

# Channel Estimation Schemes for OFDM Relay-Assisted System

Darlene Maciel, C. Ribeiro, A. Silva e Atílio Gameiro  
darlene@av.it.pt



**Workshop 2009**

2<sup>nd</sup> Dec, FEUP, Porto, Portugal



# Outline

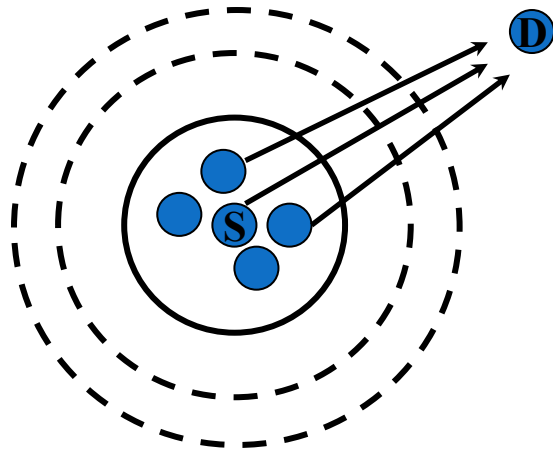
- Introduction
- Motivation
- PACE Schemes
- Simulation Scenario
- Results
- Conclusion
- Future Works

# Introduction: Diversity

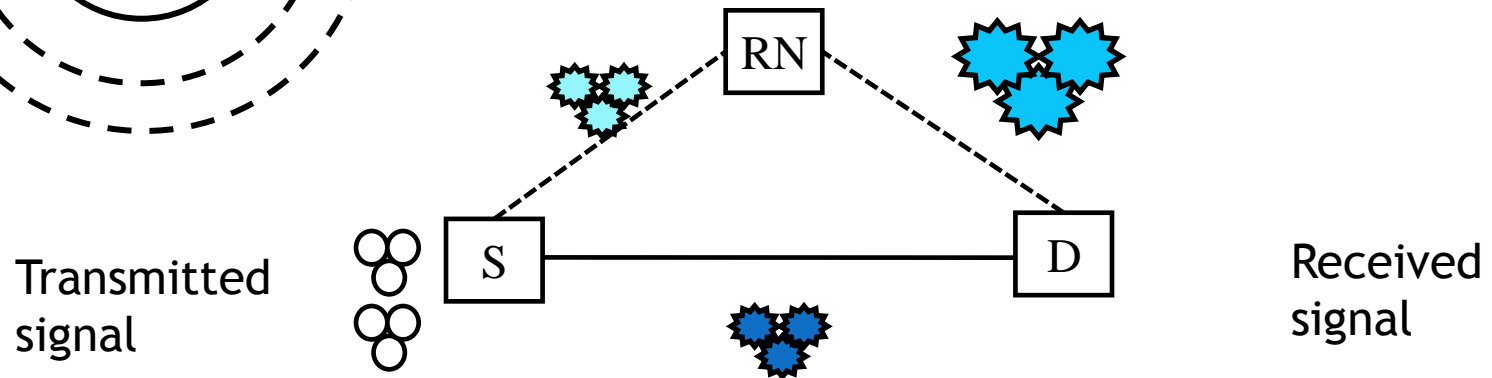
- Diversity is inherent in the physical layer: PHY diversity
  - Time, frequency, space (antenna) and polarization diversity
  - Combat the fading channel by trying to flatten the channel
- Diversity can also be achieved in the MAC or higher layer: Network diversity
  - Multiuser diversity (by scheduling or routing)
  - Cooperative diversity (by cooperative transmission)

# Introduction: Cooperation

- Redundant transmission is realized via the cooperation of third party devices rather than solely from the originating device;

