Kalman Smoothing for Irregular Pilot Patterns; A Case Study for Predictor Antennas in TDD Systems

Addressing long downlink TDD frames for high-velocity communication

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Outline

Channel information

- Problem with outdated info
- TDD vs FDD
- Channel prediction

Predictor antenna

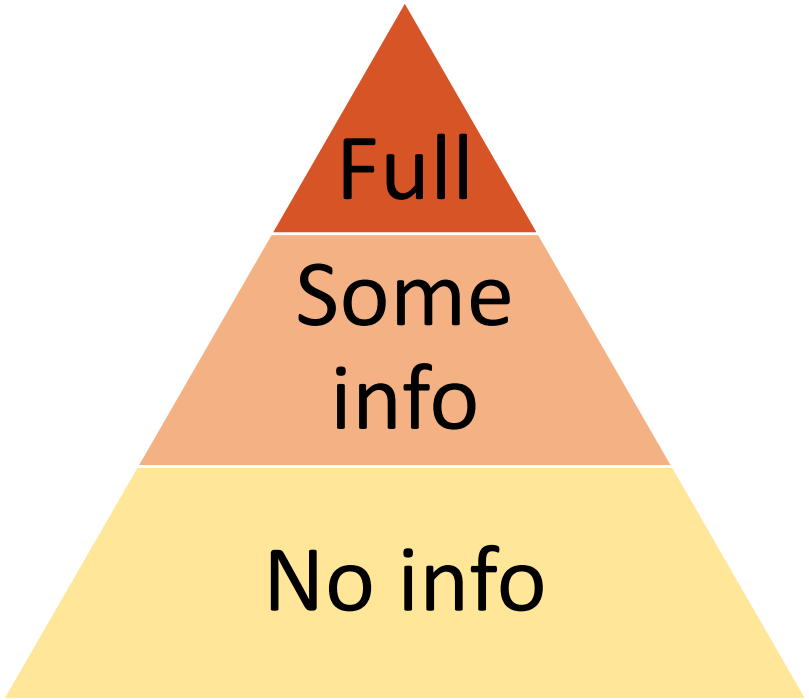
- Concept
- Prediction => Interpolation

Kalman smoothing

- Concept
- Channel smoothing performance
- Conclusion

Outdated channel information

- Outdated information
- Larger problem for TDD?
- Channel prediction



Predictor antenna

- Encounter same position twice
- Predicts the channel at the second time
- Horizon limited by antenna distance
- $h_{main}(pos) = ah_{pred}(pos)$, a - coefficient

