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Improved Linear Channel Estimation Based on Channel Shortening Prefilter for OFDMA Based WiMAX Systems

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Abstract
In this paper, we propose an improved linear channel estimation algorithm using a channel shortening prefilter for OFDMA (Orthogonal Frequency Division Multiple Access) based Worldwide Interoperability for Microwave Access (WiMAX) systems. The prefilter employs the Channel Impulse Response (CIR) length estimated from channel autocorrelation. The simulation results show that the improvement of Mean Square Error (MSE) for Signal to Noise Ratio (SNR) of 10 dB with CIR length estimation is about 10 dB when compared to conventional methods.

Keywords-OFDMA; LS; MMSE; CIR; WiMAX

Introduction

Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) are two major technologies toward next-generation mobile broadband standards, which are both expected to provide higher throughput and lower transmission latency for mobile users. To ensure efficient delivery in terms of bandwidth and available spectrum the WiMAX physical layer is based on OFDMA (Orthogonal Frequency Division Multiple Access) [1].

OFDMA is merely a special form of Frequency Division Multiple Access (FDMA), the only difference is that all the frequencies are orthogonal having no interference with one another. An OFDMA symbol consists of three types of carriers which include data carriers, pilot carriers and null carriers. The Time Division Duplexing (TDD) frame structure of WiMAX physical layer consists of preamble as the first symbol. The preamble is used for channel estimation and equalization and is known *a-priori* at the receiver. The preamble contains pilot carriers, guard bands and DC carrier and the data symbol consists of pilot carriers, data carriers, guard bands and DC carrier. The pilot placement in preamble can be considered as block type and that of data symbols can be considered comb type. The conventional channel estimation methods for block and comb type OFDM can be applied to the preamble and data symbols respectively.

Channel estimation is to estimate the channel response in time domain or frequency domain in order to correct and recover the received data. The estimation of channel using block type arrangement is much more accurate than the comb type estimation as the matrix is fully known to the receiver. However, in fast changing channels the channel has to be updated every OFDM symbol and hence comb type estimation has to be done. The block type channel estimation includes Least Squares (LS), Minimum Mean Squared Estimation (MMSE) and LS estimation with improved Discrete Fourier Transform.

The initial channel response is obtained by performing LS estimation on the preamble of symbol frame. This estimate is then used in MMSE on the data carriers to estimate the data. If the length of the Channel Impulse Response (CIR) can be estimated, the performance of the MMSE algorithm can be improved by using a shortening prefilter prior to the estimation. The length of CIR is usually approximated as the length of the Cyclic Prefix (CP). If the estimated CIR length is larger than the true CIR, the performance of the estimator and the spectral efficiency decreases whereas the complexity increases. However the CIR length varies with the statistical characteristics of the channel [2].

In the literature, different CIR length estimation techniques are available. The method in [3] usually underestimates the CIR length. The technique based on minimization of MSE of the estimated channel coefficients is described in [4] which require knowledge of channel window. Blind channel length estimation based on the interference level of CP length is proposed in [5]. The estimated CIR length can be used to vary the length of GI adaptively to achieve high spectral efficiency [6]. In [7], an approximate Power Delay Profile (PDP) is used to generate the Least Minimum Mean Square Error (LMMSE) filter coefficients. An accurate PDP estimate is used in LMMSE estimation in [8]. An adaptive GI by dynamically choosing GI from a variable length orthogonal set is proposed in [9] for Amplify and Relay systems. In [10], adaptive denoising algorithm based on mean square error criteria is use d to select GI for Power Line Communication Systems. To estimate the CIR length in time varying channel, we propose an algorithm which is based on correlation between adjacent samples in the channel. This estimated length is used to vary the length of GI in the transmitter.

The remainder of the paper is organized as follows: after a description of the OFDMA system model and linear channel estimation algorithms in Section II, the improved linear channel estimation with channel shortening prefilter is

proposed in Section III. Finally results are presented and discussed in Section IV. The paper is concluded in Section V.

