Comparison of Channel Estimation in Mobile WiMAX (IEEE 802.16e) DL-PUSC System

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ABSTRACT

Fourth generation (4G) wireless based on worldwide interoperability for microwave access (WiMAX) systems are a new promising technology that support high data rate transfer. Channel Estimation of system is carried out by finding Channel impulse response (CIR) of pilot subcarrier using LS or LMMSE algorithms and then finding Channel Frequency Response (CFR) at data subcarrier is done by time and frequency Interpolation of Pilot CIR. This paper presents BER performance for 16QAM & 64QAM Coded OFDM System evaluated at different Doppler frequencies. Results show that Channel Estimation over Coded-OFDM system gives better performance than OFDM.

Keywords

Coded OFDM System (C-OFDM), Channel Estimation, LS, LMMSE**,** Channel Impulse Response (CIR), Channel Frequency Response (CFR), Downlink Partially Used Subchannelization (DL-PUSC).

1. INTRODUCTION

The Goal of next generation of mobile wireless communication system is to achieve ubiquitous, high-quality, high-speed mobile multimedia transmission. To achieve this goal, various new technologies are constantly being applied to mobile communication systems. Academia and industry have reached a consensus that OFDM is one of the most promising core technologies in new generation of mobile communication. 4G systems are used to support high mobility and bit rates greater than 5 Mbits/sec and can reach up to 155 Mbits/sec [1]

IEEE 802.16 standard is for worldwide Interoperability for Microwaves Access called as (WiMAX) which is one of the Candidates of 4G system [2]. FWA supported by IEEE 802.16 d standards [3] and MWA supported by the IEEE 802.16e standard [4]. OFDM is Key technology of standard (802.16e) Mobile WiMAX is based on orthogonality principle support to multicarrier transmission technique that is built-up by many orthogonal carriers that transmits simultaneously. Idea behind OFDM is that to divide the transmitted bit stream in to many different sub-stream and send these over many subchannels, also the number of sub-stream is chosen to insure that each sub channel has a bandwidth less than the coherence bandwidth of the channel, so that sub channels experience relatively flat fading and due to this Inter symbol interference (ISI) on each sub-channel is small. And the remaining ISI effect is eliminated by using cyclic prefix. [5]

OFDM is widely used in the wireless system such as a WiMAX based on orthogonal frequency division multiple accesses .OFDMA is a multiuser version of OFDM. In 802.16e bandwidth is scalable (1.25 to 20MHz) [6] called Scalable Orthogonal Frequency Division Multiple Access (SOFDMA) which is scalable version of OFDMA where the bandwidth is scalable and is achieved by changing the FFT size.

In Mobile WiMAX systems, Channel estimation algorithms play a very important role here it has been used data pilot based channel estimation in DL-PUSC OFDMA. In this paper we obtain CFR by exploiting pilot at symbol data with two dimensial interpolation scheme called time –frequency interpolation. Mobile WiMAX frame in TDD mode is built up by one downlink (DL) subframe and one uplink (UL) subframe. [7] In this paper only the DL-PUSC subframe structures has been consider and channel transfer function has been obtained by exploiting pilot at symbol data by means LS and LMMSE algorithms. The Bit Error Rate performance for 16QAM and 64 QAM systems has been simulated on MATLAB

The paper is organized as follows. In section 2 explain System Description, section 3 discusses Channel estimation method, with pilot based channel estimation method by LS-Linear Interpolation and MMSE- Linear Interpolation Result have been presented in section 4, which shows the effects of FEC and Channel Estimation for Rayleigh channel and ITU channel by means of BER performance with different Doppler frequency, Sections 5 conclude the paper.

2. SYSTEM DESCRIPTION

Coded-OFDM system with pilot based Channel estimation is given in figure 1. The Random data input provided from the source is coded by means of ¾ code rate Convolution trellis code and then converted from serial to parallel to form parallel data of some subchannels.

Each parallel subchannel which contains Nu active subcarriers is modulated with the help of complex QAM modulator. Ng pilots subcarriers are then added in modulated data and then it has been arranged with other null carriers in a such a way that the total subcarriers must be in the form of N point FFT.