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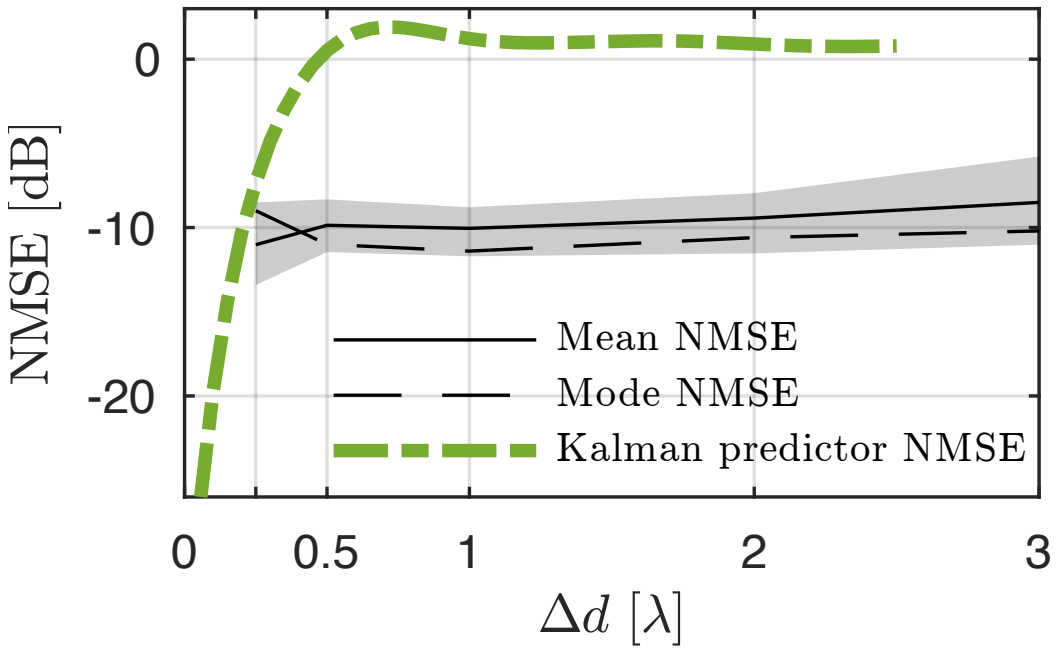
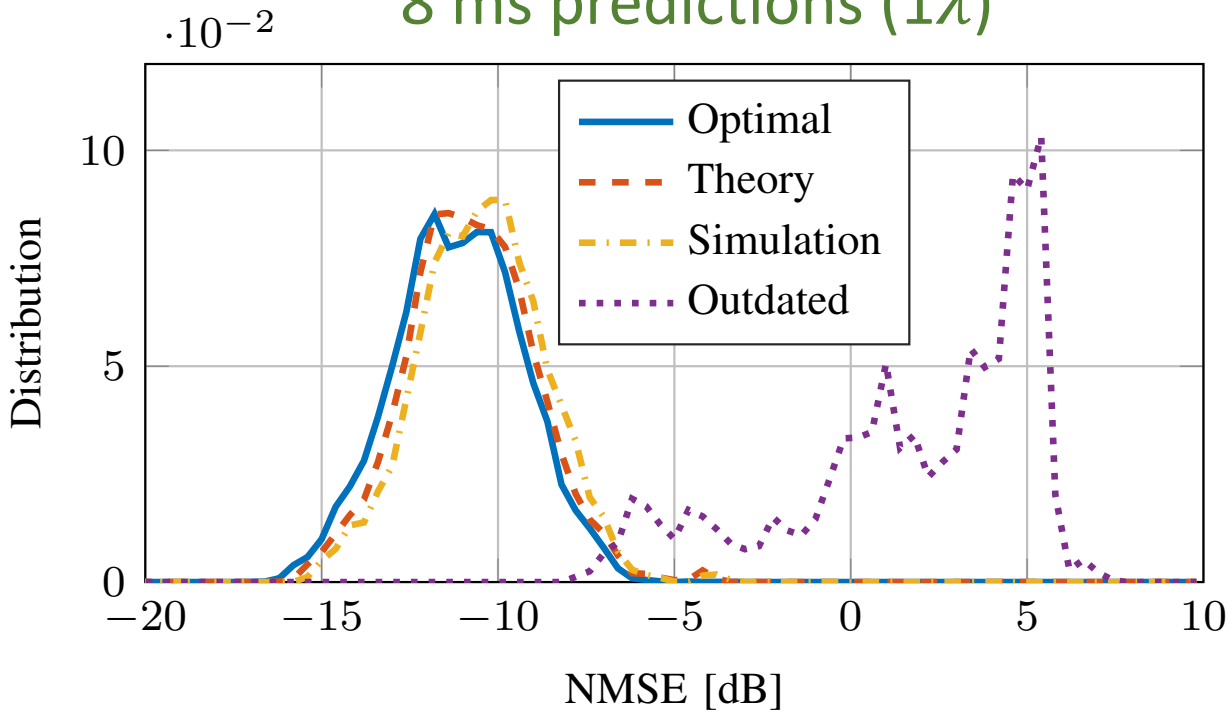
Predictor antenna performance

Predictor antenna vs extrapolation



J. Björsell et al., "Using Predictor Antennas for the Prediction of Small-scale Fading Provides an Order-of-Magnitude Improvement of Prediction Horizons," *IEEE International Conference on Communications, ICC, Workshop WDN-5G ICC2017*, Paris, France, May 2017.

