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Analytical Channel Estimation Approach For OFDM System Based On Near-Optimal Dft-Based Channel Estimator With Leakage Nulling

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Abstract

Although tremendous progress has been made on the past years on channel estimation in ofdm systems still it is considered as area of concern in wireless communication. A novel channel estimation technique with virtual sub carriers is proposed in this work namely a low-complexity but near-optimal DFT-based channel estimator with leakage nulling is proposed for OFDM systems using virtual subcarriers. The flow of the proposed approach is initially starts with time-domain (TD) index set estimation considering the leakage effect then followed by low-complexity TD post-processing to suppress the leakage. The proposed channel estimator approach outperforms the existing channel estimators in terms of efficiency and performance. Finally the performance and complexity of the proposed algorithm are analyzed by simulation results.

KEYWORDS: OFDM, Channel estimation, Time domain, Wireless communications

1. INTRODUCTION

Wireless communications are broadly classified into three different categories namely i) Conventional communication systems such as FDMA, TDMA which mainly has two drawbacks one is low data rate and low spectral efficiency. ii) Existing communication systems like CDMA are suitable for mobile and radar communication but the main drawback is drawback is data rate (speed). iii) Future generation communication models such as OFDM are used in Applications like 3G, 4G, LTE, WIFI, and WIMAX.

Orthogonal frequency division multiplexing is considered as highly successful communication model compares to conventional communication models because of low sensitivity to multipath propagation and eminent spectral efficiency. Orthogonal frequency division multiplexing too suffers from some drawbacks, high peak to average power ratio is main drawback which occurs due to the insufficiency power distribution by high power amplifier which results in in-band and out-band distortion. Digital communication are comprised of two communication representations pass band representation and base band representation, pass band represents continuous mode of communication while base band represents digital mode of communication. In our proposed work we present the base band representation of orthogonal frequency division multiplexing signal with N sub carriers as follows

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi\frac{k}{Nt_s}t}, \qquad 0 \le t \le Nt_s \quad (2.1)$$

N represents number of sub carriers

t_s=Sampling time

X represents the frequency domain of orthogonal frequency division multiplexing symbols such as $X=[X_1, X2\ldots\ldots\ldots X_{N-1}]^T$

$T=Nt_s$ =symbol duration.

When the number of sub carriers is large then it can be treated as complex Gaussian process by the central limit theorem, this complex Gaussian process technically called as Peak to average power ratio. In order to resolve this issue several theories are proposed in the literature. One of such theory proposed in the literature is μ-law Companding; it reduces the Peak to average power ratio impact on orthogonal frequency division multiplexing in small amount. To overcome the drawback of µ-law Companding in our proposed work we Orthogonal frequency division multiplexing (OFDM) has been attracted many research organizations related to high speed communication area due to its many attractive features like Orthogonality, acceptable to all types of scenarios like SISO, MIMO, MISO AND SIMO, no inter carrier interference and on the other hand it has so many drawbacks namely delay, distortion and finally peak to average power ratio.

3. GENERALIZED FRAMEWORK FOR OFDM CHANNEL ESTIMATION

Consider an OFDM system with N subcarriers in which U subcarriers with index set ΩU are actually used, i.e., ΩU⊂ΩN = {0, 1. . . N − 1}. Among ΩU, P subcarriers with index set ΩP⊂ΩU are used for pilot subcarriers. Here, V =(N−U)P/U subcarriers with index set ΩV⊂ΩN\ΩU can be considered as artificial pilot subcarriers. Also, a length-G cyclic prefix (CP) with index set ΩG = {0, 1, . . ., G− 1} is used, it is assumed that G is larger than the maximum delay spread τmax which is much larger than the maximum number of paths, L, i.e., L≪τmax≪G. Also, P and ΩP are assumed to be well designed for successful channel estimation.

Let Ωτ be the index set of the nonzero CIR taps. Then, the G× 1 CIR vector h can be written as h = [h (0) h (1) · · h (G− 1)] ^{T} with G× G covariance matrix$R \triangleq E\{hh^H$, where h (n) is the complex gain at the nth tap and nonzero only when n∈Ωτ. Then, after the CP removal, the received vector in the TD can be written a

$$y = x \otimes h + n \quad (1)$$

where x is the N× 1 transmitted OFDM symbol vector in the TD before the CP insertion, n is the N× 1 independent identically distributed (i.i.d) complex white Gaussian noise vector in the TD with mean zero and covariance matrix $\sigma n^2 IN$ and ⊗ denotes the circular convolution. Here, the time and frequency synchronizations are assumed to be perfect by applying good synchronization schemes.

