Kalman Predictions for Multipoint OFDM Downlink Channels

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Technical Report

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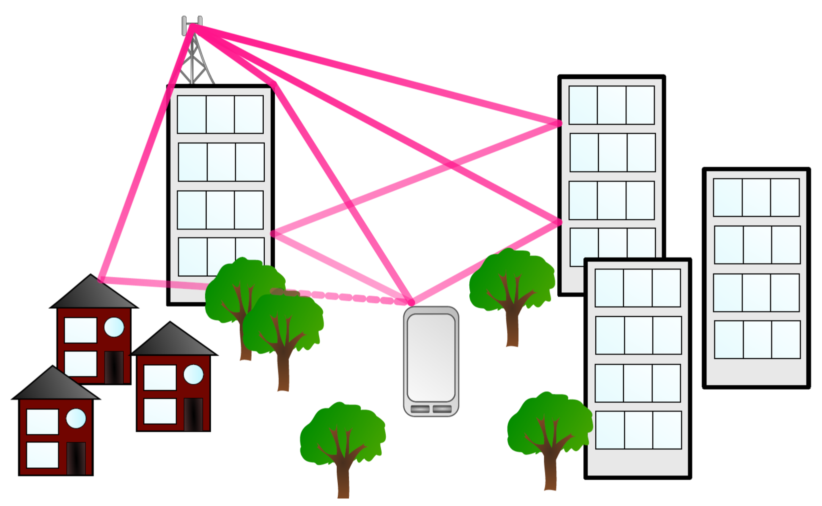


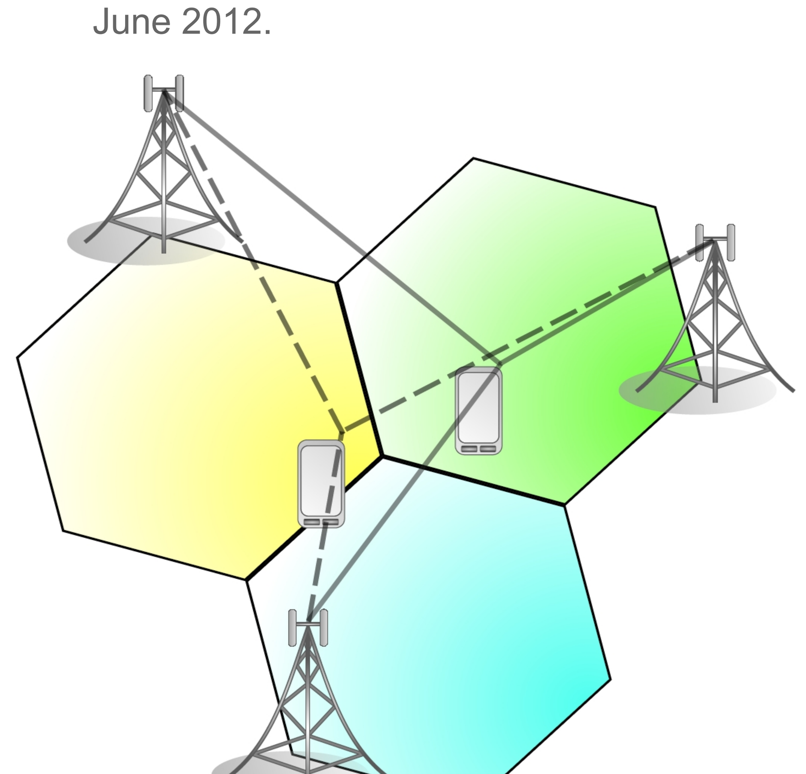
References:

[1] D. Aronsson, Channel Estimation and Prediction for MIMO OFDM Systems – Key Design and Performance Aspects of Kalman-based Algorithms, Ph. D. Thesis, Uppsala University, 2011.

[2] R. Aplefröjd and M. Sternad, " Design and measurement based evaluation of JT CoMP – a study of precoding, user grouping and resource allocation using predicted CSI," Submitted to *Eurasip Journ. On Wireless Communications and Networking*, Submitted Dec. 2013, Revised 2014.

[3] R. Aplefröjd, M. Sternad and D. Aronsson, "Measurement-based evaluation of robust linear precoding for downlink CoMP," *IEEE ICC 2012*, Ottawa, Canada, June 2012.

[4] ARTIST4G D1.4, "Interference avoidance techniques and system design, Artist4G technical deliverable," June 2012.



