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High Mobility Data Pilot Based Channel Estimation for Downlink OFDMA System Based on IEEE 802.16e Standard

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Abstract— **High mobility communication systems need suitable channel estimation to cope high frequency selectivity channel effect. In this paper we propose data pilot based channel estimation in downlink OFDMA for IEEE 802.16e standard (Mobile WiMAX). The Mobile WiMAX channel estimation can be done by exploiting pilot from preamble, in this paper we obtain channel transfer function by exploiting pilot at symbol data with two dimensial interpolation scheme. Based on our simulation, it can be shown that the proposed method have better performance compare with preamble based channel estimation method. Afterwards we compare Linear Interpolation and MMSE interpolation for proposed channel estimation method. The Symbol Error Rate for QPSK and 64 QAM system is presented by means of simulation.**

I. Introduction

Channel estimation play an important role in a telecommunication receiver, especially for high mobility communication. Channel Estimation provides information about distortion of the transmission signal when it propagates through the channel. In order to mitigate hostile channel effect on the received signal, precise channel estimation is required, especially for mobile telecommunication with highly dispersive channel.[1]

There are three main problems in designing channel estimators for wireless OFDM systems. First is the arrangement of pilot information, where pilot is the aided known reference data. The second problem is the design of a channel estimator with good performance and low complexity[2]. The third, for the comb or scattering (not fully inserted in one OFDM symbol) it is necessary to do interpolation after the channel estimation process. The channel estimation at the pilot subcarrier can use several algorithms like LS /MMSE/LMS. In this paper we only use LS due to its lowest computational complexity.

Based on pilot position, the channel function can be obtain from the used/nonzero subcarriers in the preamble of OFDMA system for IEEE 802.16e[3]. This approach only done for initial channel estimation, the updating channel estimation proces for other data was never discussed. The 2D Linear Interpolation algorithm which exploit pilot subcarrier from symbol data to obtain complete channel responses for Uplink OFDMA has been studied. The Linear Interpolation is carried out in frequency and time dimension together with LS channel estimation [2]. Other interpolation methods for frequency dimension like Second Order Polynomial, Low Pass[4,5], Spline Cubic[4], Phase Compensated [6] and Raised Cosine Interpolation[1] were discussed . Although there are many interpolation methods for obtain channel response function reported in references, it is important to have specifically design for special pilot arrangement like downlink OFDMA WiMAX system, which is not uniformly distributed within each OFDM block like those on the above references.

In this we propose data pilot based channel estimation in downlink OFDMA for IEEE 802.16e standard (Mobile WiMAX). The Mobile WiMAX channel estimation can be done by exploiting pilot from preamble, in this paper we obtain channel transfer function by exploiting pilot at symbol data with two dimensial interpolation scheme. An 802.16e frame in TDD mode is built up by one downlink (DL) subframe and one uplink (UL) subframe. In this paper only the downlink subframe structures will considered.

The Downlink Mobile Wimax channel estimation can be done by exploiting pilot from preamble[3]. In this paper we obtain channel transfer function by exploiting pilot at simbol data. After that we compare Linear Interpolation and MMSE interpolation for proposed channel estimation method. The Symbol Error Rate for QPSK and 64 QAM system is presented by means of simulation result on two different pilot position based channel estimation and simulation result on interpolation comparation.

The paper is organized as follows. In section II we explain System Description, section III discuss the proposed channel estimation method, with preamble based channel estimation

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method and two interpolation method n frequency dimension, Linear Interpolation and MMSE interpolation. Section IV evaluate computational complexities of Channel Estimation considered. Section V presents the simulation results, which indicate BER performance. Section VI conclude the paper.

II. System Description

The IEEE 802.16e wireless MAN –OFDMA physical layer (PHY), based on OFDM modulation, is designed for NLOS operation in thhe frequency bands below 11 GHz. The OFDM system with pilot based on channel estimation is given in figure 1.

