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A COMPARATIVE STUDY OF CHANNEL ESTIMATION BASED ON SYMBOL SOURCE OF PILOT FOR DOWNLINK OFDMA SYSTEM ON IEEE 802.16e STANDARD

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Abstract

Mobile WiMAX system is expected to be a base for wireless ubiquitous products all over the world. This high mobility communication systems need efficient channel estimation to cope high frequency selectivity and time variation channel effect. In this paper, two channel estimation methods based on symbol source of pilot for downlink OFDMA IEEE 802.16e standard (Mobile WiMAX) are compared and investigated. We compare preamble-symbol-based channel estimation and data-symbol-based channel estimation. Based on our simulation, it is proven that the data symbol based channel estimation method have better performance than preamble-based channel estimation method. We also try two interpolation scheme for data symbol based channel estimation. First is two dimensional MMSE (Minimum Mean Square Error)/Linear Interpolation scheme. Linear Interpolation was carried out at time domain and MMSE Interpolation was performed at frequency domain. The other is Linear Interpolation in both domain. It is shown that the MMSE interpolation at frequency domain achieve best performance at higly dispersive channel (ITU-B vehicular). We conclude symbol data based channel estimation with MMSE/Linear Interpolation is efficient and suitable scheme for the downlink OFDMA mobile WiMAX system. The performance of all methodes are shown by measuring bit error rate with 64 QAM and QPSK modulation in ITU A and ITU B vehicular channel models.

Keywords: channel estimation, OFDMA, 802.16e , mobile WiMAX

1. 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 telecomunnication with highly dispersive channel [8].

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[9]. 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[1, 2, 6, 7, 10]. In this paper we only use LS due to its lowest computational complexity.

Based on symbol sourced of pilot, the channel function can be obtain from the used/nonzero subcarriers in the preamble of OFDMA system for IEEE 802.16e[10]. This approach is only done for initial channel estimation, the updating channel estimation process for other data was out of the scope of this paper. Same method as the proposed algorithm, had been presented by Shen [9] for other system, i.e. uplink 802.16e OFDMA, which has relatively uniform pilot arrangement compare to the downlink system we use for this research. Although there are many methods to obtain channel response function, it is important to have specific design for special pilot arrangement like downlink OFDMA WiMAX system, which is not uniformly distributed within each OFDM block like those mentioned in reference [9].

In this paper we compare the preamble based channel estimation and data pilot based channel estimation in downlink OFDMA for IEEE 802.16e standard (Mobile WiMAX) with two dimensional interpolation scheme for downlink mobile WiMAX system. 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 be considered.

2. System Description

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

The data bits provided from the source are converted from serial to parralel to form parallel data of some subchannels [5]. Each parallel subchannel is modulated to complex QAM symbols of N_u active subcarriers. The modulated data with other null carriers as guardband and DC form N subcarriers.

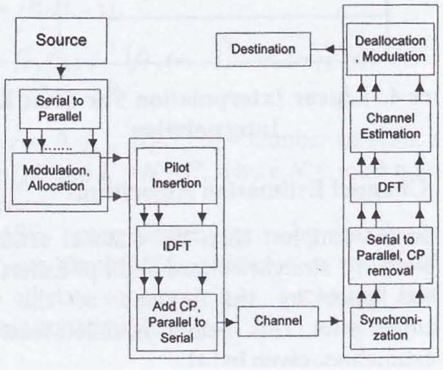

Figure 1. Blog Diagram of The Pilot Based OFDM System

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 :

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

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.

Assuming that the impulse response of the multipath fading channel is given by [8]:

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

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 processes 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 converted back to a discrete time signal y_n, the receiver does 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.

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

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

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

Following DFT 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 [9]. 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.