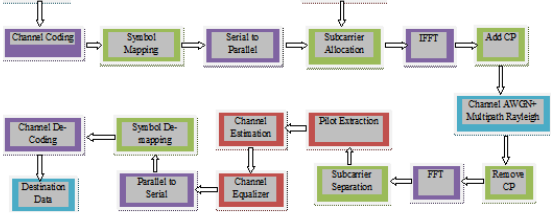

Fig.1 Block Diagram of the Pilot Based OFDM System

These parallel blocks are then fed into IFFT bock symbol by symbol to transform them into time domain and generate C-OFDM signal with the following equation.

$$x(n)=IFFT\{X(M)\}$$

$$=\sum_{\substack{m=-N_{used}/2\\ m\neq 0}}^{N_{used}/2} X(M)e^{j2\pi nm/N_{FFT}}\cdot\cdot_{0\le n\le N-1} \quad (1)$$

Where *X(n)* is the transmitted data symbol at the mth subcarriers of the OFDM symbol, *NFFT* is the fast Fourier transform (FFT) size and N_{used} is the number of nonsuppressed subcarriers. In the frequency domain, each OFDM symbol is created by mapping the sequence of symbols on the subcarriers.[8] Mobile WiMAX has three classes of subcarriers . They are *data subcarriers Nu* which contain the information of data symbols similarly *pilot subcarriers Ng* which are used to known prior at both transmitter and receiver side and *null subcarriers* which have no power allocated to them used to adjust the total bin size N

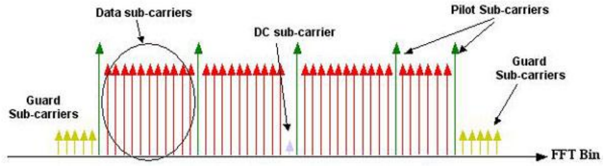

Fig 2. Frequency domain representation of OFDM symbol

The typical N point FFT with all subcarriers frequency domain description of an IEEE802.16e-2005 OFDM symbol is shown in Figure.2

After the addition of cyclic prefix (CP) which is used to remove ISI , the signal is transmitted through the wireless channel mainly here AWGN and Rayleigh multipath. The channel impulse response is assumed that the entire impulse response lies in between the guard time. At the receiver, the signal which is affected by the channel noise is received. After synchronization and removing the CP, the simplified baseband model of the received samples is.

$$y(n)=\sum_{l=0}^{L-1}x(n-l)h(l)+w(n) \quad (2)$$

where L is the number of sample-spaced channel taps, w(n) is the additive white Gaussian noise (AWGN) sample with zero mean and variance of σ_w^2 , and the time domain channel impulse response (CIR) for the current OFDM symbol, *h(l)*, is given as a time invariant linear filter. Note that perfect time and frequency synchronization is assumed. After taking FFT of the received signal *y(n)*, the samples in frequency domain can be written as

$$Y(M)=FFT\{y(n)\}$$

$$=X(m)H(m)+W(m) \quad (3)$$

Where ***H*** and ***W*** are FFTs of ***h*** and ***w*** respectively

3. CHANNEL ESTIMATION

3.1 Pilot Based Channel Estimation

In this paper, channel estimation method based on clusters is used in order mitigate the effect of frequency selective fading; the IEEE 802.16e standard has a very unique method to allocate subcarrier including pilot is called permutation and there are a few types of permutations. In this paper it has been used a method called Downlink Partially Used Subchannelization (DL-PUSC) [6]. In DL-PUSC, the subcarriers are divided into clusters containing 14 adjacent subcarriers each. Figure 3 shows a cluster structure and the position of pilot subcarriers in each cluster for even and odd symbols. The channel responses at the rest of data subcarrier are estimated by interpolation.

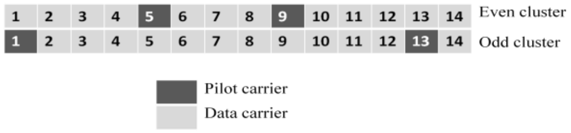

Fig 3.Cluster structure for DL PUSC

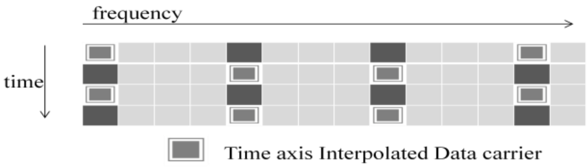

Fig 4.Cluster structure after time interpolation

First is interpolation at time dimension which has 2 symbols time spacing. In this paper we use linear interpolation for time dimension interpolation because it is sufficient for small time spacing. The time dimension interpolation steps are shown in figure 4

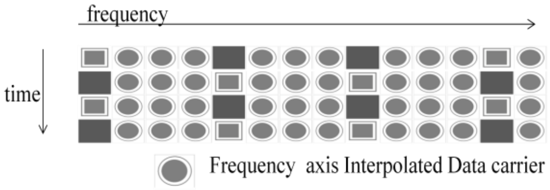

Fig 5.Cluster structure after frequency interpolation

Next is frequency dimension interpolation is done shown in figure 5 and we get complete Channel Frequency Response of the Channel.