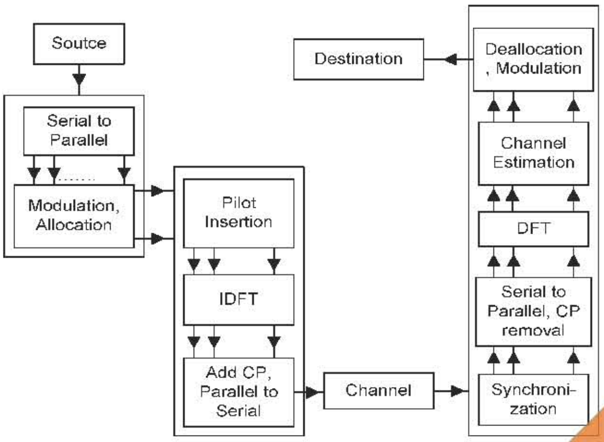

Fig. 1 Blog Diagram of The Pilot Based OFDM System

The data bits provided from the source are converted from serial to parralel to form parallel data of some subchannels[7]. Each parallel subchannel modulated to complex QAM symbols of N_u active subcarriers. The modulated data with other null carrier as guardband and DC form N subcarriers. This data sequence of length N $\{X_k\}$ are then fed into IDFT block symbol by symbol to transform them into time domain and generate an OFDM signal $\{x_n\}$ with the following equation :

$$x_n = IDFT\{X_k\} = \sum_{k=0}^{N-1} X_k e^{j2\pi kn/N}, \quad n = 0,1,\ldots,N-1 \tag{1}$$

Where N is the DFT length or the number of subcarriers. To prevent inter-symbol interference (ISI), a cyclic prefix of N_g samples is inserted at the beginning of every symbol. After D/A conversion, the signal is transmitted through the frequency selective time varying fading channel with additive noise.

Assumed that the impulse response of the multipath fading channel is given by [1]:

$$h(t,\tau) = \sum_r h_r(t)\delta(\tau - \tau_r), \tag{2}$$

Where $h_r(t)$ and τ_r are the gain and delay of the r-th path, respectively. The path gains $h_r(t)$ are wide sense stationary (WSS) narrow-band complex Gaussian process and are mutually independent. The received signal, which has been corrupted by the multipath fading channel and contaminated by the additive white Gaussian noise can be formulated as

$$y(\tau) = \sum_r h_r(t)x(\tau - \tau_r) + w(\tau), \tag{3}$$

Where $x(\tau)$ is the continuous-time representation of the transmitted discrete-time signal, x_n. The received continuous-time signal then convert back to a discrete –time signal y_n, the receiver do synchronization, downsampling, and removes the cyclic prefix. The simplified baseband model of the received samples takes the form of :

$$y_n = \sum_{l=0}^{L-1} h(l)x(n-l) + w(n) \tag{4}$$

Where L is the number of sample-spaced channel taps, w(n) is additive white Gaussian noise (AWGN) sample with zero mean and variance of σ^2_w, and h(l) is the time domain channel impulse response (CIR) for the current OFDM symbol. It is assumed that time and frequency synchronization is perfect.

FFT transforms y_n to the frequency domain received base band data :

$$\begin{aligned} Y_k &= FFT(y_n) \\ &= X_k H_k + W_k \end{aligned} \tag{5}$$

Where H and W are FFT of h and w repectively.

Following FFT block, the pilot signals are extracted and the Channel Estimation is carried out to obtain estimated channel response $\hat{H}_k$ for the data sub-channels. Then the transmitted data is estimated by equalization process :

$$\hat{X}_k = \frac{Y_k}{\hat{H}_k} \tag{6}$$

After signal demapping, the sourece binary information data are re-constructed at the receiver output.

