Superimposed Training for Multiuser MIMO-OFDM Systems

Qinghai Yang, Shaoyi Xu, Huamin Zhu *and* Kyung Sup Kwak

UWB Wireless Communications Research Center (UWB-ITRC), the Graduate School of Information Technology
and Telecommunications, Inha University, #253 Yonghyun-dong, Nam-gu, Incheon, 402-751, Korea
Email: yangqing_hai@hotmail.com and kskwak@inha.ac.kr

Abstract—In this paper, a superimposed training design for estimating multiuser channels is proposed for MIMO-OFDM uplinks. To diminish the effects of embedded data on the performance of channel estimation, a novel combining algorithm is proposed at the LS channel estimator. Optimal multiuser pilot symbols are developed with respect to the channel estimate s MSE. Simulation results show that our proposed scheme outperforms the conventional pilot aided approach as on low SNR regime.

Key words: MIMO-OFDM, multiuser channel estimation, LS, superimprosed pilot.

1. Introduction

[*]The MIMO technology using multiple transmit and receive antennas can provide the advantages of spatial diversity or/and spatial multiplexing, while OFDM technique can significantly reduce the receiver complexity in broadband wireless systems. Thus, combining MIMO with OFDM, i.e., MIMO-OFDM [1] has recently been recognized as an attractive solution for future wideband wireless communication systems. However, exploiting those advantages relies upon the channel state information, efforts to develop clever channel estimation techniques are encouraged.

Channel can be estimated with the aid of training pilots. For MIMO-OFDM systems, a common approach is to frequency-multiplex (FM) pilots with data symbols [2, 3], i.e., pilot and data symbols are transmitted on different subcarriers. In turn, this sort of method guarantees decoupled channel estimation and data detection in the frequency domain. As lots of subcarriers have to be assigned as pilot tones, it may thus be argued that this approach is bandwidth inefficient.

Superimposed pilot aided channel estimation attracts the focus for its potential spectral efficiency. Unfortunately, this approach has a disadvantage that the performance of channel estimation is affected by the embedded unknown data. Hence, endeavors to mitigate these effects have been taken up in literatures. In [4], the data-dependent sequence that is able to cancel those impacts is developed but it is only suitable for single-carrier transmissions. And, the algorithm proposed in [5] tries to diminish the effects by using the first order statistics of the data. Even so, while applying this approach to MIMO-OFDM systems, few results have ever appeared according to our knowledge.

With the aid of superimposed pilots, a novel multiuser channel estimation scheme for MIMO-OFDM uplinks is developed in this letter. Unlike OFDMA systems, the systems under the consideration allow all users to use all available subcarriers independently and thus involve multiuser interference in the frequency domain [6]. To decrease the unknown-data effects, a new signal combining algorithm is proposed at the estimator. In addition, optimal pilot symbols are derived with respect to the mean square error (MSE) of the least square (LS) channel estimate.

2. System Model

The multiuser MIMO-OFDM system consists of U user terminals and one base station (BS), the uplink of which is shown in Fig. 1. Each of the users is equipped with N_T transmit antennas, while the BS with N_R omni-directional antennas. We assume that all users share the same frequency band, which is split into K subcarriers (tones) via the OFDM modulation.

As shown in Fig. 1, $s_{u,t}(k,n)$ is defined as the symbol being transmitted from the u-th user's t-th antenna over the k-th subcarrier at time instance n ($n \in [0, N-1]$). Define the transmit power of $s_{u,t}(k,n)$ as ρ_s. In FM pilot schemes [2, 3], symbols $s_{u,t}(k,n), \forall u,t$ on some subcarriers are known pilots, as shown in Fig.2 (a). Whereas, for superimposed pilot schemes shown in Fig.2 (b), $s_{u,t}(k,n)$ can be expressed as

$$s_{u,t}(k,n) = d_{u,t}(k,n) + c_{u,t}(k,n) \tag{1}$$

where $d_{u,t}(k,n)$ and $c_{u,t}(k,n)$ are data and pilot symbols with power $\rho_d = (1-\alpha)\rho_s$ $(0 < \alpha < 1)$ and $\rho_c = \alpha\rho_s$, respectively. Here, data and pilots are independent each other. In Fig. 1, a block of K symbols from collecting $s_{u,t}(k,n)$, $\forall k$ consists of one OFDM symbol, which is computed by the subsequent *IFFT* process. Before transmission, a cyclic prefix (*CP*) of length L is added to eliminate inter-symbol interference. Here, L represents the maximum length of all channels. On the BS side, after removing the *CP* and performing the *FFT* process (OFDM demodulation), the observed signal vector at all received antennas over the k-th tone at time n is denoted as $Y(k,n) = (y_1(k,n), \cdots, y_{N_R}(k,n))^T$, which is given by

$$Y(k,n) = \sum_{u=1}^{U} H_u(k,n)[D_u(k,n) + C_u(k,n)] + \eta(k,n) \tag{2}$$

where $D_u(k,n) = (d_{u,1}(k,n), \cdots, d_{u,N_T}(k,n))^T$ and $C_u(k,n) = (c_{u,1}(k,n), \cdots, c_{u,N_T}(k,n))^T$; $\eta(k,n)$ is complex-valued additive white Gaussian noise (AWGN) vector with zero mean $\mathbf{0}_{N_R \times 1}$ and variance matrix $\sigma_\eta^2 I_{N_R}$; $H_u(k,n)$ ($N_R \times N_T$) is the discrete-time channel frequency response matrix corresponding to the u-th user, which is expressed as

$$H_u(k,n) = \sum_{l=0}^{L} h_u(l,n) e^{-j2\pi lk/K} \tag{3}$$

where matrix $h_u(l,n)$ ($N_R \times N_T$) represents the channel impulse response of the l-th tap at time instance n for the u-th user. With (3), we can rewrite (2) into the form:

$$Y(k,n) = [E_k \otimes \mathbf{D}^T(k,n) \otimes I_{N_R}]\mathbf{h}(n) + [E_k \otimes \mathbf{C}^T(k,n) \otimes I_{N_R}]\mathbf{h}(n) + \eta(k,n) \tag{4}$$

where $E_k = (1, \cdots, e^{-j2\pi Lk/K})$; $\mathbf{D}(k,n) = (D_1^T(k,n), \cdots, D_U^T(k,n))^T$ and $\mathbf{C}(k,n) = (C_1^T(k,n), \cdots, C_U^T(k,n))^T$; $\mathbf{h}(n) = [\mathbf{h}_1^T(n), \cdots, \mathbf{h}_U^T(n)]^T$ with $\mathbf{h}_u(n) = [\mathrm{Vec}(h_u(0,n))^T, \cdots, \mathrm{Vec}(h_u(L,n))^T]^T$; $\otimes$ denotes the

---

[*] This research was supported by the University IT Research Center Project (INHA UWB-ITRC), Korea.