3.2 Channel Estimation Algorithms.

In this the simplest case, the channel estimates, are found by straight forward multiplying the received pilot by the inverse of the known transmitted pilot. This method is called least square (LS) estimator, given by [8]

$$\hat{H}_{P,LS}=X_P^{-1}Y_P$$

$$=\left[\frac{Y_P(1)}{X_P(1)}\,\frac{Y_P(2)}{X_P(2)}\cdots\frac{Y_P(N_P)}{X_P(N_P)}\right]^T \quad (4)$$

Without using any knowledge of the statistics of the channels, The LS Estimator has very low complexity, but they suffer from a high mean-square error. The MMSE channel estimator employs the second order statistics of the channel condition to minimize the mean square error. The major disadvantage of the MMSE estimator is its high complexity, which grow exponentially with the observation sample. So reduce the computational complexity of it new algorithm employ called linear MMSE (LMMSE). The frequency domain LMMSE estimate of channel response is given by [8]

$$\hat{H}_{LMMSE} = R_{H_P H_P}\left(R_{H_P H_P} + \frac{\beta}{SNR} I\right)^{-1} \hat{H}_{LS} \quad (5)$$

Where β is a constant depending on the signal constellation. In the case of 16QAM transmission, β=17/9. $R_{H_P H_P}$ Is the channel Autocorrelation matrix of pilots and is given by [9],[10]

$$E\left\{H_m H_n^{*}\right\} = \begin{cases} 1, m = n \\ \dfrac{1-e^{-j2\pi(N_g(m-n)/N)}}{j2\pi(N_g(m-n)/N)}, m \neq n \end{cases} \quad (6)$$

So if $R_{H_P H_P}$ and SNR are known before hand or a set to fixed nominal value, the matrix $\left(R_{H_P H_P} + \frac{\beta}{SNR} I\right)^{-1}$ needs to be calculated only once. [8] After the estimation of channel transfer response of pilot subcarrier by using LS or LMMSE the rest of data sub carrier are obtained by interpolation process using channel information at pilot subcarrier. In this paper we consider a piecewise linear interpolation for both time and frequency interpolation. [10] The linear interpolation method obtain the channel response at the mth subcarrier as

$$\hat{H}(m) = \hat{H}(sL+1)$$

$$= \hat{H}_P(s) + \frac{l}{L}\left(\hat{H}_P(s+1) - \hat{H}_P(s)\right), 0 \le l \le L \quad (7)$$

Where m=0,1,.....N$_P$-l. and N$_p$= number of pilot $sL \le m \le (s+1)L$ and N=total number of subcarriers.

4. SIMULATION RESULTS

In this simulation the parameters used are given in Table 1.

TABLE 1: SIMULATION PARAMETERS

Parameters	Value
FFT size (N_{FFT})	1024
System Bandwidth(MH_Z)	10
Sampling Frequency(MH_Z)	11.2
Channel Coding	CC-trellis code
Code rate	¾
Modulation	16QAM,64QAM
Number of used Subcarrier Nu=Nd+Np	840=720+120
Cyclic Prefix ratio(Ng)	1/8=256
Number Of Cluster used	24
OFDM Symbol Duration(µs)	102.86
Fading Channel	Rayleigh(2Tap, ITU-A, ITUB)
Carrier Frequency(GH_z)	2.5

the Channel estimation performance is measured in term of Bit Error Rate (BER) .The effect of frequency selective fading mitigated by using Channel estimation and Channel coding for 16QAM and 64QAM are shown in figure 6-7, In that the doppler frequency is set to be 40Hz and it shown that

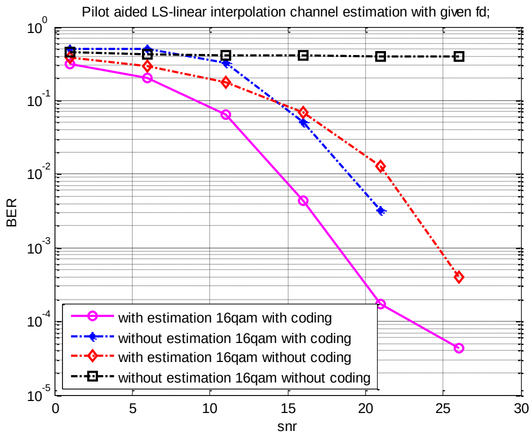

Fig.6 BER performance of Pilot-aided 16QAM for Rayleigh Channel

BER performance is improved by using estimation and channel coding compared to without estimation without coding.

