OFDM Channel Estimation and Signal Detection on Nonintegral-Delay and Fast Time-Varying Channels

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Abstract. A novel channel estimation and signal detection technique is presented for orthogonal frequency division multiplexing (OFDM) system on fast time-varying fading channel with nonintegral-delays. This technique, based on a linear parametric channel model, rotationally employs estimating signal parameter via rotational invariance techniques (ESPRIT) and interchannel interference (ICI) mitigation to get more accurate channel estimation and data detection. Simulation results show that the proposed method is robust to changes in channel characteristics, and the performance of which is superior to other structures without ICI mitigation or with integral-delays.

Keywords: Fast time-varying channel, nonintegral-delay, channel estimation, signal detection, ESPRIT.

1 Introduction

Due to its spectral efficiency and robustness over multipath channels, OFDM has severed as one of the major modulation schemes for high data rate communication systems [1]-[2]. Yet fast time-varying fading channels are encountered when OFDM systems operate at high carrier frequencies, high speed, and high throughput for mobile reception, bringing on ICI and increasing the difficulty of channel estimation and signal detection [1], [3].

Previous researches have been dedicated on ICI mitigation on time-varying channel with integer-delays [3]-[4], and quasi-static channel estimation with nonintegral-delays [5]-[6]. For example, based on a linear model of the fast time-varying channel, Chen gets the channel estimation and signal detection by mitigating ICI in time-domain [3], and Y.M. mitigates ICI by utilizing cyclic prefix (CP) or adjacent symbols [4]. However, they are not robust to non-integral channel delay due to the integral model. As to nonintegral-delay case, a parametric channel estimation, based on ESPRIT, is used for quasi-static channel

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[5]-[6], but the performance degrades in proportion to the Normalized Doppler Frequency (NDF) due to ICI in nonquasi-static channel. Yet to the author's best, no such paper has mentioned on OFDM channel estimation and signal detection on nonintegral-delay and fast time-varying channels.

Therefore, in this paper we proposed a novel parametric channel estimation and signal detection scheme by rotationally utilizing ESPRIT for channel parameters estimation and the detective data for ICI mitigation. Firstly, we get channel delays by ESPRIT. Secondly, we get ICI estimation assisted with the coarse detective data so that we can update of channel estimation. And finally, we update signal estimation and detection. Simulation results show that the estimator is robust to changes in channel characteristics. For example, if the channel encounter with non-integral delays and the NDF of which is 0.1, the integral channel estimation [3] encounters BER floor at the BER level of about 4E-002 while the proposed method with one iteration at the level of 1E-003, and when compared with conventional ESPRIT [5], the proposed method can acquire more than 7 dB gains at the bit error rate (BER) level of 1E-002.

The outline of this paper is stated as follows. In section 2 we formulate the linear OFDM system model. In section 3 we propose a novel channel estimation and signal detection technique on nonintegral-delay and fast time-varying channel. Section 4 presents the simulation results. Finally, a brief summary is stated in section 5.

2 System Model

In OFDM systems, the discrete form of the receptive signals in one symbol can be written as $\boldsymbol{y} = [y_0, y_1, \cdots, y_{N-1}]^T$, with elements given by [6]

$$y_n = \frac{1}{\sqrt{N}} \sum_{l=0}^{L-1} h_l(\tau_l) \sum_{m=0}^{N-1} X_m e^{j2\pi m(n-\tau_l)/N} + w_n \ , \ 0 \leq n \leq N-1 \ , \tag{1}$$

where $h_l(\tau_l)$ and L denote channel pulse response and the multipath number respectively; X_m is the frequency domain data of the transmitted symbol, which is composed with X_{data} and X_p which denote the modulated source data and the pilot; w_n denotes channel additive white Gaussian noise (AWGN) with variance σ^2, $\tau_l = T_l/T_s$ is normalized path delays (NPD), T_l is path delays, T_s is symbol period, and $0 \leq \tau_l \leq I_{cp}$, where I_{cp} is the length of guard period. It is necessary to mention that τ_l here could be non-integral number.

Demodulate $\boldsymbol{y}$ by taking the normalized N-point Fast Fourier Transform (FFT), and the output is $\boldsymbol{Y} = [Y_0, \cdots, Y_{N-1}]^T$, with elements given by

$$Y_k = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} y_n e^{-j2\pi nk/N} + W_k \ , \ 0 \leq k \leq N-1 \ , \tag{2}$$

where W_k is the element of $\boldsymbol{W} = [W_0, W_1, \cdots, W_{N-1}]^T$, which is the normalized N-point FFT of AWGN within one OFDM symbol.