8 ms predictions (1λ)

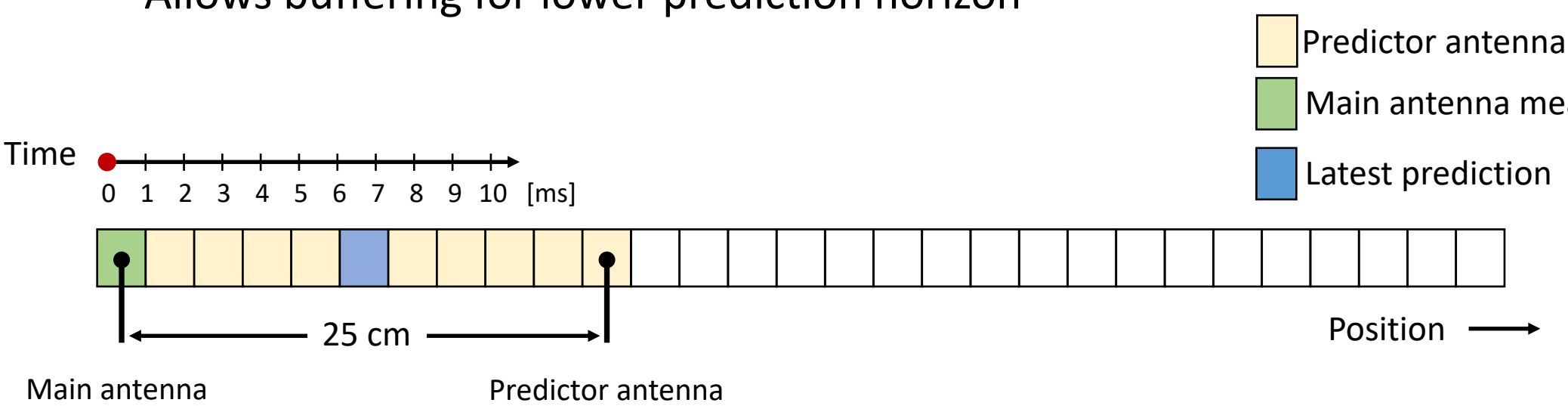


J. Björsell et al., "Predictor Antennas in Action," *IEEE Annual International Symposium on Personal, Indoor, and Mobile Radio Communications, PIMRC*, Montreal, Canada, October 2017.

Predictor antenna for FDD

- One subcarrier in an OFDM FDD system
- Limit of 10 ms prediction horizon in this example
  - Assume 5 ms here
- Allows buffering for lower prediction horizon

Pilot rate	**1 per ms**
Velocity	**90 km/h**
Antenna separation	**25 cm (2λ)**
Carrier frequency	**2.5 GHz**