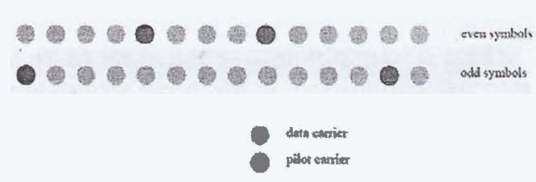

Figure 2. Downlink OFDMA 802.16e Cluster/Tile Structure

3. Channel Estimation

3.1 Channel Estimation based on Pilot Position /Symbol Source of Pilot

There are two types of Channel Estimation for OFDMA/OFDMA system based on pilot position. The first is Preamble based Channel Estimation [1, 10] and Data Symbol based Channel Estimation [2, 6, 9]. 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 the estimated channel function, interpolation in time domain is done. Next step is interpolation in frequency domain.

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 [10] the performances of mobile station with channel estimation methods using such a preamble is analysed. The next paragraph explain about data pilot based channel estimation.

In general, the fading channel response of the OFDM/OFDMA system can be viewed as a two dimensional (2D) lattice in time-frequency plane [9]. For the downlink of mobile WiMAX system, inside a tile/cluster, the fading channel responses are sampled at 4 pilot subcarriers as shown at Figure 3. The channel responses at the rest of data subcarrier are estimated by interpolation.

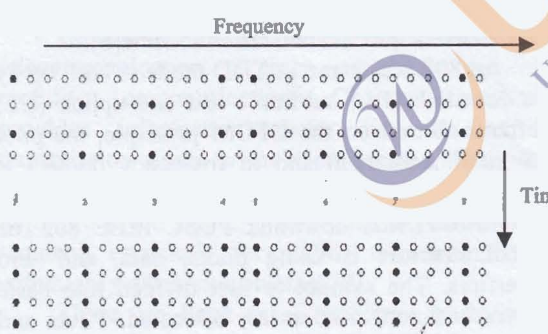

Figure 3. Pilot Position Before (Above) and After Time Domain Interpolation (Below)

First is interpolation at time domain which has 2 symbols time spacing. In this paper we use linear interpolation for time domain interpolation because it is sufficient for small time spacing. The time domain interpolation steps are shown in Figure 4. Next is frequency domain interpolation. The subcarrier spacing after time interpolation is 4 subcarriers and 1 subcarrier.

In this paper, we compare these two different approaches for downlink OFDMA 802.16e to calculate channel estimation employing LS estimator at the pilot subcarriers. The channel response of pilot subcarrier is then linearly frequency domain interpolated, 2[nd] order polynomial, lowpass, Lagrange and MMSE interpolation.

P_1
$H = \frac{1}{2} P_1 + \frac{1}{2} P_2$
P_2

Figure 4. Linear Interpolation For Time Domain Interpolation

3.2 Channel Estimation Algorithms

In the simplest case, the channel estimations, are found by straightforward multiplication of the received pilot by the inverse of the known transmitted pilot. This method is called least square (LS) estimation, given by[4] :

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

$$= \left[\frac{Y_P(1)}{X_P(1)} \frac{Y_P(2)}{X_P(2)} \cdots \frac{Y_P(N_P)}{X_P(N_P)} \right]^T \qquad (7)$$

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[9].

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 estimation of channel response is given by[6]:

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

Where $H_{P,LS}$ is the LS estimation 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

$$R_{H_P H_P} = E\left\{ H_P H_P{}^H \right\} \qquad (9)$$

For this case, the correlation function between the channel frequency response value is given by[1] :

$$E\left\{H_m H_n^*\right\} = \begin{cases} 1, & m = n \\ \dfrac{1 - e^{-j2\pi(N_g(m-n)/N)}}{j2\pi(N_g(m-n)/N)}, & m \neq n \end{cases} \qquad (10)$$

From equation (10) we can get R_{HpHp}.

3.3 Interpolation Methods

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 [10].