OFDMA is based on OFDM modulation. It support subchannelization in both UL and DL. The OFDMA frame structure is similar to the OFDM structure, except the subchannelization. At OFDMA system, broadcast message can be transmitted at the same time (on different subchannels) as data. The frame is divided into a number of zones that each use a different subchannelization scheme[6].

An 802.16e frame in TDD mode is built up by one downlink (DL) subframe and one uplink (UL) subframe. Based on the OFDM principle, the pilot both in time domain and in frequency domain is assigned for channel estimation calculation process. [2]

The OFDMA downlink PUSC IEEE 802.16e symbol structure is using pilots, data, and zero subcarriers. The symbol is first divided into basic clusters and zero carriers are allocated. Pilots and data carriers are allocated within each cluster. Figure 2 below depicts the cluster structure

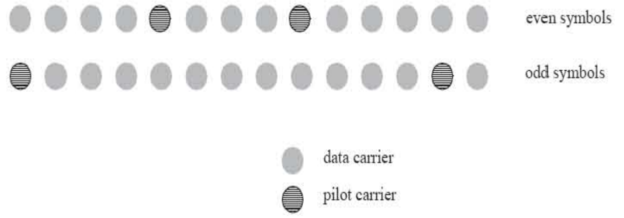

Fig. 2 Downlink OFDMA 802.16e cluster/tile structure

III. CHANNEL ESTIMATION

There are two types of Channel Estimation for OFDMA /OFDMA system based on the source of pilot used for estimation. The first kind of Channel Estimation type is Preamble based Channel Estimation [3, 5] and Data Symbol based Channel Estimation [2, 4, 6]. Both type of channel estimation can employ the usual Channel Estimation algorithms, for example, Least Square (LS) Method, Minimum Mean Square Error (MMSE) method to estimate channel response at the pilot position. Then using this channel function estimate, interpolation in time dimension is done. Next step is interpolation in frequency dimension.

A. Preamble Pilot Based and Data Pilot Based Channel Estimation

Preamble Pilot based channel estimation exploit the first symbol of each downlink subframe dedicated as a preamble in OFDMA mode of 802.16e standard. This preamble is used for initial estimation of time varying channel. The LS estimation at non zero position at every third subcarrier in the preamble is done after FFT block at receiver. More processing (interpolation) is required to estimate complete channel response. In [3] the performances of mobile station initial channel estimation methods using such a preamble is analyse. The next paragraph explain about data pilot based channel estimation that we propose for downlink OFDMA 802.16e standard.

In general, the fading channel response of the OFDM/OFDMA system can be viewed as a two dimensional (2D) lattice in time-frequency plane [2]. For Downlink mobile WiMAX system, inside a tile/cluster, the fading channel responses are sampled at 4 pilot subcarriers as shown at figure 2. The channel responses at the rest of data subcarrier are estimated by interpolation.

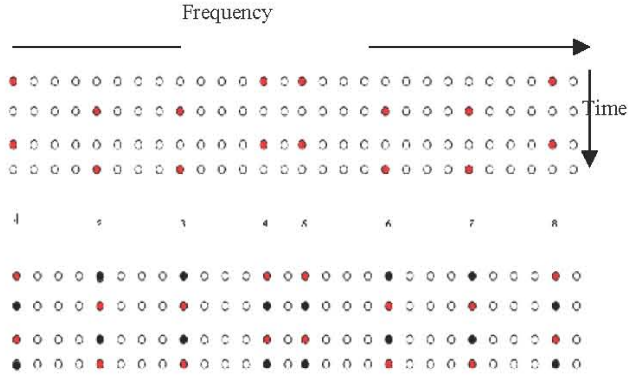

Fig. 3 Pilot Position before Interpolation (above) and after time interpolation (below)

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 3. Next is frequency dimension interpolation. The subcarrier spacing after time interpolation is 4 subcarriers and 1 subcarrier. In this paper we use linear and MMSE frequency dimension interpolation.