Let Ω F and Ω T respectively be the selected FD and TD index sets of the DFT-based channel estimator. Also, F denotes the N× N unitary DFT matrix with$[\mathrm{F}]_{m.n} \triangleq \exp(-j2\pi mn/N)$. Then, the estimated CIR hˆ and channel frequency response present the Non linear Companding transform technique for efficient results.

gˆ can be respectively described by least square (LS) estimation, FD index selection, FD postprocessing, TD index selection, and/or TD post-processing as

$$\hat{g} = F_{U,T}\hat{h} = \frac{U}{NP}\Phi\left(F_{P,G}\mathrm{h} + \mathrm{Q}F_{P,N}\mathrm{n}\right) \quad (2)$$

$$\hat{h} = \frac{U}{NP}P(F_{F,T})^H KQF_{P,N}y \quad (3)$$

where K and P respectively denote the |ΩF|× P FD post processing matrix and the |ΩT|×|ΩT| TD post-processing matrix, Q ≜diag^{-1}(F^P,N^x), and Φ ≜$F_{U,T}P(F_{F,T})^H K$.

In this letter, a slowly time-varying channel is assumed so that K and P need to be computed once in a long period and Q can be pre-computed so that the corresponding complexity is negligible. Thus, computing (2) and (3) requires N3 log2 N complex multiplications for the N-point fast Fourier transform (FFT) operation [5] ($F_{P,NY}$), P for the LS estimation (Q$F_{P,NY}$), (K) for the FD post-processing matrix multiplication $(KQF_{P,NY})\frac{NP}{3U}\log_2\frac{NP}{U}$ for the NPU -point inverse FFT (IFFT) operation($\frac{U}{NP}(F_{F,T})^H KQF_{P,NY}$ for the TD post processing matrix multiplication ($\frac{NP}{U}(F_{F,T})^H KQF_{P,NY}$), and $\frac{N}{3}\log_2 N$ for the N-point FFT operation (F$_U$,T$^{h^}$) so that the complexity (the number of complex multiplications) of a generalized DFT-based channel estimator can be expressed as

$$C = \frac{2N}{3}log_2^N + P + \frac{NP}{3U}log_2^{\frac{NP}{U}} + \langle K \rangle + \langle P \rangle \quad (4)$$

4. PROPOSED METHOD

For more accurate channel estimation with low complexity, the proposed estimator first performs the TD index set estimation from the G× 1 CIR estimate hˆ = 1/P(F$_{P,G}$) H $QF_{P,NY}$ and then the TD post-processing with the leakage nulling matrix P to suppress the leakage

(i) Threshold setting and TD index set estimation

Let L=$({F_{P,G}}^H)F_{P,G} - PI_G$ be the G×G leakage matrix with $[L]_{m,n} \triangleq \exp\left(-\frac{j\pi(m-n)}{NP/U}\right)\frac{\sin\left(\frac{\pi U(m-n)}{N}\right)/N}{\sin\left(\frac{\pi U(m-n)}{N}\right)/NP}$. Then, with virtual subcarriers (i.e., V≠0 and N≠U), the G× 1 CIR estimate is obtained as

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$$\hat{h} = \frac{1}{P} P\left(F_{F,G}\right)^{H} Q F_{P,N} y = h + l + w \quad (5)$$

Where l = denotes the G× 1 leakage vector with G× G covariance matrix Rll ≜E{ll^H} = $\frac{1}{P^2}$ LRL^H. However, the accuracy of the MST selection with virtual subcarriers is severely degraded due to the distortion caused by the leakage. Also, the leakage remains in the selected MST so that an error floor occurs unless a proper processing for the leakage is performed. To overcome the above problems, the proposed MST selection scheme is composed of the two steps as in Fig. 1: an initial index set estimation with the initial threshold γi to reduce the number of candidates (|ΩC||ΩG|) followed by a recursive MST selection with a successive leakage cancellation to determine the TD index set ΩT..