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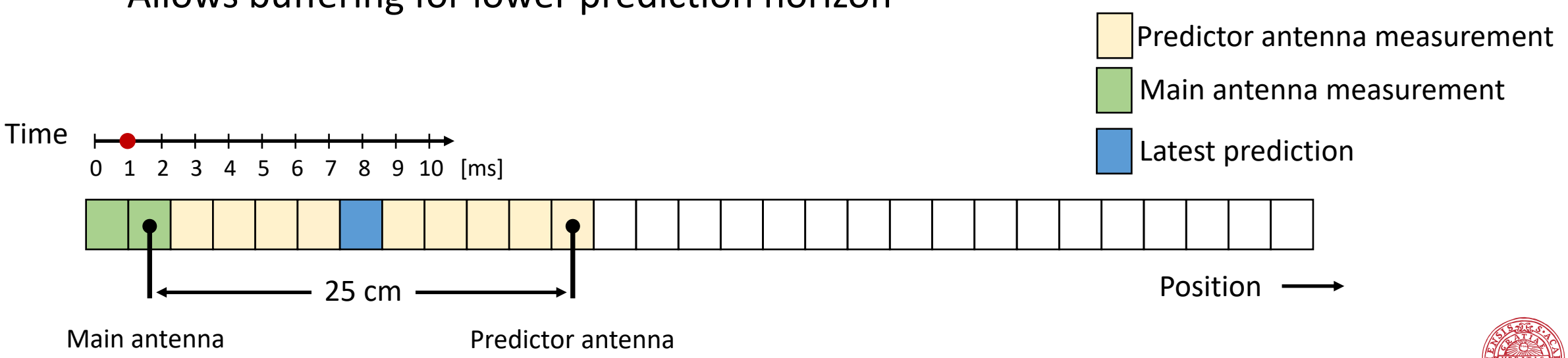

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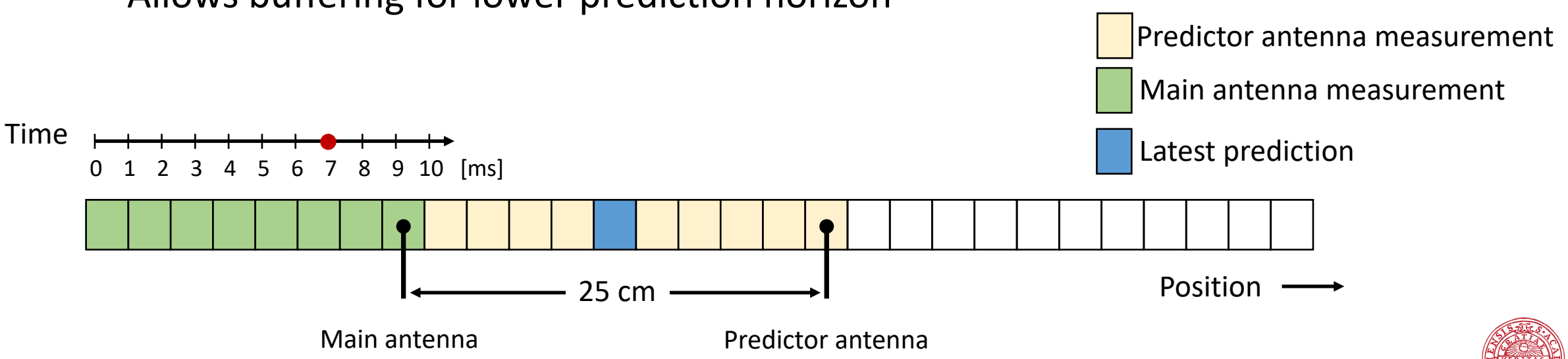

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Predictor antenna for TDD

- Case study of TDD
  - 2 ms uplink frames
  - 4 ms downlink frames
- For 5 ms prediction we can buffer 5 ms before predicting the channel

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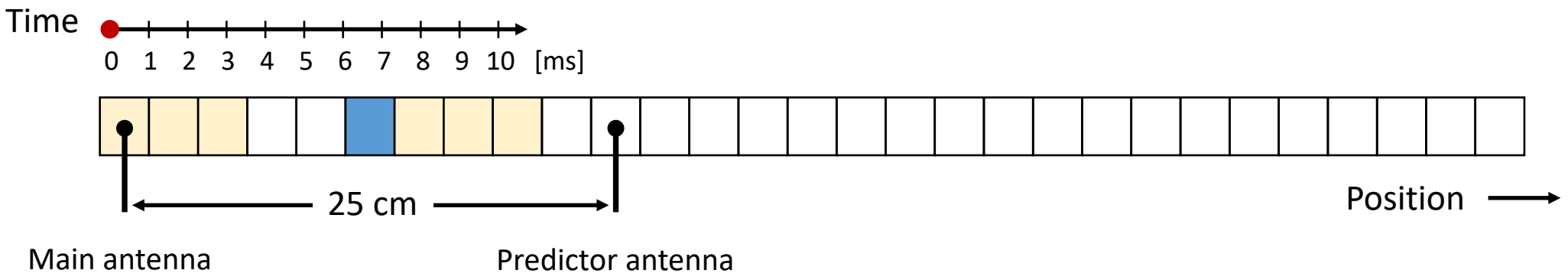
Predictor antenna measurement