B. Channel Estimation Algorithms

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

$$\hat{H}_{P,LS} = X_P^{-1} Y_P = \left[\frac{Y_P(1)}{X_P(1)} \; \frac{Y_P(2)}{X_P(2)} \cdots \frac{Y_P(N_P)}{X_P(N_P)} \right]^T \quad (7)$$

Without using any knowledge of the statictics of the channels, The LS Estimator has very low complexity , but they suffer from a high mean-square error[2].

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. The frequency domain MMSE estimate of channel response is given by[6]:

$$\hat{H}_{P,MMSE} = R_{H_P H_P}\left(R_{H_P H_P} + \sigma_n^2 \left(X_P X_P^H\right)^{-1}\right)^{-1} \hat{H}_{P,LS} \quad (8)$$

$$R_{H_P H_P} = E\{H_P H_P^H\}$$

Where $\hat{H}_{P,LS}$ is the LS estimate of channel condition at pilot position, σ_n^2 is the variance of noise W_K, X_P is a matrix containing the transmitted pilot on its diagonal, $R_{H_P H_P}$ is the channel autocorrelation matrix defined by

For this case, the correlation function between the channel frequency response value is given by[5] :

$$E\{H_m H_n^*\} = \begin{cases} 1, & m = n \\ \dfrac{1-e^{-j2\pi(N_g(m-n)/N)}}{j2\pi(N_g(m-n)/N)}, & m \neq n \end{cases} \quad (9)$$

From equation (9) we can get $R_{H_P H_P}$.

C. *Frequency Dimension Interpolation*

After the estimation of channel transfer responses of pilot subcarriers, the channel responses of the rest data sub carrier are obtained by interpolation process using the channel information at pilot subcarriers[6].

In this paper we consider a piecewise linear, and a MMSE interpolation. First interpolation methode have inherent low complexity and easy to implement. Other interpolation, MMSE interpolation, has better performance at highly frequency-dispersive environments. [3]

The linear interpolation method obtains the channel response at the k-th subcarrier, as[1]

$$\begin{aligned} \hat{H}(k) &= \hat{H}(mL+1) \\ &= \hat{H}_P(m) + \frac{l}{L}\left(\hat{H}_P(m+1) - \hat{H}_P(m)\right), 0 \le l < L \end{aligned} \quad (10)$$

where $m = 0, 1, \ldots N_P-1$, N_P= number of pilot, $mL \le k < (m+1)L$ and $L = N/NP$, where N = total number of subcarriers.

MMSE interpolation can be perform by modifying the MMSE estimator at equation (8) to obtain all data subcarrier's channel responses, with this equation[3] :

$$\hat{H}_{MMSE} = R_{HH_p}\left(R_{HH_p} + \sigma_n^2\left(X_P X_P^H\right)^{-1}\right)^{-1}\hat{H}_{P,LS} \quad (11)$$

In this paper we only consider Linear and MMSE interpolation since both interpolation are most suitable for un-uniformly distributed pilot in downlink OFDMA 802.16e system.

IV. Computational Complexities

Computational complexities determined by required number of complex multiplication are shown at table II for each scheme and for a single OFDMA symbol. The linear interpolation of preamble based scheme requires N_u-$N_{ppreamble}$ = 840–280 = 560 complex multiplications. (Nppreamble = number of pilot subcarriers at preamble). The linear interpolation of data pilot based scheme requires N_u-N_p = 840-120 = 720 complex multiplications. MMSE interpolation with preamble based scheme require Nu.Nppreamble=235200 complex multiplication and MMSE interpolation with data pilot based scheme requires 2.Nu.Np = 201600 complex multiplication.

TABLE I

Computational Complexities Comparation

Channel Estimation Method	Interpolation	Complex Multiplication
Preamble Based LS	Linear	560
	MMSE	235200
Data Symbol Based LS	Linear	720
	MMSE	201600

V. Simulations

In this section, we report computer simulation carried out to evaluate and compare performance of the considered channel estimation. We used downlink OFDMA system of IEEE 802.16e. The OFDMA system parameters used in the simulation are indicated in Table II.