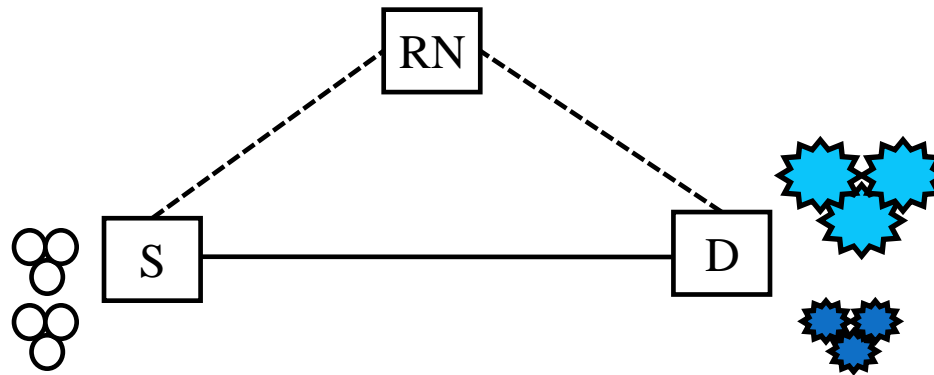


- Node S cooperates with neighbors to send information to D
  - AF, DF, SDF or CF
  - Half duplex AF: 2 phases



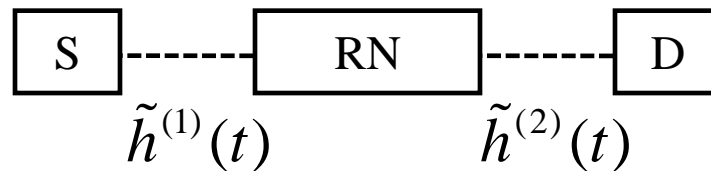
Simple forms of cooperation involves 3 links

# Introduction: Amplify-and-Forward Protocol



- In the half duplex AF protocol receiver at D needs
  - First phase: Estimate channel S-D:
    - ✓ Single link → Conventional Channel Estimation
  - Second Phase: Estimate channel S-RN-D:
    - ✓ Compound Channel

# Motivation: Equivalent Channel



- Compound Channel

$$h_{\text{Eq}}(t) = A \cdot \tilde{h}^{(1)}(t) \square \tilde{h}^{(2)}(t) \Rightarrow h_{\text{Eq}}(m) = A \cdot h^{(1)}(m) h^{(2)}(m)$$

- The Power Delay Profile - PDP

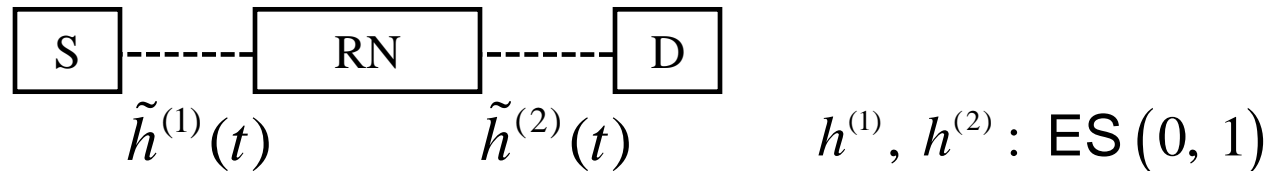
$$\text{PDP} = E\{|\tilde{h}^{(1)}(t) \square \tilde{h}^{(2)}(t)|^2\} = \text{PDP}^{(1)} \square \text{PDP}^{(2)}$$



Maximum delay = Delay channel 1 + Delay channel 2

# Taps of the compound channel will depend on the both channels PDP

# Motivation: Equivalent Channel



- Two sources of Noise. The total noise at the D:

$$w_t(m) = Ah^{(2)}(m)w^{(1)}(m) + w^{(2)}(m) \quad \Rightarrow \quad \sigma_t^2(m) = E\{|w_t(m)|^2\} = A^2\sigma_n^2 + \sigma_n^2$$

- Conditioned to a specific channel realization the noise variance:

$$\sigma_t^2(m) = A^2 |h^{(2)}(m)|^2 \sigma_n^2 + \sigma_n^2$$

The conventional channel estimation schemes should be adapted to this scenario

**LS , MMSE**

# Motivation: Questions

- Questions to be Solved:
  - How does the statistics of the compound channel affect the performance of classical PACE in OFDM signalling?
  - How much can be gained through the knowledge of  $h^{(2)}$ ?