Latest prediction



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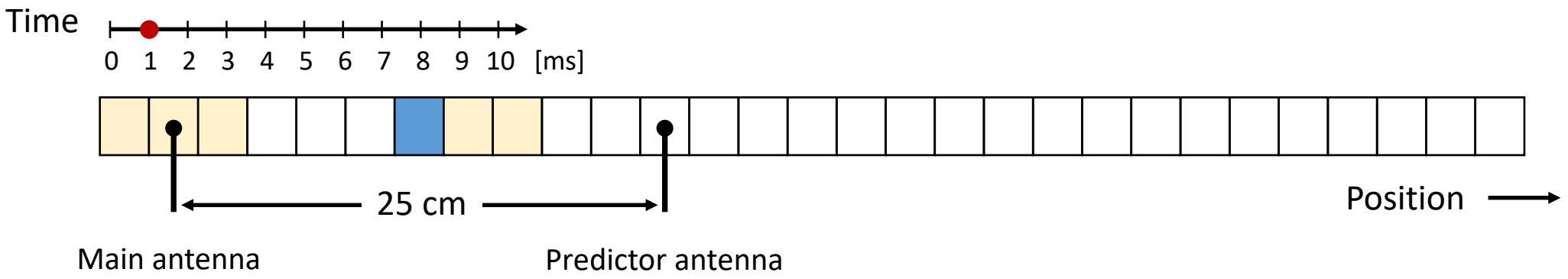

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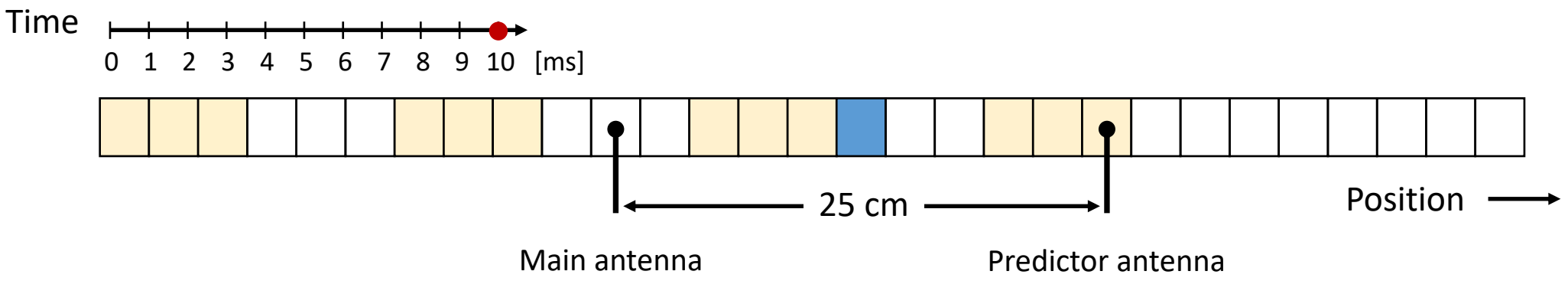

