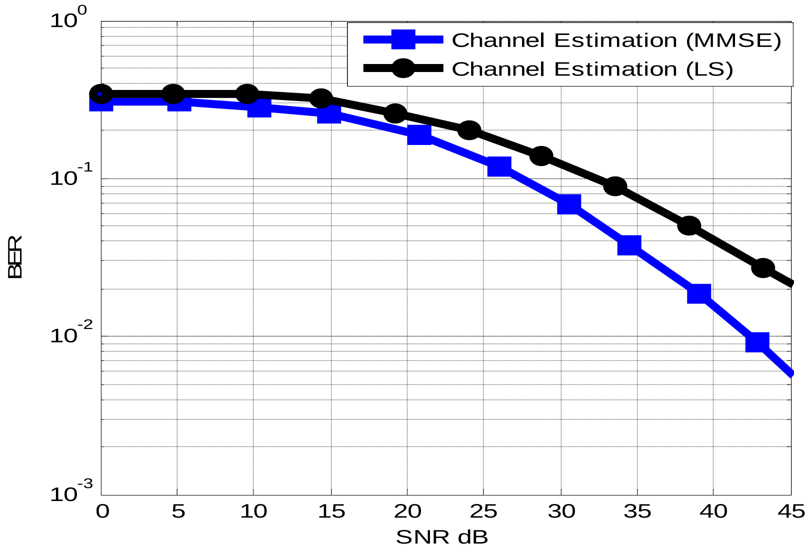

Fig .(10). BER performance of Mobile WiMAX in AWGN & Multipath a Vehicular Channel B

Table (2) Performance Comparison and Analysis

Channel For BER=10^{-3}	AWGN	Indoor Channel A	Indoor Channel B	Pedestrian Channel A		Pedestrian Channel B		Vehicular	
				AWGN & Multipath Stationary Pedestrian A	AWGN & Multipath Moving Pedestrian A	AWGN & Multipath Stationary Pedestrian B	AWGN & Multipath Moving Pedestrian B	Channel A	Channel B
LS dB	9.9	14.75	21.1	15.75	18.2	26.2	36.2	Poor	poor
MMSE dB	7.8	11.2	17.15	13.75	16.3	24	33.2	37.7	poor

5. Conclusions

The key contribution of this paper was the implementation of the Mobile WiMAX (IEEE 802.16e) PHY layer based the OFDMA structure 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 ITU 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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