Maximum-Likelihood Symbol Timing Estimation Algorithm for OFDM Systems with a Repetitive Preamble

설창규, 전경훈
포항공과대학교 전자컴퓨터공학과
cheun@postech.ac.kr

Maximum-Likelihood Symbol Timing Estimation Algorithm for OFDM Systems with a Repetitive Preamble

Changkyu Seol and Kyungwhoon Cheun
Division of Electrical and Computer Engineering, Pohang University of Science and Technology
cheun@postech.ac.kr

Abstract

An efficient synchronization scheme based on a repetitive preamble structure for orthogonal frequency division multiplexing systems was proposed by Schmidl and Cox. However, standard autocorrelation based estimation algorithms result in a plateau in the timing metric due to the cyclic prefix (CP), resulting in a region of uncertainty. Several modifications, either to the preamble structure itself or the estimation algorithm, have been proposed to remedy this problem. In this paper, we present a maximum-likelihood (ML) symbol timing estimation algorithm taking into account the presence of the CP. The performance of its practical modification is evaluated via computer simulations.

I. Introduction

In recent years, orthogonal frequency division multiplexing (OFDM) has become the most popular modulation scheme for wireless communications due to its efficiency over multipath fading channels. As with any digital modulation scheme, the synchronization step, which requires the estimation of the symbol timing epoch, is a prerequisite. Several methods have been proposed for acquiring synchronization in OFDM systems. Most of them exploit either the correlation between the cyclic prefix (CP) and the useful part of the OFDM symbol [1][2] or the correlation among the repeated parts within a preamble [3]-[5]. The former method is suitable for systems requiring NDA (non-data aided) synchronization whereas the latter requires a dedicated preamble.

In this paper, a maximum-likelihood (ML) symbol timing estimation algorithm is derived based on the preamble structure proposed in [3]. The resulting algorithm and its practical modifications contain, in addition to the correlation terms among the identical parts, correlation terms between the CP and the useful part of the preamble. The result is a timing metric that does not exhibit a plateau. Unlike schemes proposed in [4][5], the plateau in the timing metric is removed without reducing the number of cell/sector identification sequences. The proposed timing metric turns out to be a linear combination of the correlation terms among regularly spaced samples. This allows for a recursive computation of the timing metric similar to the metric proposed in [3] resulting in a hardware efficient receiver structure.

The remainder of this paper is organized as follows. The assumed system model is presented in Section II. In Section III, the ML symbol timing estimation algorithm and its practical modifications are derived. Performance of the proposed schemes are evaluated via computer simulations and compared to those existing algorithms in Section IV and section V concludes the paper.

This work was supported by the center for Broadband OFDM Mobile Access (BrOMA) at POSTECH through the ITRC program of the Korean MIC, supervised by IITA. (IITA-2005-C1090-0502-0008)

II. System Model

We consider a time division duplex (TDD) OFDM signal generated by taking the inverse fast Fourier transform (IFFT) of a block of modulation symbols belonging to the QAM or PSK constellation. Let $X_i[k]$, $i = -U, -(U-1), \cdots, -1, 0, 1, 2, \cdots, D-1$, $k = 0, 1, 2, \cdots, N-1$ denote the symbol modulated onto the kth subcarrier of the ith OFDM symbol where U and D represent the number of the uplink and downlink OFDM symbols within a TDD frame and N is the IFFT size. As with the scheme proposed in [3], the downlink signal begins with the preamble corresponding to index $i = 0$, prepended by a CP of length G samples followed by two identical parts. The two identical parts are obtained by taking the IFFT of nonzero symbols modulated only on the even subcarriers as follows:

$$X_0[k] = \begin{cases} \sqrt{2}A_{k/2}, & k \text{ even} \\ 0, & k \text{ odd.} \end{cases} \quad (1)$$

Here, A_i, $i = 0, 1, 2, \cdots, N/2-1$ are modelled as independent and identically distributed (i.i.d.) random