MODELING AND ESTIMATION OF WIRELESS OFDM CHANNELS BY USING TIME-FREQUENCY ANALYSIS

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Abstract. Orthogonal frequency division multiplexing (OFDM) has become a very popular method for high data rate wireless communications because of its advantages over single carrier modulation schemes on multipath, frequency selective fading channels. However, intercarrier interference, due to Doppler frequency shifts, and multipath fading severely degrade the performance of OFDM systems. Estimation of channel parameters is required at the receiver. In this paper, we present a channel modeling and estimation method based on the time-frequency representation of the received signal. The discrete evolutionary transform provides a time-frequency procedure to obtain a complete characterization of the multipath, fading, and frequency selective channels. Simulations are used to illustrate the performance of the proposed procedure and to compare it with other time-varying channel estimation techniques.

Key words: Wireless OFDM communications, time-varying channels, time-frequency analysis, discrete evolutionary transform.

1. Introduction

Orthogonal frequency division multiplexing (OFDM) is considered an effective technique for broadband wireless communications because of its great immunity to fast fading channels and intersymbol interference (ISI). It has been adopted in several wireless standards such as digital audio broadcasting (DAB) and digital video broadcasting (DVB-T), as well as the wireless local area network (IEEE 802.11a) and the metropolitan area network (IEEE 802.16a) standards. OFDM
partitions the assigned bandwidth into parallel subchannels by dividing the data bit stream into parallel, low bit-rate data streams to modulate the subcarriers of those subchannels. As such, OFDM has a relatively longer symbol duration than single carrier systems, which makes it very immune to fast channel fading and impulse noise. The independence among the subchannels simplifies the design of the equalizer. Because of all these advantages, OFDM is becoming a standard in digital audio/video broadcasting and wireless communications [13], [21], [24].

However, intercarrier interference (ICI) caused by the frequency dispersion of the channel, i.e., Doppler shifts, phase offset, and local oscillator frequency shifts, severely degrades the performance of the system [13], [20], [3]. For fast-varying channels, especially in mobile systems, large fluctuations of the channel parameters are expected between and during OFDM transmit symbols. Estimation of the channel parameters is required to use coherent receivers. Most current channel estimation methods assume a time-invariant model for the channel during one OFDM symbol, which is not valid for fast-varying environments [19], [7]. To combat time and frequency dispersion effects introduced by the wireless channel, various improvements on OFDM systems are presented in the literature. Pulse shaping OFDM [9], [10], lattice OFDM (LOFDM) [20], and adaptive multicarrier modulation [8] are among them. In [23] Wu and Gu present insights to ICI and interblock interferences in wireless OFDM systems. Adaptive Wiener filters [16] and prediction methods [17] are proposed to estimate the time-varying OFDM channel. In [12], a semi-blind channel estimation method is proposed using a superimposed training. As we will show here, a complete time-varying model of the channel can be obtained by means of time-frequency representation methods.

In this paper, we present a channel modeling and estimation method based on the time-frequency representation of channel output. The discrete evolutionary transform (DET) provides a time-frequency representation of the received signal from which the spreading function of the multipath, fading, and frequency selective channel can be modeled and estimated. The rest of the paper is organized as follows. In Section 2, we give a brief summary of the OFDM system and wireless channel model used in our approach. Section 3 presents time-frequency modeling and estimation of wireless OFDM channels via DET. A time-frequency receiver is also given in Section 3 for the detection of data symbols using estimated channel parameters. In Section 4, we give some simulation results to illustrate the performance of our algorithm in different levels of channel noise and Doppler frequency shifts and compare it with other methods. Conclusions follow in Section 5.

2. OFDM system model

In this section, we give a brief introduction to the OFDM signal model and the time-varying communication channel model considered in our work. In a baseband OFDM model, the available bandwidth $B_d$ is divided into $K$ subchannels.