1: Initialization step : $\Omega_T \leftarrow \phi$

2: First step (candidate index set estimation): $\Omega_T \leftarrow (\hat{\boldsymbol{h}})$

3: Second step (recursion): while

4: k← $arg \max_{n \epsilon \Omega_C} |\hat{\boldsymbol{h}}(n)|$

5: If $|\hat{\boldsymbol{h}}(k)| > \gamma_r, \Omega_C \leftarrow \Omega_C\{k\}, \Omega_T \leftarrow \Omega_T \cup \{k\},$ and

$\hat{\boldsymbol{h}}(j) \leftarrow \hat{\boldsymbol{h}}(j) - \frac{1}{P}\hat{\boldsymbol{h}}(k)[L]_{j,k} for\ j \epsilon \Omega_C\{k\}$

6: else break

7: end while

Similarly as shown under these assumptions, the initial threshold is obtained as

Similarly as shown in [11] under these assumptions, the initial threshold is obtained as

$$\boldsymbol{\gamma}_i = \sqrt{\frac{1}{L}\left(\frac{1}{L} + \frac{1}{P^2 G^2} tr(LL^H) + \frac{1}{\rho P}\right) ln\left(\frac{1}{1 - P_{MD}}\right)} \qquad (6)$$

In step 2, a successive MST selection and leakage cancellation is done with the recursive threshold γr. By assuming that the leakage is sufficiently suppressed, the recursive threshold in [8] can be directly used to minimize the MSE as

$$\boldsymbol{\gamma}_r = \sqrt{\frac{\ln((G - L)\rho P / L^2)}{\rho P - L}} \qquad (7)$$

Time-domain post-processing

The regularization-based TD post processing matrix for a given constant SNR ρ¯ is generated from the TD index set ΩT obtained as

$$P = P\left[(F_{P,T})^H F_{P,T} + |\boldsymbol{\Omega_T}|/\bar{\rho} I_{|\boldsymbol{\Omega_T}|}\right]^{-1} \qquad (8)$$

5. SIMULATION RESULTS

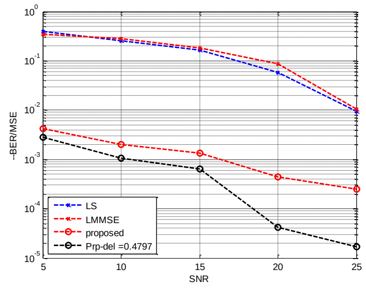

Figure 2: MSE performance versus SNR ρ

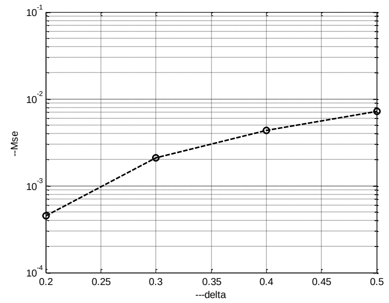

Figure 3: Performance of proposed method in terms of Delta vs MSE

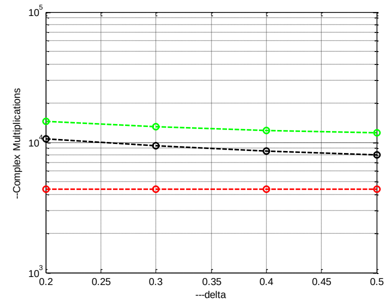

Figure 4: Performance of proposed method in terms of Delta vs Complex multiplications

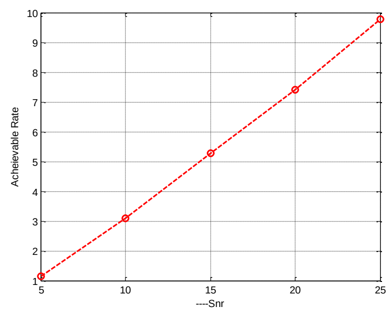

Figure 5: SNR achievable rate

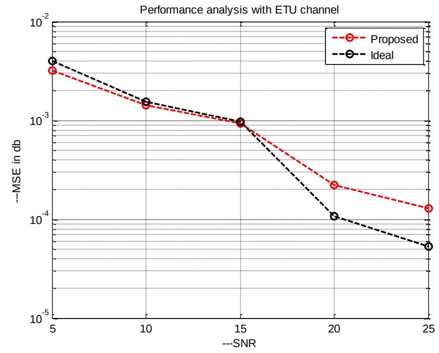

Figure 6: Performance analysis with ETU channel

EXTENSION

Channel estimation is a challenging task in the orthogonal frequency division multiplexing, in our proposed work we use estimated power delay profile algorithm for channel estimation using additive white Gaussian noise channel. Estimation of channel estimation is done by using the ETU channel for better performance and low run time complexity.

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