The linear interpolation method obtains the channel response at the k-th subcarrier, as[8]

$$\hat{H}(k) = \hat{H}(mL+1) = \hat{H}_P(m) + \frac{l}{L}\left(\hat{H}_P(m+1) - \hat{H}_P(m)\right), 0 \le l < L \qquad (11)$$

where $m = 0, 1, \ldots N_P\text{-}1$, 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 performed by modifying the MMSE estimator at equation (8) to obtain all data subcarrier's channel responses, with this equation[10] :

$$\hat{H}_{MMSE} = R_{HH_P}\left(R_{HH_P} + \sigma_n^2\left(X_P X_P^H\right)^{-1}\right)^{-1} \hat{H}_{P,LS} \qquad (12)$$

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.

4. Simulation

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 and the parameters used in the simulation are indicated in Table 1.

The channel models used in the simulation are the ITU-R A and ITU-R B channel for vehicular environment which represent the channel condition for mobile WiMAX system. We set the vehicle speed of user to 60 km/h.

Two channel estimation methods, preamble pilot based channel estimation [10] and proposed data pilot based channel estimation, are simulated and compared. Both methods used LS estimator and linear interpolation, and the result are shown in Fig. 5 - 6.The horizontal axis is signal to noise ratio and the vertical variable is Bit Error Rate. From Fig . 5-6 we see that the performance is improved significantly when the data pilot based channel estimation is applied.

Table 1. 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

Performance improvement at the data pilot based (2D linear interpolation) channel estimation in view of the fact that this method obtains channel response function every in symbol periode. On the contrary, preamble pilot based channel estimation only take once at the initial of the frame. This condition make the data pilot based channel estimation can follow time domain channel response variation due to high mobility better than preamble based channel estimation.

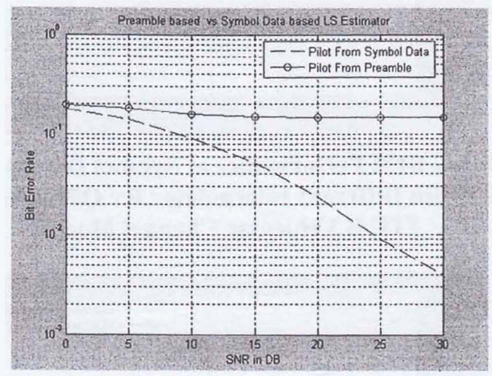

Figure 5. BER Performance of The Different Pilot Position Based Estimation Methods for 64 QAM under ITU A Vehicular Channel Model.

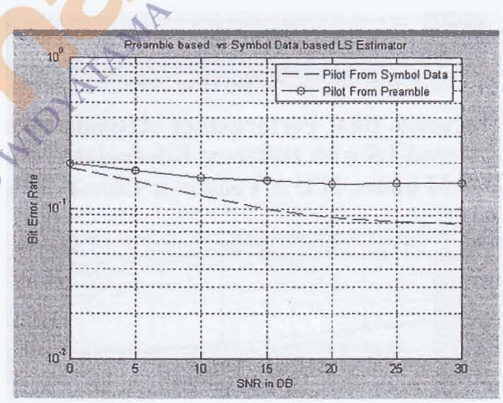

Figure 6. BER Performance Of The Different Pilot Position Based Estimation Methods for 64 QAM under ITU B Vehicular Channel Model.

Two interpolation method, linear method and MMSE method are simulated and compared. Both interpolation method use LS estimator and data symbol based channel estimation algorithm. The result are shown in Figure 7-10.

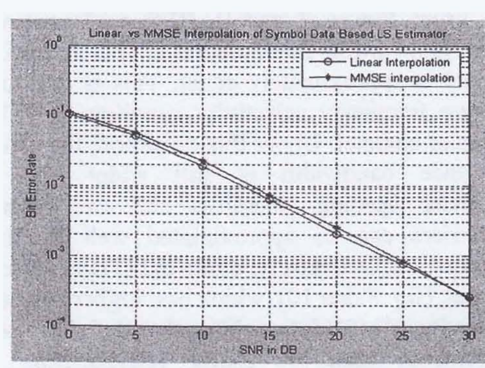

Figure 7. BER Performance of Symbol Data Based LS with Different Interpolator for QPSK under ITU A Vehicular Channel Model.