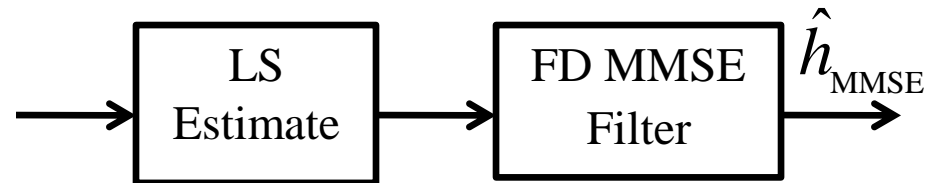
# Classical Pilot Aided Channel Estimation Schemes

- FD - LS (Least Square):

$$\hat{h}_{LS}^P = X_P^{-1} Y_P$$

$$\hat{h}_{LS} = W \hat{h}_{LS}^P$$

$W$ : Interpolator



- FD - MMSE (Mean Minimum Square Error) :

$$\hat{h}_{MMSE} = W_{MMSE} \hat{h}_{LS}^P$$

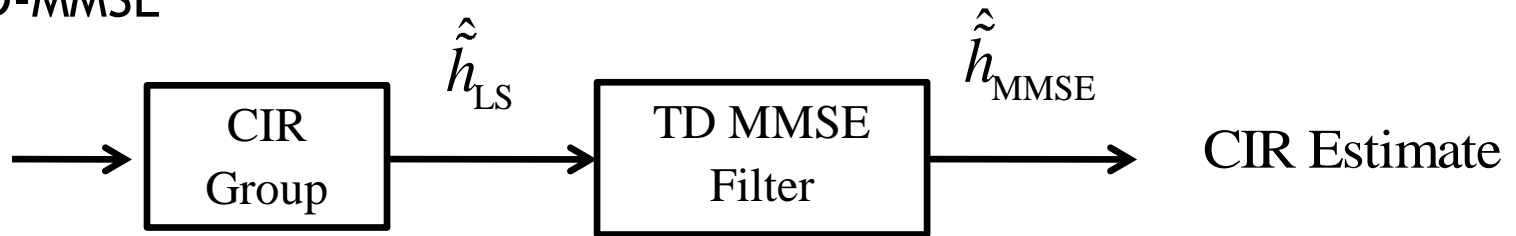
$$W_{MMSE} = R_{HP} R_P^{-1}$$

$R_P$  = Autocorrelation;

$R_{HP}$  = Cross-correlation;

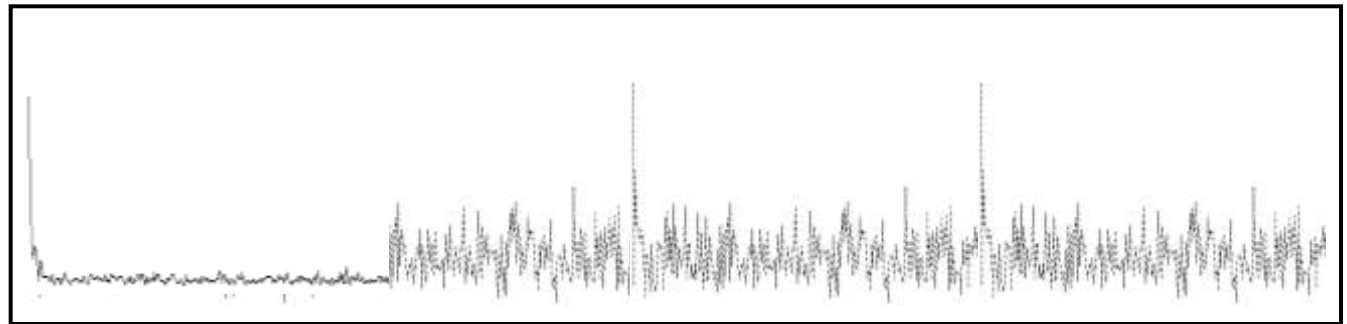
# Classical Pilot Aided Channel Estimation Schemes