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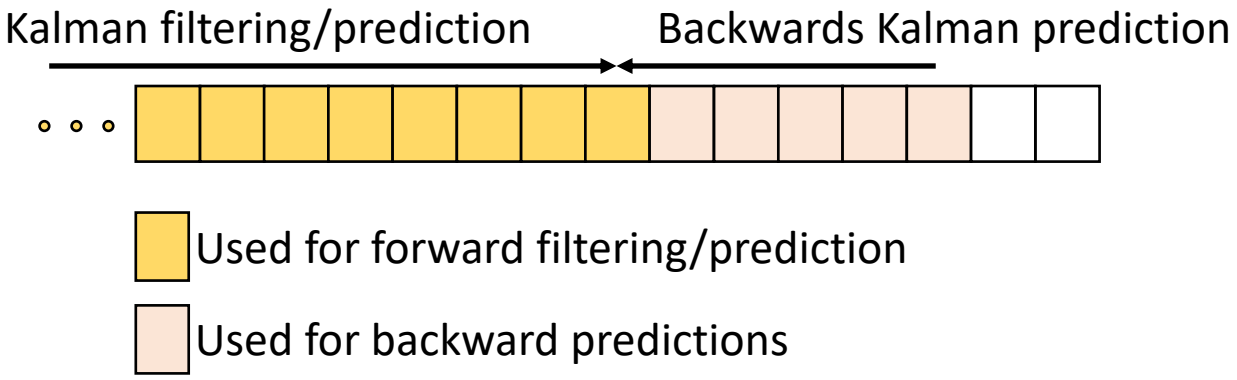
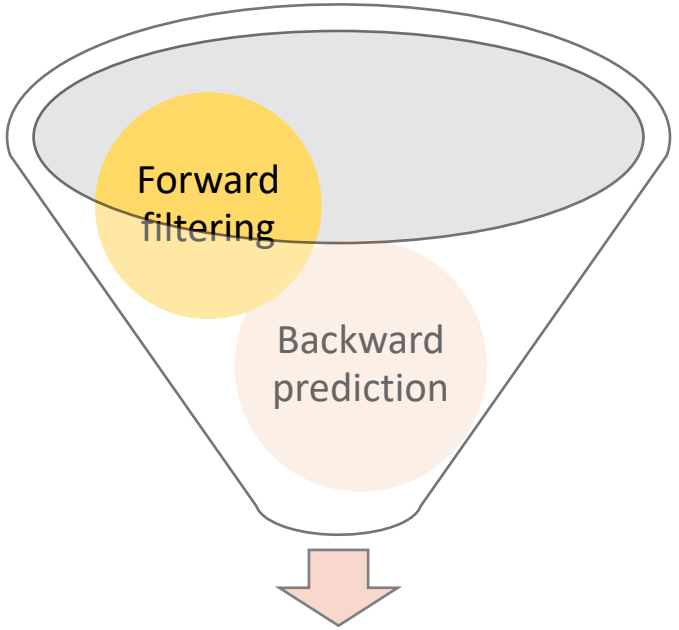
Kalman smoothing

