Channel Estimation for B-IFDMA – Interpolation Filters versus Decision Directed Estimation

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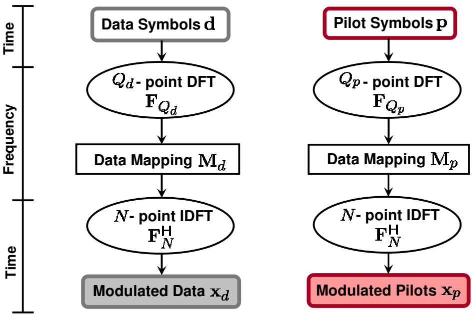
System Model



Transmit signal $\mathbf{x} = \mathbf{x}_d + \mathbf{x}_p$ + cyclic prefix

$\mathbf{x} \circ\!\!-\!\!\bullet\, \mathbf{X} = [X_0, \cdots, X_{N-1}]$

Transmission over Channel

- flat fading channel for each allocated subcarrier in frequency domain
- due to cyclic prefix, the orthogonality between subcarriers is maintained
- for each allocated subcarrier: $R_n = H_n \cdot X_n + V_n$

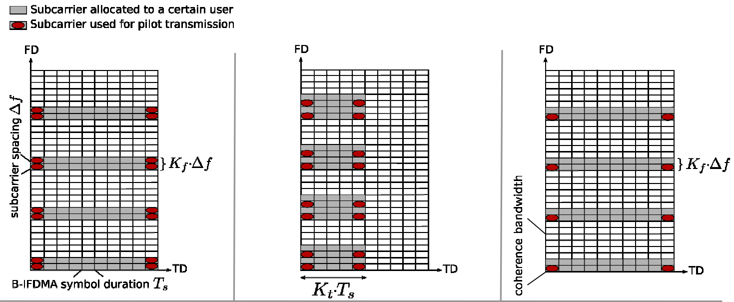
Least-Squares Channel Estimation

- for each pilot carrying subcarrier: $\hat{H}_n = \frac{R_n}{X_n} = H_n + \frac{V_n}{X_n}$

Pilot Arrangements & Channel Estimation

Pilot Arrangement

2 times 1-D interpolation for non-pilot carrying subcarriers and symbols



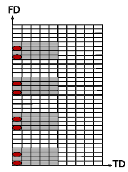
1. Frequency Domain	Least-Squares on each subcarrier	Wiener Interpolation Filter	Repetition

2. Time Domain

Wiener Interpolation Filter ⟶ Pilot symbol overhead increases with decreasing number K_t of successively transmitted B-IFDMA symbols in time domain

Reduction of pilot symbol overhead in time domain

- Application of Repetition in time domain
- Decision Directed Channel Estimation (DDCE)



Iterative Decision Directed Channel Estimation with Wiener Filtering

1. Initialization

- Channel Estimation in FD for pilot carrying symbol:
  LS on each subcarrier, Wiener Filter or Repetition
  $\longrightarrow \hat{\mathbf{H}}(0)$
- Data estimation $\longrightarrow \hat{\mathbf{D}}(1)$
- Decision Directed Estimation: $\hat{\mathbf{H}}_{\mathrm{DDE}}(1) = \frac{\mathbf{R}(1)}{\hat{\mathbf{D}}(1)}$
- Wiener Filtering
  $\tilde{\mathbf{H}}(1) = c_1 \cdot \hat{\mathbf{H}}(0) + c_0 \cdot \hat{\mathbf{H}}_{\mathrm{DDE}}(1)$
  with $c_0,\ c_1$ the Wiener filter coefficients

$i = 1$

2. Equalization

Equalization with $\tilde{\mathbf{H}}(i)$
Estimation of transmitted symbols
$\longrightarrow \hat{\mathbf{D}}(i+1)$

3. Decision Directed Estimation

$\hat{\mathbf{H}}_{\mathrm{DDE}}(i+1) = \frac{\mathbf{R}(i+1)}{\hat{\mathbf{D}}(i+1)}$