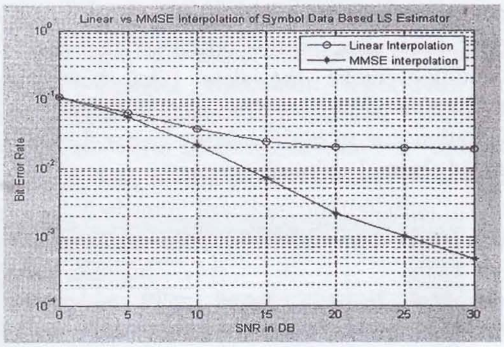

Fig.8. BER Performance of Symbol Data Based LS with Different Interpolator for QPSK under ITU B Vehicular Channel Model.

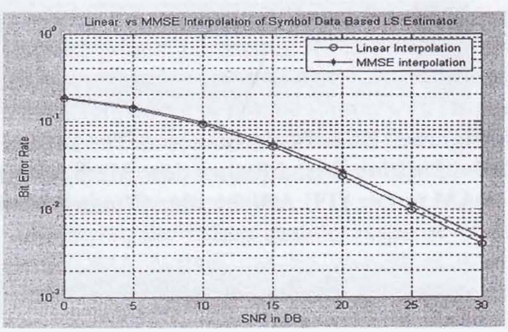

Figure 9. BER Performance of Symbol Data Based LS with Different Interpolator for 64QAM under ITU A Vehicular Channel Model.

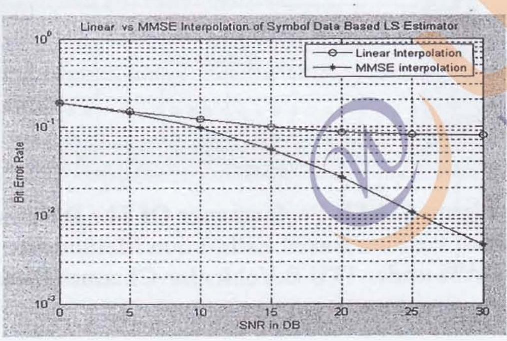

Fig.10. BER Performance of Symbol Data Based LS with Different Interpolator for 64QAM under ITU B Vehicular Channel Model.

From Figure 7 and 9, BER performance of Linear and MMSE interpolation at ITU A vehicular channel is approximately equal. This is due to the medium frequency selectivity condition in ITU A vehicular channel. Under this condition, the channel coherence bandwidth is still wider than the subcarrier spacing, therefore the two adjacent subcarriers can be approximated well by linear interpolation. Conversely, under the ITU B vehicular channel, (fig. 8 dan 10) which has higher frequency selectivity, MMSE Interpolation has definitely better performance than the Linear Interpolation. The decreasing of Linear Interpolation performance is due to unlinearity channel response between pilots, then Linear Interpolation is not valid anymore. On the other hand, MMSE interpolation provides the knowledge of the channel correlation in more subcarriers which alows better performance in highly selectivity channel condition at ITU-B vehicular channel.

5. Conclusion

In this paper a high mobility data symbol based with 2D interpolation channel estimation method for downlink IEEE 802.16e is proposed and presented. The channel response of pilot subcarrier are estimated by LS estimator based on pilot at symbol data. The channel response of complete data subcarrier are interpolated by two dimensional Interpolation using MMSE interpolation and Linear Interpolation at frequency domain. From the simulations, it is shown that the symbol based channel estimation with MMSE/linear interpolation method achieve best BER performance compared to the preamble based method presented by Yucek [10] and linear interpolation method presented by Yushi, especially for highly dispersive channel with high frequency selectivity and high time variation (ITU B vehicular). We conclude that this channel estimation scheme is suitable for practical application of downlink IEEE 802.16e OFDMA systems in the high mobility (vehicle speed 60 km/h) condition.

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