- TD-MMSE



Example

CIR estimate



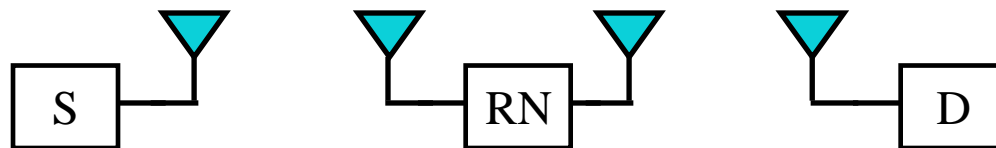
$$W[n] = \frac{R_{\tilde{h}\tilde{h}}[n]}{R_{\tilde{h}\tilde{h}}[n] + \sigma_n^2}$$

$R_{\tilde{h}\tilde{h}}[n]$  (Auto-correlation Function)  $\Leftrightarrow$  Channel PDP

$$\begin{cases} \text{PDP} = \text{PDP}_1 \square \text{PDP}_2 \\ \sigma_n^2 = \sigma_t^2 \end{cases}$$

# Simulation Scenario

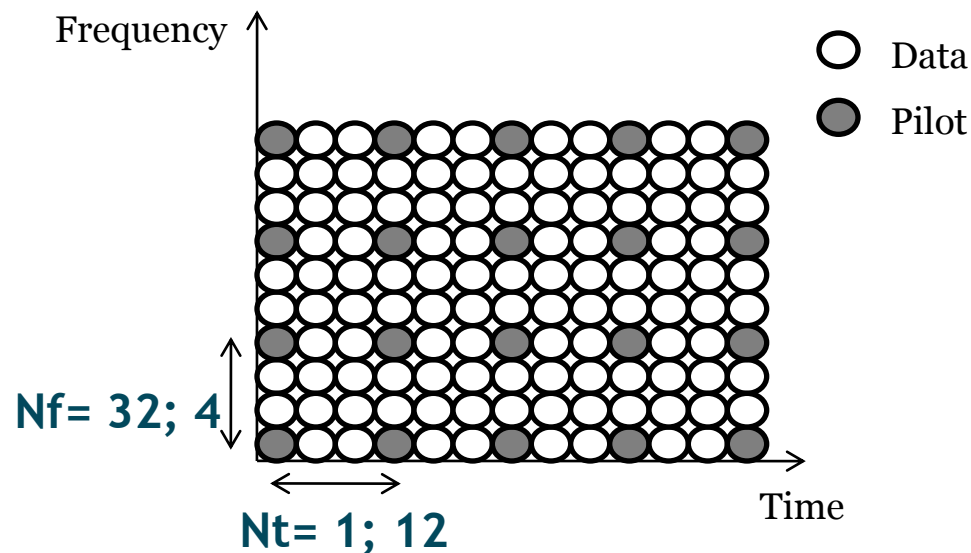
- Scenario and Parameter



Path	Delay(ns)	Relative Power(dB)
1	0.0	0.0
2	65.1 (T)	-0.7
3	260.4 (4T)	-0.8
4	586.0 (9T)	-6.0
5	1041.67 (16T)	-10.0
6	1627.6 (25T)	-14.0
7	2474.0 (38T)	-19.0