4. Wiener Filtering

$\tilde{\mathbf{H}}(i+1) = \sum_{s=1}^{S-1} c_s \cdot \tilde{\mathbf{H}}(i+1-s) + c_0 \cdot \hat{\mathbf{H}}_{\mathrm{DDE}}(i+1)$

$c_s,\ s = 0, \ldots, S-1$, - Wiener filter coefficients
S - filter length

$i = 2, \ldots, K_t - 1$

Simulation Parameters

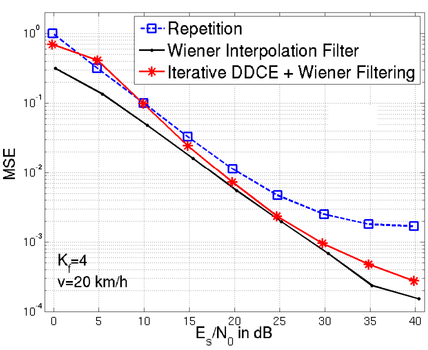
Carrier frequency	3.7 GHz
Bandwidth	40 MHz
Total no. N of subcarriers	1024
Subcarrier spacing Δf	39.1 kHz
No. Q of subcarriers per user	16
No. K_t of successive symbols	10
Guard interval	3.2 μs
Channel	WINNER SCM, Urban Macro
Coherence bandwidth	$B_{\mathrm{coh}} < 20 \cdot \Delta f$
Filter length S	2

Performance Analysis

Mean Square Error: $\mathrm{MSE} = \sum_{i=0}^{K_t-1} \| \mathbf{H}(i) - \tilde{\mathbf{H}}(i) \|^2 / (Q \cdot K_t)$

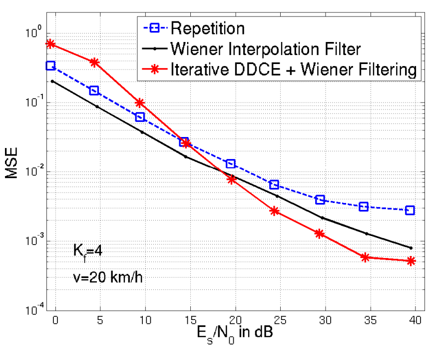
Pilot Symbol Overhead in dB: $\Lambda = 10 \cdot \log_{10}\left(\frac{Q \cdot K_t}{Q \cdot K_t - \text{No. of pilot symbols}}\right)$ is included in results as an SNR degradation

Subcarrierwise Least-Squares in FD



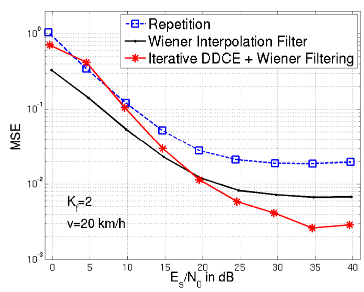
- Iterative DDCE + Wiener Filtering clearly outperforms the interpolation with Repetition
- Wiener Interpolation Filtering shows the best performance, because reliable channel estimation in frequency has been obtained by LS on each subcarrier

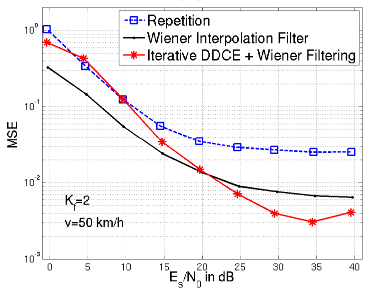
Wiener Interpolation Filter in FD



- Iterative DDCE + Wiener Filtering outperforms the interpolation with Repetition and with Wiener Interpolation Filtering for large E_s/N_0
- The estimation error in frequency domain can be mitigated by the iterative DDCE + Wiener Filtering

Repetition in FD





- The iterative DDCE+Wiener Filtering is reasonable if the channel estimation performance in frequency domain is degrading, because it mitigates estimation errors in frequency domain
- For velocities up to 50 km/h, the iterative DDCE+Wiener Filtering outperforms the conventional Wiener Interpolation Filter

Single Carrier FDMA Workshop, Mar 2009, New York, U.S.A.