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Performance Analysis of Pilot-Aided Channel Estimation for MC-CDMA System using Wavelet Transform and MMSE Estimator

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Abstract

Channel state information (CSI) plays a crucial role in coherent detection of multi-carrier (MC) transmission systems. Therefore, we present a new channel estimation method for MC-CDMA (MC-Code Division Multiple Access) system using WT (Wavelet transform) and MMSE (Minimum Mean Square Error) estimator to obtain CSI. Thanks to excellent AGWN (Additive Gaussian White Noise) cancellation capability of WT, pilot channels are estimated quite exactly and then, they are used in 2-degree polynomial interpolating the other remaining data symbol channels. The simulation results for Short WATM (Wireless Asynchronous Transfer Mode) channel show that our method significantly outperforms the reference in [1].

1. Introduction

MC-CDMA, a combination of OFDM (Orthogonal Frequency Division Multi-access) and CDMA, has been drawing a considerable attention of many researchers all over the world since the terminology MC-CDMA appeared in 1993. It is considered as a bright candidate for the 4th-Generation Mobile Communications System, where users can get access to a large range of voice, data and video communication services anywhere in the world at any time. This system benefits from the advantages of both techniques OFDM and CDMA: the robustness against the frequency selective fading, multiple access capacity, high bandwidth efficiency and flexibility, and low cost of system complexity. In addition, low symbol rate on each sub-carrier makes the job of synchronization much easier. Many detection techniques have been utilized to recover the transmitted signal at the MC-CDMA receiver including single-user detection and multi-user detection. In order to support these techniques in obtaining their fullest abilities, channel estimators have to work efficiently to provide sub-channel gains for detectors. Some pilot-aided channel estimation algorithms were suggested [1][2] for MC-CDMA system over frequency-selective Rayleigh fading channel but flat fading for each sub-carrier. However, these papers paid no attention to removing AGWN before applying LS (Least Square) estimate to identify pilot channel coefficients. Consequently, their performance degrades considerably and then leading to a significant decrease in BER performance of the system.

The term "Wavelet" was first mentioned in Alfred Haar's thesis in 1909. Since then, it has been attracted the interest of signal processing researchers. Due to WT capable of flexibly analyzing the signal in both time and frequency (scale) dimensions by choosing the appropriate shift and scale factors, it has been applied popularly in many fields for recent years, especially, in noise suppression and signal compression. In this paper, we take advantage of WT in quite completely suppressing AGWN and then use LS to estimate pilot channel coefficients that are used to interpolate other data channels. To further improve the estimation performance, we follow [1] by inserting MMSE (Minimum Mean Square Error) estimator before interpolation process.

2. Wavelet Transform

The continuous WT of a signal $f(t)\in L_2(R)$ is defined as [3]

$$CWT(a,b)=\int_{-\infty}^{\infty}\psi^{*}_{a,b}(t)f(t)dt=\langle\psi_{a,b}(t),f(t)\rangle \tag{1}$$

where <.> is the inner product and $\psi_{a,b}(t)$ is a function obtained by shifting and scaling a "mother wavelet" $\psi(t)\in L_2(R)$,

$$\psi_{a,b}(t)=\frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right) \tag{2}$$

where a, b $\in$ R ($a \neq 0$), and the normalization ensures that $\|\psi_{a,b}(t)\|=\|\psi(t)\|$.

Moreover, the wavelet satisfies the admissibility condition

$$\int_{-\infty}^{\infty}\frac{|\Psi(\omega)|^2}{|\omega|}d\omega<\infty \tag{3}$$

where $\Psi(\omega)$ is the Fourier transform of $\psi(\omega)$. In practice, $\Psi(\omega)$ will always sufficiently decay so that the admissibility condition reduces the requirement that $\Psi(\omega)=0$.

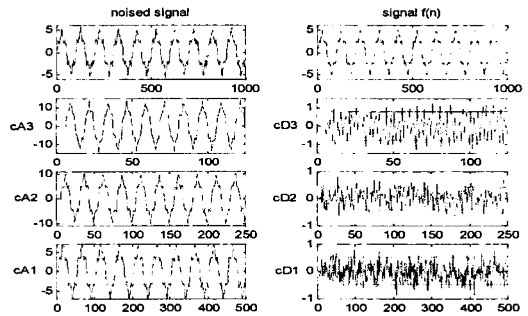

Fig. 1: Demonstration of WT (the dotted lines are noise-suppressing threshold levels)

From (1), we recognize that WT breaks down a signal into shifted and scaled versions of a (mother) wavelet $\psi(t)$. Thus, the versions of shorter intervals ($a<1$) provide more precise high frequency information and longer ones ($a>1$) with more exact low frequency information. In addition, the Wavelet transforming a signal for every continuous scale and shift is time-consuming and requires a huge memory volume to store the result. To alleviate these wastes, DWT (Discrete Wavelet Transform) is preferred by discretising the (a,b) plane in the form of $(\Delta 2^j, \Delta k2^j)$, where $(k,j)\in Z^2$. Another