

Chapter 7

On Uplink Channel Estimation in WiMAX Systems

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ABSTRACT

In this paper, channel estimation algorithms are proposed and compared for uplink WiMAX systems, which are OFDMA based. These algorithms are investigated based on a dynamic resource allocation scheme, and it is shown that each of them is suitable to specific system scenarios. For example, for a system with a bandwidth of 10MHz operating in the low frequency region (2-11GHz), a two-dimensional averaging algorithm outperforms other algorithms, such as a bilinear interpolation algorithm, because the correlations between the pilots and signals are sufficiently high in both the frequency and the time dimensions.

INTRODUCTION

The orthogonal frequency division multiplexing (OFDM) modulation technique has various advantages in high rate data transmission, such as high bandwidth efficiency (Edfors, Sandell, Beek, Landstrom, & Sjoberg, 1996). Orthogonal frequency division multiple access (OFDMA)

adds multiple access to OFDM by allowing a number of subscribers to transmit simultaneously on different subcarriers every OFDM symbol. It provides efficient control of the varying data rates of each user by changing the number of allocated subcarriers. It also provides both time and frequency diversities by trying to avoid both severe long-duration fades and deep narrow-band fades. OFDMA has been used in WiMAX systems for wireless metropolitan area network

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(MAN) communications and broadcasting. And it has been standardized in the IEEE 802.16e/D10, which specifies the air interface for fixed broadband wireless access (BWA) systems supporting multimedia services (IEEE-SA Standards Board, 2005).

Channel estimation is an important issue in any OFDM-based system for demodulation and decoding. In general, an OFDM waveform can be viewed as a two-dimensional (2D) lattice in the time-frequency plane. For pilot-assisted channel estimation techniques, where pilots refer to reference signals known at both transmitter and receiver, this 2D lattice can be viewed as being sampled at the pilot positions, and the channel characteristics between pilots are estimated by interpolation. The two basic aspects of OFDM channel estimation are the arrangement of pilot positions, and the design of the channel estimator to interpolate between the pilots. The goal in designing channel estimators is to solve this problem with a satisfactory tradeoff between complexity and performance.

Channel estimation techniques for OFDM systems have been widely studied. In particular, Edfors, Sandell, Beek, and Wilson (1998) and Coleri, Ergen, Puri, and Bahai (2002) presented algorithms for OFDM channel estimation with a block-type pilot arrangement and a comb-type pilot arrangement, respectively, and Shen and Martinez (2006) summarized and compared these two basic channel estimation strategies. The two fundamental principles behind these algorithms are to reduce the computational complexity by adopting one-dimensional (1D) rather than two-dimensional (2D) channel estimators, and to improve the interpolation accuracy by employing second-order statistics of the fading channel in either the frequency or in the time dimension.

In WiMAX systems standardized by IEEE-SA Standards Board (2005), however, a different transmission structure and corresponding arrangement of pilot positions are used to fully employ the diversities in both the time and the frequency

dimensions. The subcarriers allocated to a subscriber are both separated in frequency and hopped periodically in time. This dynamic resource allocation scheme makes it unfeasible to employ second-order statistics in either the frequency or the time dimension for uplink channel estimation, in other words, it is unfeasible to apply traditional OFDM channel estimation algorithms to WiMAX systems. However, on the other hand, because channel estimation has been constrained inside a small basic transmission unit, 2D interpolation is tolerable in terms of computational complexity Shen and Martinez (2007).

This paper is organized as follows. In Section II, the baseband model and the dynamic resource allocation scheme in an uplink WiMAX system are illustrated. In Section III, possible uplink channel estimation algorithms are proposed for the WiMAX system model described in Section II. In Section IV, the proposed algorithms are analyzed and compared under different scenarios, with respect to the system bandwidth, the center frequency, and the speed of the mobile subscriber. Simulation results and conclusions are presented in Section V.

BASEBAND MODEL OF WIMAX SYSTEM

We consider the uplink of an OFDMA system. Assume there are K subcarriers, among which K_u are active subcarriers used for data and pilot transmission, and the others are null subcarriers used for guard bands and a DC carrier. The active frequency bands (K_u subcarriers) are allocated among multiple users, and each subcarrier is assigned to a unique mobile station (MS). As shown in Figure 1, the MS of the desired user inserts its information bits at the subcarriers allocated to it, inserts zeros at the active subcarriers allocated to other users, and adds the null subcarriers. Then, a K -point IFFT is used to transform the data sequence into the time domain. A cyclic prefix (CP), which

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