System Model

Assuming that the guard time is longer than the channel delay spread and the CIR remains invariant within a OFDM symbol, the received symbol is amplitude scaled and noise corrupted version of the transmitted symbol. The received symbol at an arbitrary carrier i can be expressed as

$$y_i = h_i s_i + n_i \quad (1)$$

where y_i is the received symbol, s_i is the transmitted symbol, h_i is the channel response and n_i is the AWGN noise having zero mean and variance of σ_n^2.

In matrix form equation (1) can be written as

$$y = Sh + n \quad (2)$$

The task of channel estimation is to determine***h.*** Figure 1 shows the OFDMA frame structure in WiMAX system. The symbols known to both transmitter and receiver (pilot symbols) are arranges as block in the preamble.

Frame Structure

In mobile WiMAX, both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) are supported. The TDD frame consists of one uplink (UP) subframe and one downlink (DL) subframe. The first symbol in DL subframe is the preamble. It is used for channel estimation, carrier and timing synchronization. The Frame Control Header (FCH) is used for carrying system control information [12]. The DL-MAP and UL-MAP provides control information for DL and UL subframes respectively.

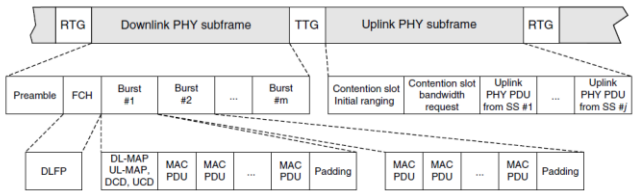

Figure 1. OFDMA Frame in TDD Mode [11]

Least Square Estimation (LS)

The LS estimation attempts to minimize the square error [13]

$$\epsilon^2 = (y - Sh)(y - Sh)^H \quad (3)$$

The channel estimate is given by

$$h_{ls} = S^{-1} y \quad (4)$$

Thus the LS estimate of the channel is obtained by simply multiplying the received symbol with the pilot value. The drawback of the estimation is that the noise component n_i influences the performance leading to high Mean Square Error (MSE).

Minimum Mean Square Error Estimation (MMSE)

The MMSE algorithm employs both channel autocorrelation and noise variance. The channel estimate is given by [13]

$$h_{mmse} = R_{hh}(R_{hh} + \sigma_n^2 (SS^H)^{-1})^{-1} h_{ls} \quad (5)$$

where $R_{hh} = E\{hh^H\}$ is the channel autocorrelation matrix. Thus the MMSE estimate improves the LS estimate but the drawback is the complexity.

Linear Channel Estimation with Delay Profile Estimation

The improvement in linear estimation can be obtained using the fact that the number of actual CIR taps is equal to the channel delay profile and usually far less than the FFT size. Hence if we are able to estimate the delay spread, a channel shortening prefilter can be employed to reduce the number of taps in the LS estimated channel.

From the LS channel estimates, the instantaneous channel frequency correlation values can be calculated as

$$R_h(\Delta) = E_k\{\hat{H}_m(k)\hat{H}_m(k+\Delta)\} \quad (6)$$

Where E_k is the mean with respect to k.

These instantaneous correlation estimates can be averaged over several OFDM symbols given by

$$R_h(\Delta) = \begin{cases} R_h(\Delta) \; if \; \Delta \neq 0 \\ R_h(0) \; if \; \Delta = 0 \end{cases} \quad (7)$$

The Power Delay Profile (PDP) estimate can be obtained by taking Inverse Discrete Fourier Transform (IDFT) of the averaged frequency correlation estimates

$$\tilde{R}_{hh}(\tau) = IDFT\{R_h(\Delta)\} \quad (8)$$

The estimated exponential PDP is given by

$$\tilde{R}_{hh}(\tau) = \frac{e^{-j2\pi\tau_0 k/N}}{1+j2\pi\tau_{rms}k/N} \quad (9)$$

Where τ_0 is the initial delay and τ_{rms} is the root mean square of the delay spread.

The length of the channel impulse response can be approximated to be equal to the maximum excess delay spread.