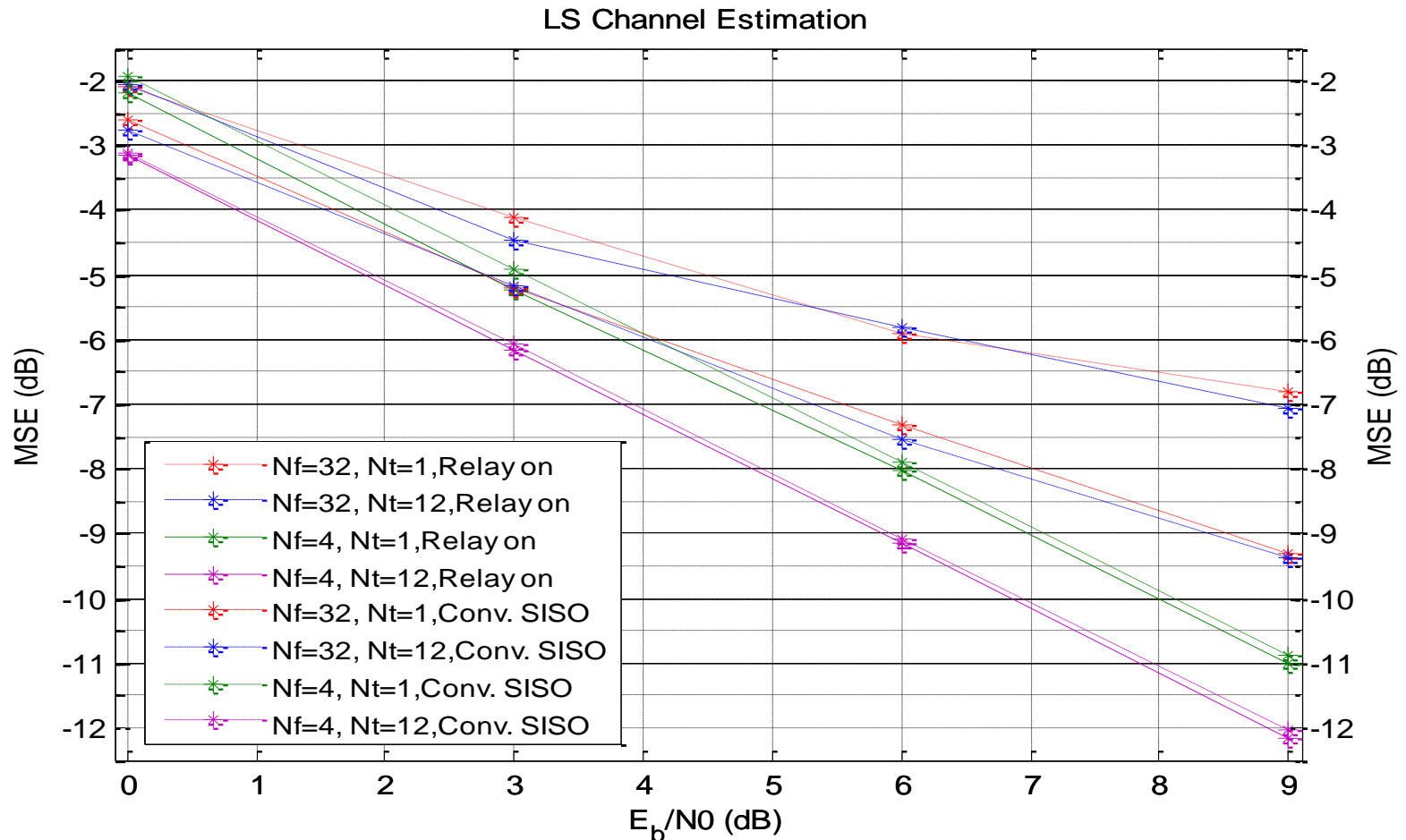
# Simulation Scenario

- Simulation Parameters
  - The pilots are multiplexing in the symbol:



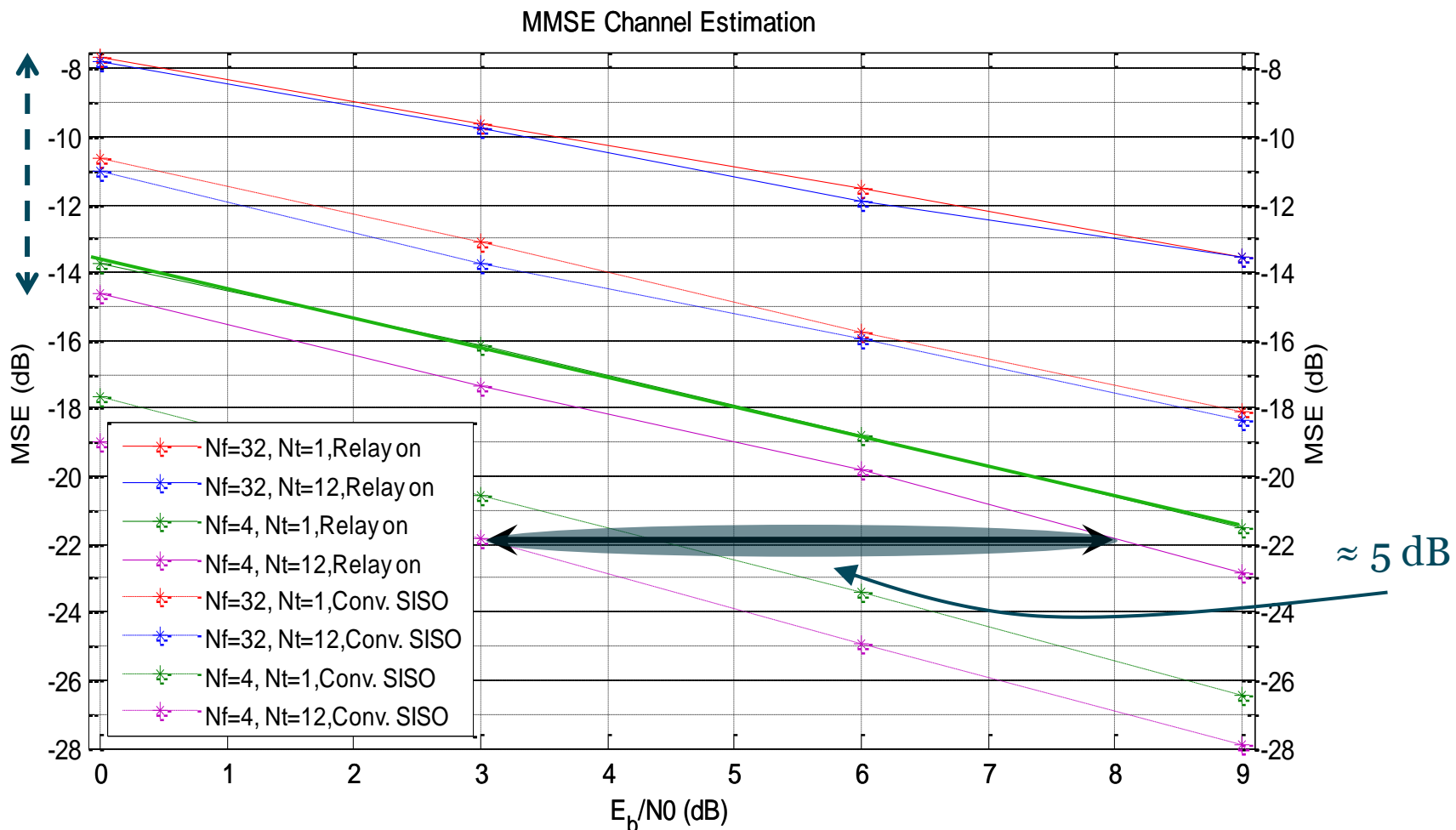
# Results

- FD - LS Estimator

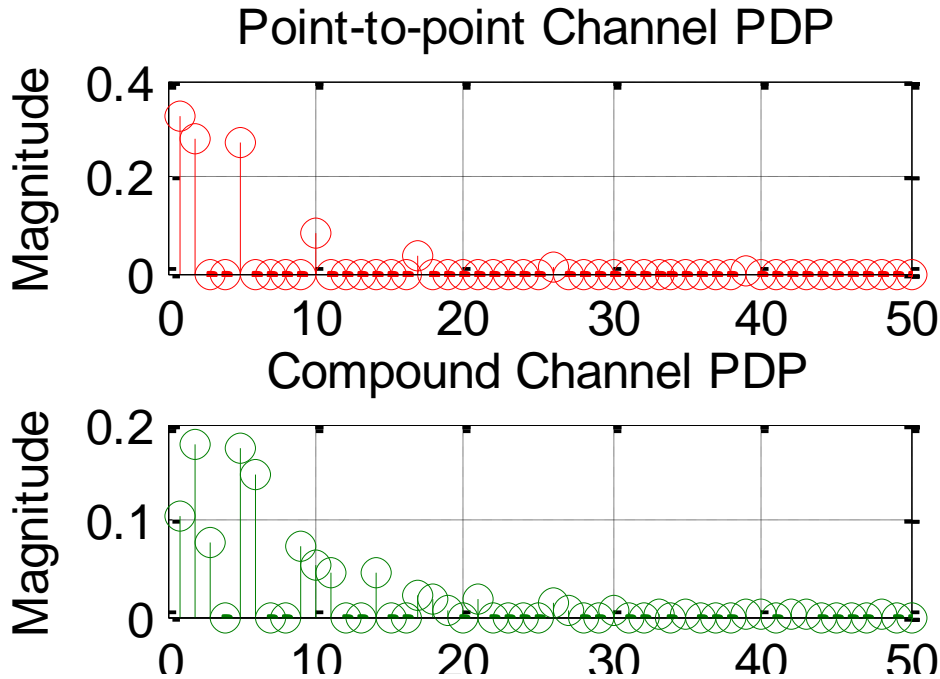


# Results

- TD - MMSE Estimator



# Example



P2P Channel  
 $N1 = 7$  Taps

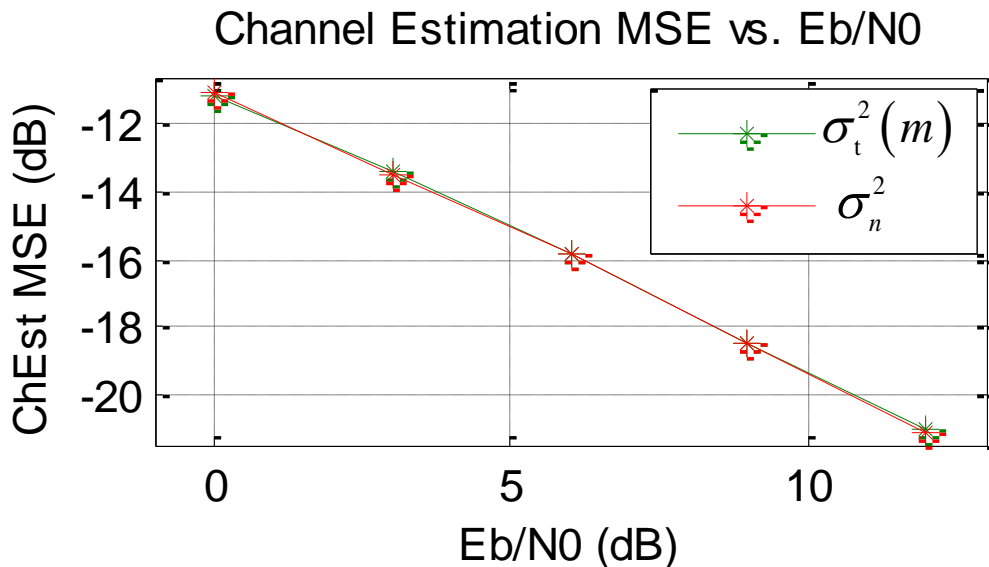
Compound Channel  $\rightarrow$   
conv (P2P Ch, P2P Ch)  
 $N2 = 27$  Taps

$$N2 \leq \frac{(N1 + 1)N1}{2}$$

$N2$  can be quite larger than  $N1$

Taps  $\uparrow$   $\rightarrow$  SNR per Tap  $\downarrow$   $\rightarrow$  MSE  $\uparrow$

# How much can be gained through the Knowledge of $h_2$ ?



$$\sigma_t^2(m) = A^2 \left| h^{(2)}(m) \right|^2 \sigma_n^2 + \sigma_n^2$$

No noticeable improvement by the knowledge of  $h_2$ ;

Number of non-zero taps  $\ll$   $N_c/N_f$

Filter design is robust to errors in the estimate of the noise variance

# Conclusion

- In AF the equivalent channel S-RN-D has a larger delay than point-to-point
  - Increases the minimum pilot density that can be used;
  - Degrades the performance of the MMSE;
- The robustness of the TD-MMSE filter to errors in the estimate of noise variance
- The knowledge of individual P2P channels does not bring any noticeable improvement;

# Future Works

- Consider a scenario which the channel statistics can bring improvements to the channel estimate:
  - Antenna array at the BS;
  - Equalize-and-Forward Protocol;
  - Power constraints at the RN;
  - Channels with different statistics.