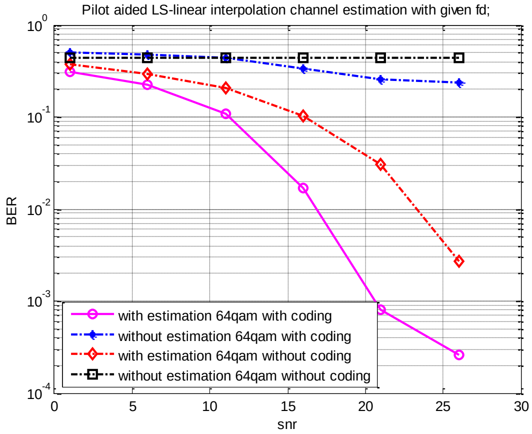

Fig.7 BER performance of Pilot-aided 64QAM for Rayleigh Channel

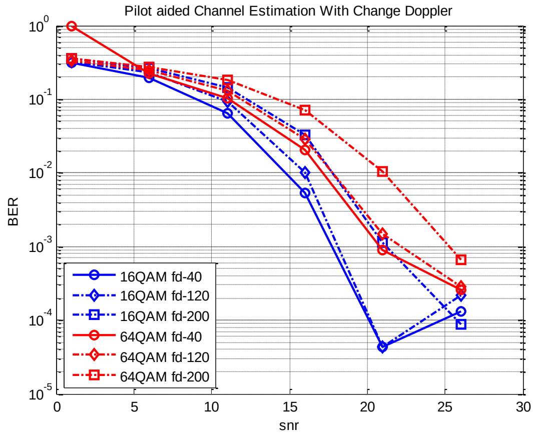

Fig.8 BER performance of Pilot-aided 16QAM & 64QAM for Rayleigh Channel with different doppler frequency

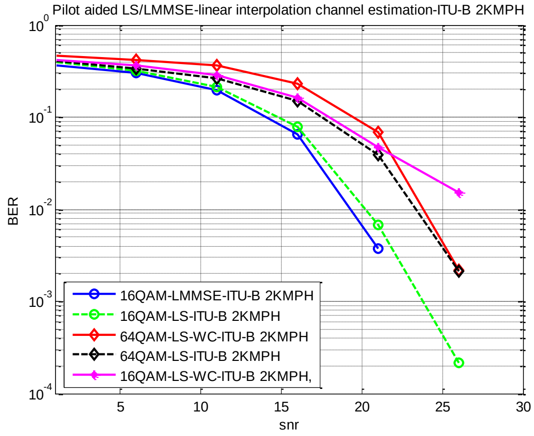

Fig.9 BER performance of Pilot-aided LS/LMMSE linear Interpolation for ITU-R B channel

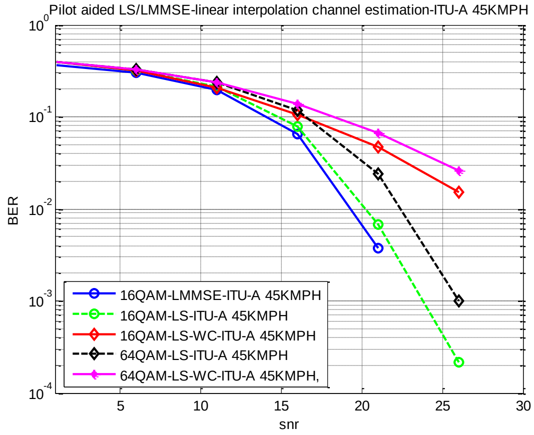

Fig.10 BER performance of Pilot-aided LS/LMMSE linear Interpolation for ITU-R A channel

In above Figure.8 BER comparison of 16QAM and 64QAM with different Doppler frequencies 40Hz,120Hz and 200Hz are shown, and it is observed that as the Doppler frequency increase BER performance is decline to be a worst ,also the BER performance of 64QAM is worst Compare to 16QAM under given parameter as Shown in Table 1.

In Figure 9-10, the BER versus SNR for 16QAM modulation with LS/LMMSE –linear interpolation has been compared for ITU-R B and ITU-R A with doppler frequency respectively 4.6Hz and 104.2Hz which are correspond to pedestrian velocity of 2kmph and Vehicular 45kmph, and it is observed that the BER can be reduce by using LMMSE compare to the LS estimation at lower SNR.

5. CONCLUSION

In this paper Mobile WiMAX system based on IEEE 802.16e Standard has been discussed with main focus to downlink channel estimation at receiver with higher Doppler frequency is carried out under multipath Rayleigh Channel with ITU-R-A and ITU-R B channel specification. The channel estimation methods based on pilot source position and two interpolation methods with LS and LMMSE have been analysed and compared. It can be conclude from this results that the data pilot based channel estimation with linear interpolate LMMSE estimator has a priori knowledge of channel statistics in the form of β and autocorrelation of the channel, So for low SNRs, the LMMSE is good compared to LS but its Complexity is large compared to the LS estimator. For high SNR the LS estimator is simple and adequate both.

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