A. ***Structure***

Fig. 2. shows the structure of OFDMA transmitter and receiver. A channel shortening prefilter is inserted after channel estimation block. This shortening filter employs the algorithm to estimate the delay spread using channel autocorrelation. The shortened channel is fed back to the channel estimator to be used in the detection of data symbols.

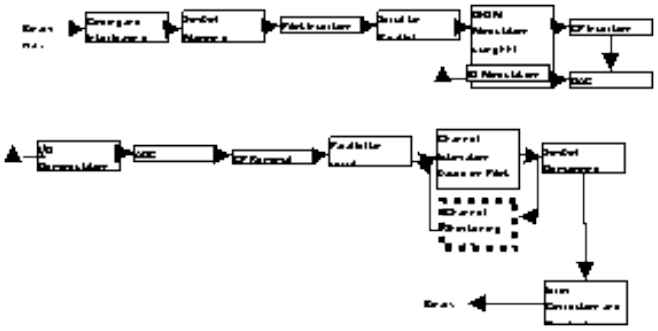

Figure 2. OFDMA Transmitter and Receiver

Results and Discussions

The performance of the proposed algorithm is carried out using MATLAB simulation in Rayleigh fading channel. The simulation parameters and the PDP of the channel parameters are presented in Table I and Table II.

TABLE I. **SIMULATION PARAMETERS**

Modulation	16QAM
Number of Subcarriers N	128
Cyclic Prefix Ration	1/8
Channel model	Rayleigh
Carrier Frequency	2.5 GHz
Duplexing Mode	TDD
Channel Profile	ITU Channel 103

TABLE II. **MULITPATH CHANNEL MODELS FOR PERFORMANCE SIMULATION [14]**

Channel Model	Path 1 (dB)	Path 2 (dB)	Path 3 (dB)	Path 4 (dB)	Path 5 (dB)	Path 6 (dB)
ITU Ped. B. Ch-103	-3.92	-4.82	-8.82	-11.92	-11.72	-27.82
ITU Veh. A. Ch-104	-3.14	-4.14	-12.14	-13.14	-18.14	-23.14

The improved linear estimation with channel shortening prefilter is done through following steps:

i) *The LS estimation is performed on the preamble and the CIR is estimated.*

ii) *The excess delay spread is estimated from the LS estimate using channel correlation minimization algorithm.*

iii) *The CIR length is shortened to be equal to that of excess delay spread.*

iv) *The shortened channel is used to perform MMSE estimation on the data carriers.*

The MSE of the estimated channel with and without channel shortening prefilter is compared with that of ideal channel in Fig. 3.

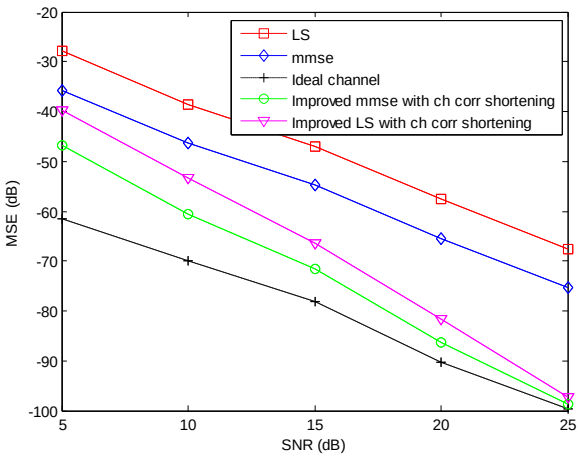

Figure 3. MSE of the channel with and without channel shortening prefilter

At a low SNR of 10 dB, the MSE of improved MMSE with channel autocorrelation shortening is 10 dB less when compared to conventional MMSE estimation. Similarly at 10 dB, the MSE of improved LS estimation is 12 dB less than the conventional LS estimation.