Introduction

System delays in the order of tens of ms are common for Coordinated Multipoint (CoMP) transmission. This outdates Channel State Information (CSI) making it unusable for coherent joint transmission. Kalman predictors have the potential to counteract this.

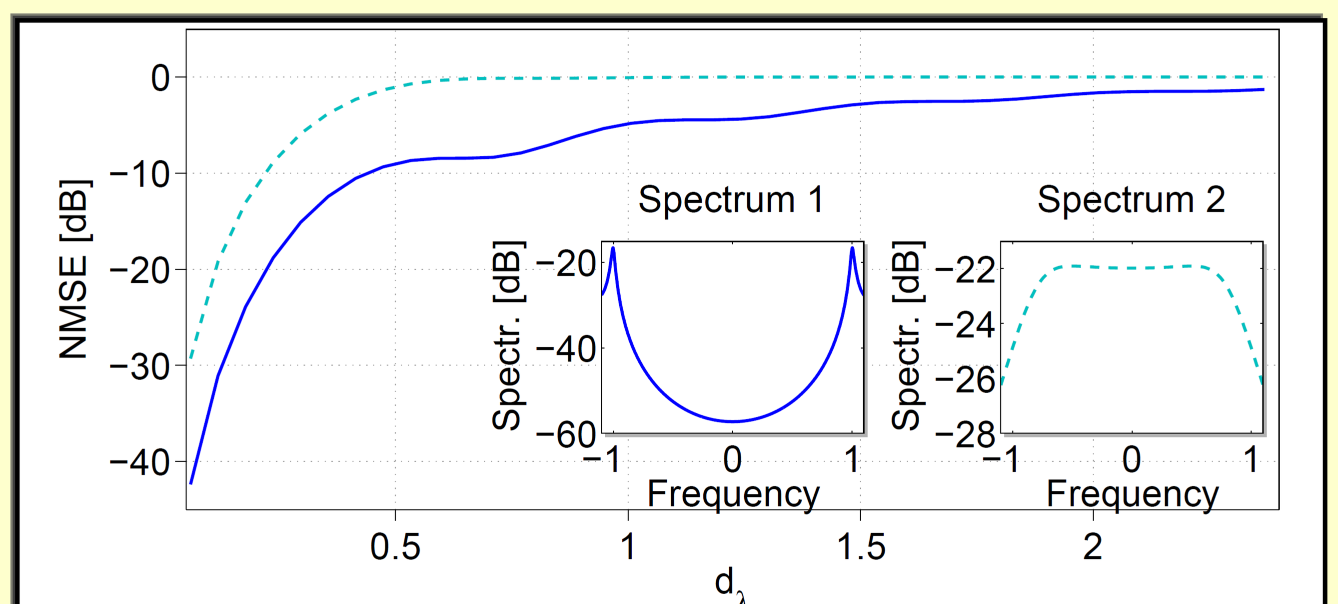
This report includes:

- Kalman filter equations for multipoint OFDM FDD downlink channels based on results for MIMO OFDM channels in [1].
- Description on how to model state space models to represent the small scale fading of the channels.
- Discussions on issues with the above bullets.
- A model for including realistic prediction errors in a block fading simulation environment.
- Detailed studies of the simulation results from [2-4]

AR-modeling

A fading channel can be represented by an AR model.

Predictability:

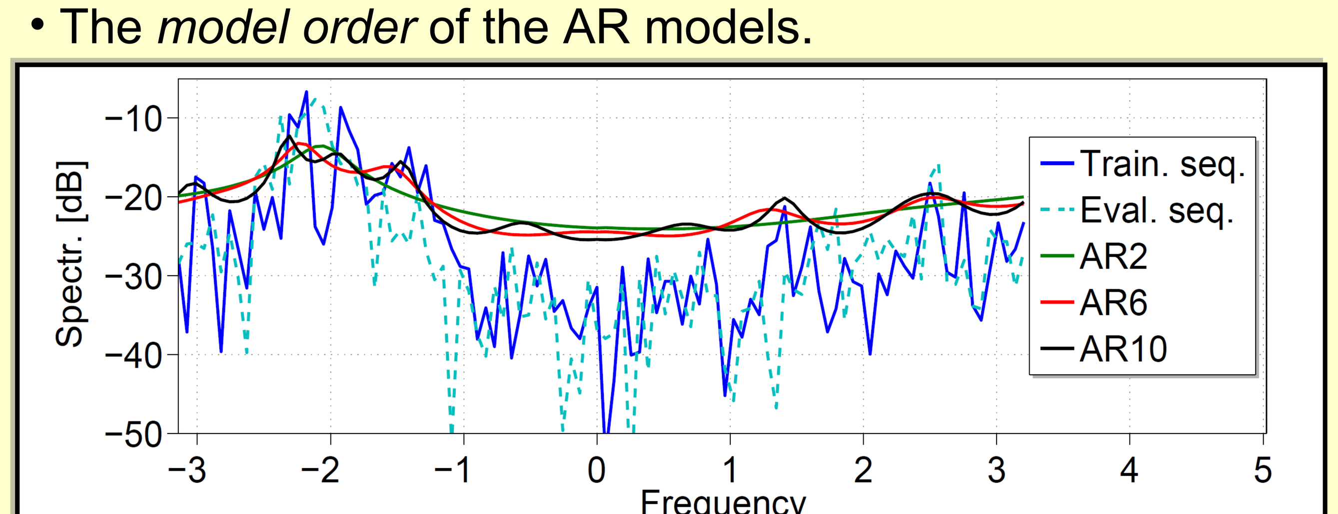


Spatial predictability (in wavelength) for 4:th order AR models with spectrum 1 and 2 resp.

Model estimation

AR models can be estimated, based on a *training sequence*. The report includes discussions on:

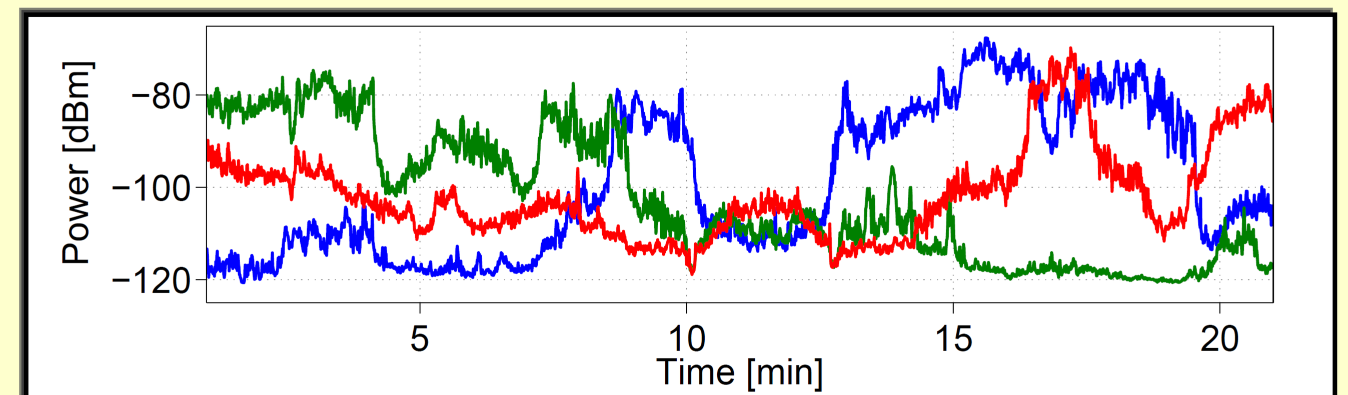
- *Subsampling* of the training sequence.
- The *time interval* for for re-adjusting the AR model.
- The *model order* of the AR models.



Spectra of the train. seq., the eval. seq. and the AR models

Kalman aided predictions

- Kalman filters can provide the optimal τ-step prediction with respect to minimizing the mean square error.
- The Kalman filter is recursive and therefore low in memory requirements.
- The Kalman filter also provides the covariance of the filter channel estimate with. This can be used e.g. in robust linear precoding [2,3] for coherent joint transmission coordinated multipoint (CoMP).
- Predictions are evaluated on measurement data from 3 omnidirectional BS in Kista, (collected by Ericsson).



The received powers of the pilots in the measurements.

Included topics

- The *location* of the filters: in the user terminals or at the network side.
- The number of *w jointly predicted* adjacent pilot-bearing subcarriers.
- The time that it takes to reach the *stationary filter*.
- *Pilot pattern* structure over the resources.