The channel models used in the simulation is same as [3], the ITU-R A and ITU-R B channel for vehicular environment. We set the vehicle speed of user to 60 km/h.

Two channel estimation method, preamble pilot based channel estimation [3] and proposed data pilotlbased channel estimation, are simulated and compare. Both methode used LS estimator and linear interpolation and the result are shown in Fig. 4 - 5.The horizontal variable is signal to noise ratio and the vertical variable is Bit Error Rate. From Fig . 4-5 we see that the performance is improved significantly when the data pilot based channel estimation is applied.

Table II

Parameter Used In The Paper

Parameter	Value	Note
N	1024	FFT Size
N_u	840	Number of used subcarrier
N_g	256	CP Size
N_P	120	Number of pilot subcarrier
$N_{PPREAMBLE}$	280	Number of used/pilot subcarriers in preamble

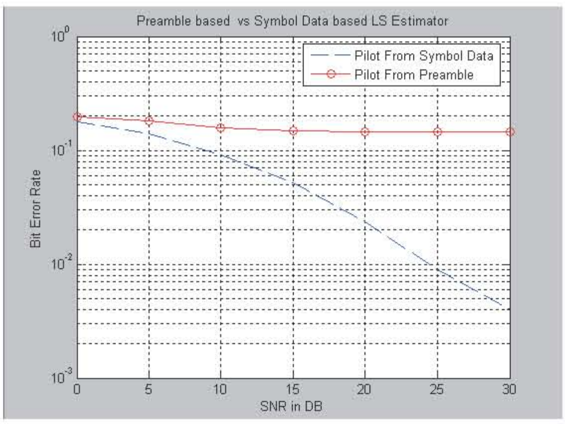

Fig.4. BER performance of the different pilot position based estimation methods for 64 QAM under ITU A vehicular channel model.

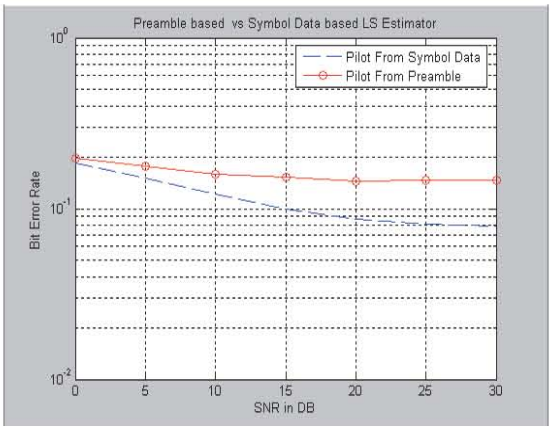

Fig.5. BER performance of the different pilot position based estimation methods for 64 QAM under ITU B vehicular channel model.

The performance improvement at the data pilot based channel estimation in view of the fact that the data pilot based channel estimation method obtain channel response function every symbol periode, on the contrary preamble pilot based channel estimation only take once at the initial of the frame.

Two interpolation method, linear method and MMSE method are simulated and compared. Both interpolation methode use LS estimator and data symbol based channel estimation algorithm. The result are shown in figure 6-9.

From figure 6 and 8, BER performance of Linear and MMSE interpolation at ITU A vehicular channel is approximately equal. This is due to the medium frequency selectivity condition can be coped well by linear interpolation. However, at high frequency selectivity (fig.7,9) the performances decrease due to unlinearity channel response between pilots occurred. [3]

VI. Conclusion

In this paper an OFDMA system based on IEEE 802.16e standard has been discussed with focus to downlink channel estimation at receiver. Two channel estimation method base on pilot source position and two interpolation method at the proposed channel estimation method are analysed and compare . We conclude that the data pilot based channel estimation with linear interpolate LS estimator achieve good trade off and has acceptable performance. The proposed channel estimation scheme with LS channel estimation is suitable for practical application of downlink IEEE 802.16e OFDMA systems. On the other hand MMSE interpolation can be employed in the highly frequency dispersive and selectivity environments with the consequence of higher complexity.

