Power Delay Profile and Noise Variance Estimation for OFDM

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***Abstract*— In this letter, we present cyclic-prefix (CP) based noise-variance and power-delay-profile estimators for Orthogonal Frequency Division Multiplexing (OFDM) systems. Signal correlation due to the use of the CP is exploited without requiring additional pilot symbols. A heuristic estimator and a class of approximate maximum likelihood (ML) estimators are proposed. The proposed algorithms can be applied to both unitary and non-unitary constellations. These algorithms can be readily used for applications such as minimum mean-square error (MMSE) channel estimation.**

***Index Terms*— OFDM, channel estimation, SNR estimation.**

I. Introduction

NOISE variance or (equivalently) signal to noise ratio (SNR) is an important measure of channel quality. Their estimation is hence required in many communication applications such as adaptive modulation, turbo coding and others. Several SNR estimation algorithms have been proposed for systems using unitary constellations (i.e., binary phase shift keying (BPSK) and quaternary phase shift keying (QPSK)) over AWGN channels [1], [2]. They can be classified as data-aided (DA), which requires pilot symbols, and non-data aided (NDA) estimators, which do not. In [3], an NDA estimator is extended to systems with non-unitary constellations over Rayleigh fading channels.

In orthogonal frequency division multiplexing (OFDM) systems, noise variance and power delay profile (PDP) are needed for many algorithms such as minimum mean-square error (MMSE) channel estimation and ML frequency offset estimation. In [4], a noise-variance estimator is proposed that directly uses the receiver statistics. A subspace approach is presented in [5] that uses the sample covariance matrix of the received signal. However, both algorithms are DA estimators, which constitute a bandwidth loss. The estimation of the number of multipath gains and associated time delays has been proposed in [6], where pilot symbols are also needed, and channel multipath power and noise variance are required. In [7], a noise variance and SNR estimator that uses training symbols is developed for multiple antenna OFDM systems. Except for these contributions, to the best of our knowledge, no other NDA noise variance and PDP estimators for OFDM systems have been published to date.

In this letter, we develop noise-variance and PDP estimators for OFDM systems over multipath fading channels; the key is to use the fact that the cyclic prefix contains the repeated samples which will introduce a special correlation structure on the received samples. The noise variance, the number of multipath taps, multipath time delays and powers are jointly estimated without pilots. The maximum likelihood (ML) function for the estimated parameters is derived, resulting in an ML estimator.

II. Noise Variance and PDP Estimator

In OFDM, source data are grouped and mapped into $X_k \in \mathcal{Q}$, where $\mathcal{Q}$ is a complex signal constellation, and $E\{|X_k|^2\} = 1$. Complex data are modulated by inverse discrete Fourier transform (IDFT) on N parallel subcarriers. The symbol interval and block interval are denoted by T_s and NT_s. The resulting OFDM symbol during the mth block interval that comprises N samples is given by

$$x_n(m) = \frac{1}{N}\sum_{k=0}^{N-1} X_k(m) e^{\jmath(2\pi kn/N)},\ n = 0, 1, 2, \cdots, N-1. \tag{1}$$

The guard interval, inserted to prevent inter-block interference, includes a cyclic prefix that replicates the end of the IFFT output samples. The number of samples in the guard interval N_g is assumed to be larger than the delay spread of the channel. The signal is transmitted over a multipath fading channel given by

$$h(t) = \sum_{l=0}^{L-1} h_l \delta(t - \tau_l) \tag{2}$$

where L is the total number of multipaths, $h_l \sim \mathcal{CN}(0, \sigma_l^2)$, and τ_l is the delay of the l-th path. The received signal after sampling is given by

$$y_n(m) = \sum_{l=0}^{L-1} h_l x_{n-d_l}(m) + w_n(m) \tag{3}$$

where $w_n \sim \mathcal{CN}(0, \sigma^2)$ is an Additive White Gaussian Noise (AWGN), and $d_l = \lfloor \tau_l / T_s \rceil$ is the delay normalized by T_s. For simplicity, we round d_l to an integer without considering leakage. However, the correlation approach in this paper may also be extended to fractional d_l. We assume perfect synchronization, and that the channel is invariant within each OFDM block. If there exists a synchronization error, a decision directed algorithm may be applied using our

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