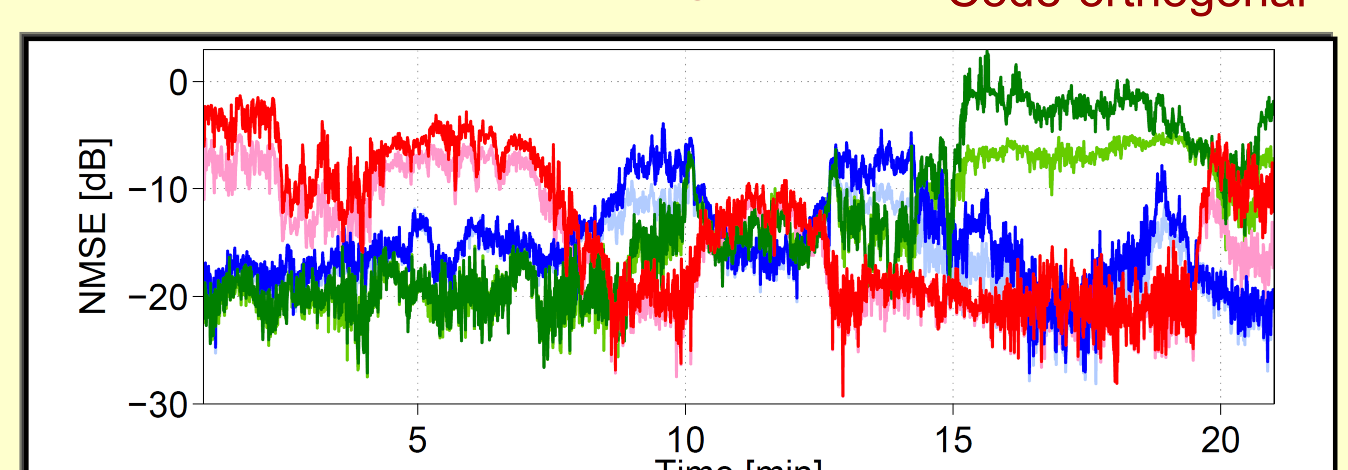
Subcarrier/BS 1 2 3

$$\begin{matrix} 1 \\ 2 \\ 3 \end{matrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Resource-orthogonal

$$\begin{matrix} & 1 & 2 & 3 \\ 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & 1 \\ 3 & 1 & 1 & -1 \\ 4 & 1 & -1 & -1 \end{matrix}$$

Code-orthogonal



The prediction error NMSE for a 5 ms prediction horizon with code-orthogonal pilots (dark colors) and resource-orthogonal pilots (light colors) of the channels to the 3 BS.

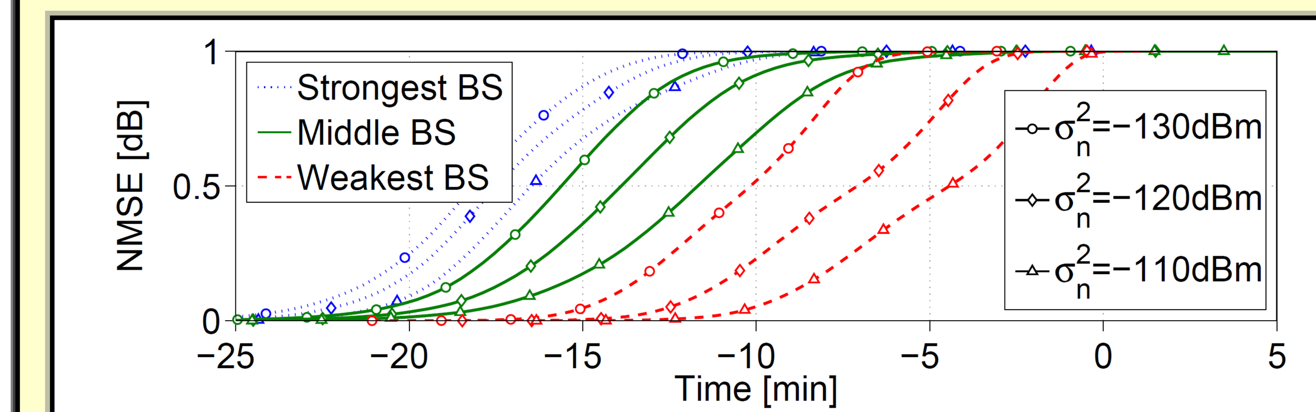
Simulating prediction errors

- A model on how to incorporate prediction errors corresponding to those of Kalman predictors in a *block fading environment*.

Kalman aided predictions, cont.