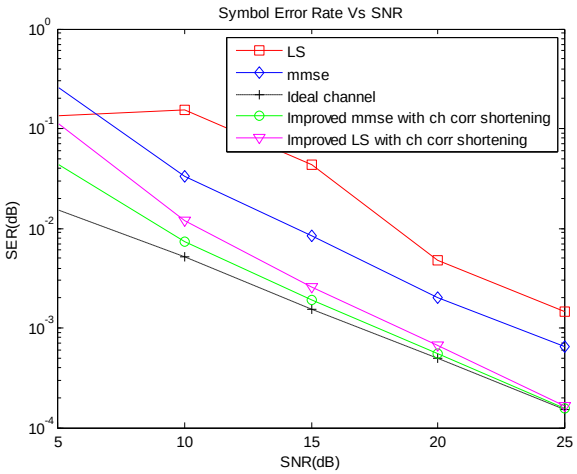

Figure 4. SER Performance with and without channel shortening prefilter

The Symbol Error Rate (SER) performance of the system with and without channel shortening prefilter is given in Fig. 4. At low SNR there is significant reduction in SER whereas at high SNR, it approaches to that of the ideal channel.

Conclusion

In this paper, improved pilot based linear channel estimation algorithms using channel shortening prefilter in OFDMA based WiMAX system is proposed. The prefilter uses channel autocorrelation function to estimate the excess delay spread of the channel. Our future research focuses on analyzing the performance of adaptive guard interval in recursive channel estimation and quantitative analysis of spectral efficiency.

References

[1] WiMAX Forum-WiMAX and the IEEE 802. 16m Air Interface Standard-April 2010-www. wimaxforum. org

[2] V. D. Nguyen and H. P. Kuchenbecker, "Intercarrier and intersymbol interference analysis of OFDM systems on time-variant channels", Proc. IEEE Int. Symp. on Personal Indoor and Mobile Radio Commun., IEEE PIMRC 2002, Portugal, setp. 2002.

[3] E. G. Larson, G. Liu, J. Li, and G. B. Giannakis, "Joint symbol timing and channel estimation for OFDM based WLANs", IEEE Communication Letters, 2001.

[4] J. H. Chen and Y. Lee, "Joint synchronization, channel length estimation, and channel estimation for the maximum likelihood sequence estimator for high

speed wireless communications", Proceedings of the 56th IEEE Vehicular Technology Conference, sept. 2002.

[5] Bin Sheng, Xiangyang Wang, Xiaohu You, Lan Chen "Blind Estimation of channel length for OFDM system", 5th International conference on "Wireless Communications, Networking and Mobile Computing, sept. 2009, conference publication, pp 1-3.

[6] Zhang Zhao-yang, Lao Li-feng, "A novel OFDM transmission scheme with length-adaptive cyclic prefix", journal of Zhejiang University SCIENCE, ISSN 1009-3095, 2004 5(11):1336-1342.

[7] Kun-chien Hung and David W., "Pilot-Based LMMSE channel estimation for OFDM systems with Power Delay Profile Approximation", IEEE Transaction on Vehicular Technology, vol. 59, Issue. 1, January 2010, pg: 150-159

[8] Young-Jin Kim and GinHong Im, "Pilot-Symbol Assisted Power Delay Profile Estimation for MIMO OFDM systems", IEEE Communication Letters, vol. 16, Issue. 1, January 2012, pg: 68 – 71.

[9] Xin Gao, Xianbig Wang, Yulong Zou, Ho P., "An Efficient OFDM with adaptive Guard Interval for Amplify and Forward Relay systems", IEEE 78th Vehicular Technology Conference (VTC Fall), 2013. Pg:1-5, ISSN:1090-3038

[10] Gacanin H., "Joint iterative channel estimation and guard interval selection for adaptive powerline Communication systems", 17th IEEE International Symposium on Power Line Communications and its Applications (ISPLC), 2013. Pg:197-202, ISBN: 978-1-4673-6014-2.

[11] IEEE P802. 16e/D9 Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems: Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, IEEE, New York, June 2005

[12] R. Prasad, F. J. Velez, "WiMAX Networks-Techno-Economic Vision and Challenges, 2010, Springer, ISBN: 978-90-481-8751-5.

[13] S. Haykin, "Adaptive Filter Theory", Englewood Cliffs, New Jersey: Prentence-Hall, 1986.