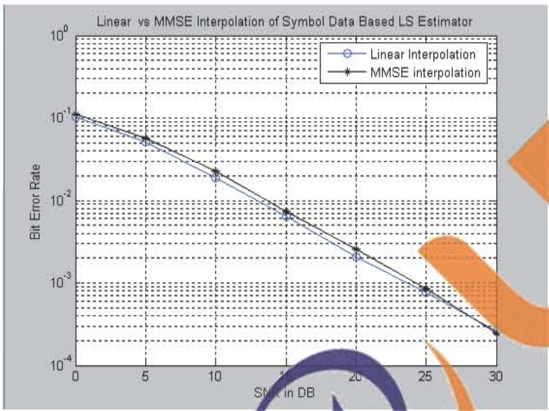

Fig.6. BER performance of Symbol Data Based LS Estimate with different interpolator for QPSK under ITU A vehicular channel model.

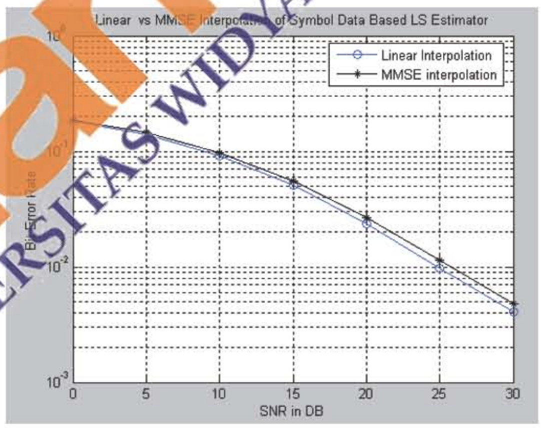

Fig.8. BER performance of Symbol Data Based LS Estimate with different interpolator for 64QAM under ITU A vehicular channel model.

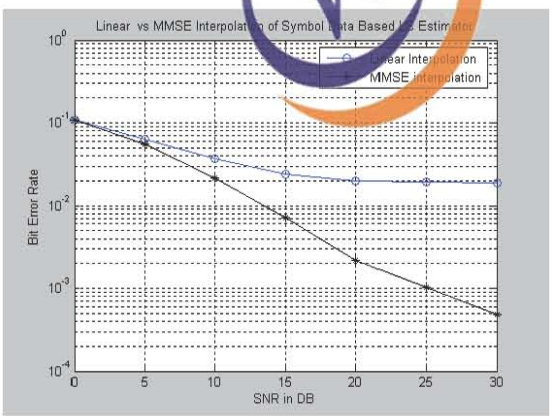

Fig.7. BER performance of Symbol Data Based LS Estimate with different interpolator for QPSK under ITU B vehicular channel model.

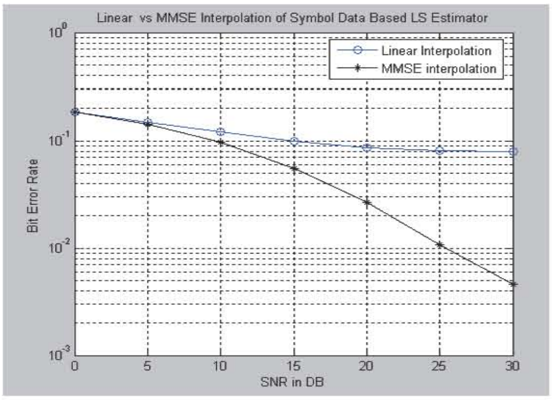

Fig.9. BER performance of Symbol Data Based LS Estimate with different interpolator for 64QAM under ITU B vehicular channel model.

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