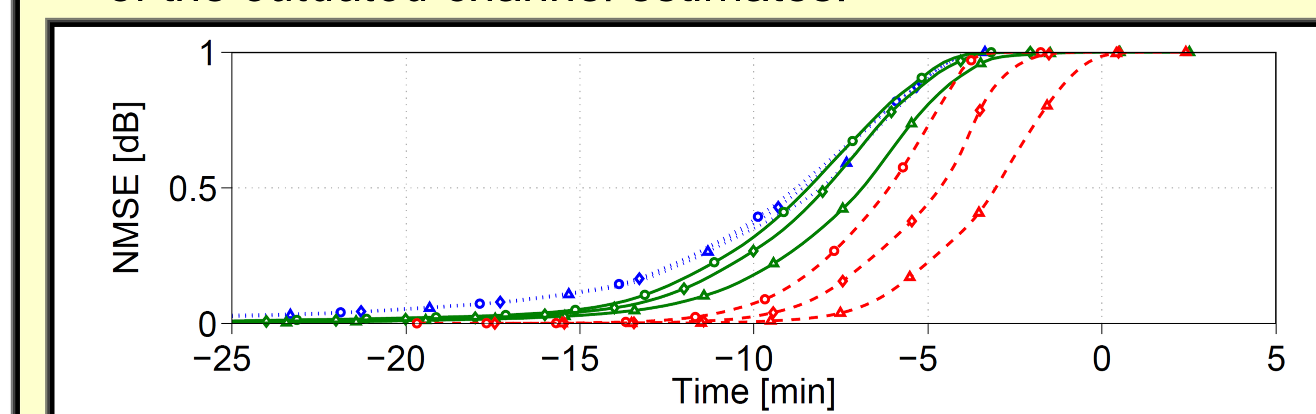
Included topics, cont.,

- The impact of different levels of *intracluster interference*.



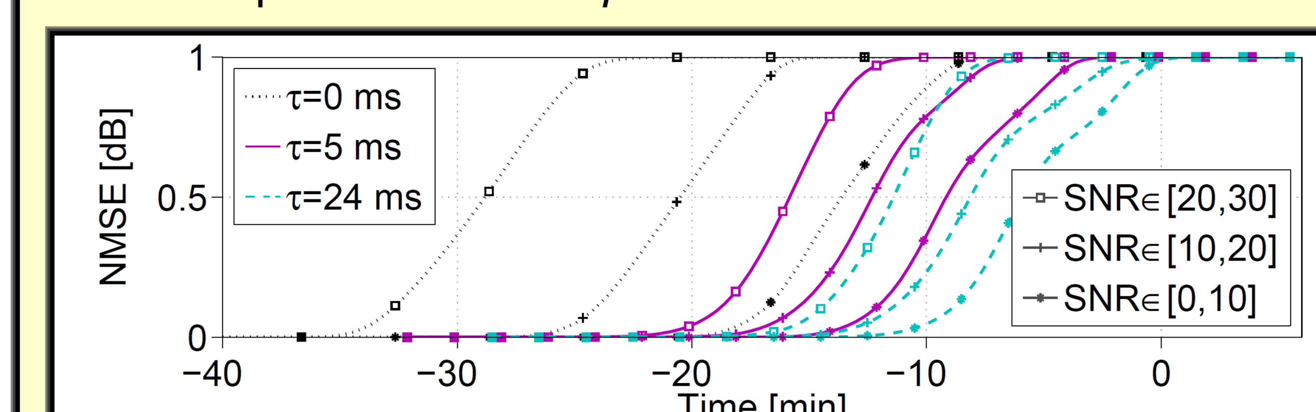
CDF of the NMSE of predicted CSI at τ=10 ms.

- The NMSE of the predicted channels versus the NMSE of the *outdated* channel estimates.



CDF of the NMSE of outdated CSI at τ=10 ms. Legends as above.

- The impact of different *prediction horizons*.



CDF of the NMSE of estimated or predicted CS.

Conclusions

- Outdated CSI is not sufficient for coherent JT CoMP, even for short system delays and low mobility.
- Prediction with Kalman filters increase CSI significantly and may ensure coherent JT CoMP gains, even for vehicular mobility (for short system delays).
- It is important that the weak channels are not allowed to be "rotten apples" in the precoder solution for CoMP.
- Code-orthogonal should not be used for antennas at different base stations, but may be used for antennas at the same base station.
- It is important, for accurate predictions in CoMP, that the system delays are kept short and that intercluster interference is low. Especially for vehicular users.