- Using same AR-model of order 4
- Jointly modeling and estimating 4 subcarriers

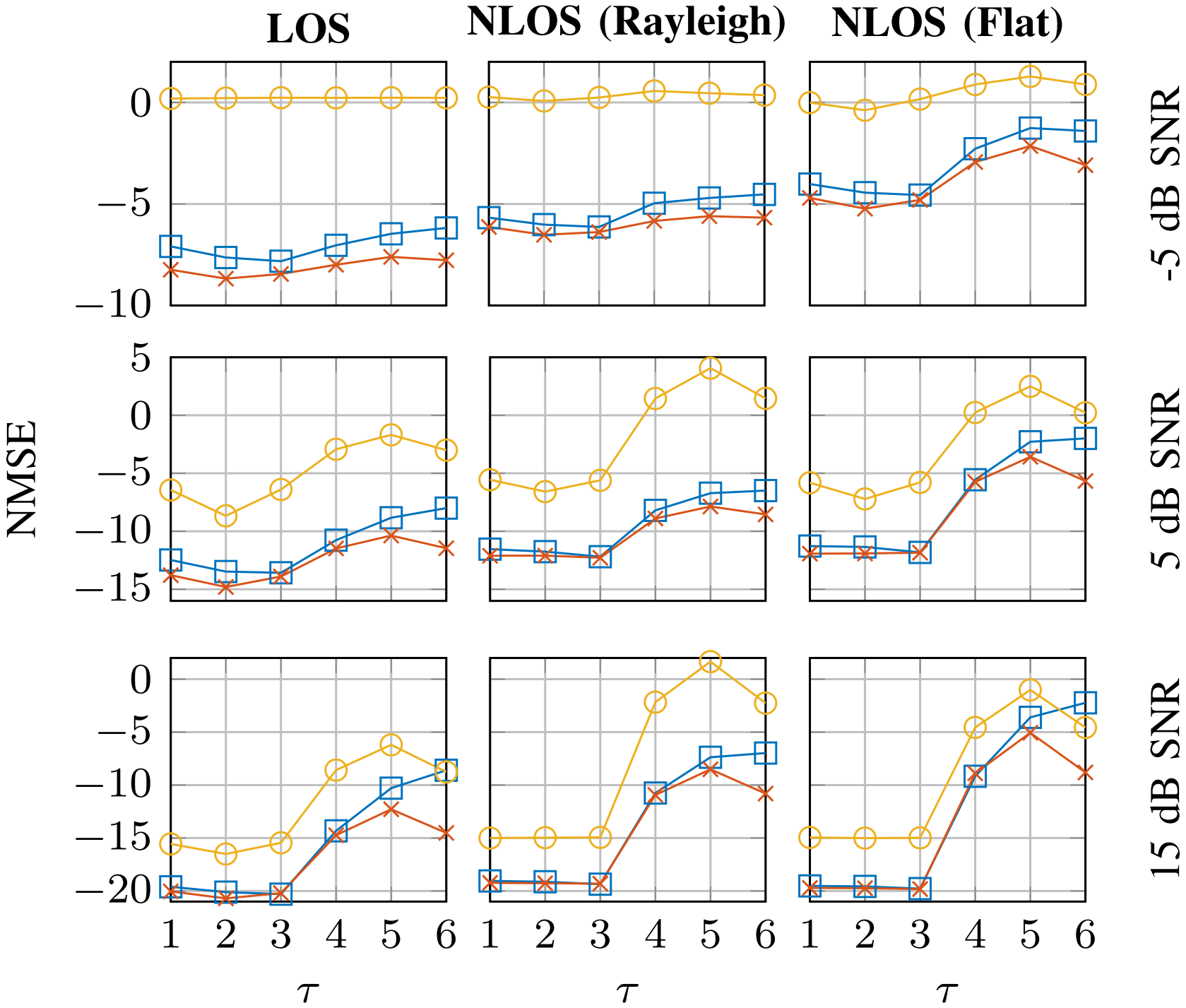


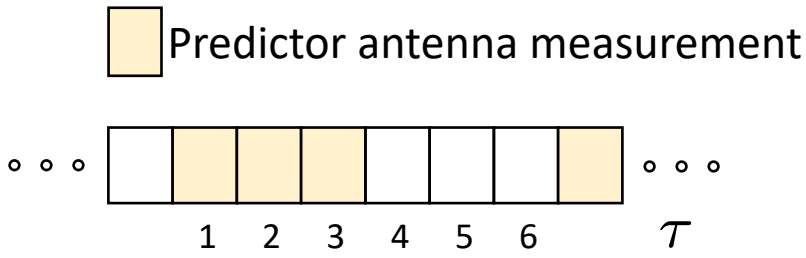


Optimally weighted average

Results

- 3 case studies (different fading environments)
- Real measurements
- Artificial noise levels





Main Conclusion

- Restrictions to the length of TDD frames due to channel aging can be loosened through the use of Kalman smoothing in combination with predictor antennas.
- Increased flexibility in system design is desirable from operators perspective.

Additional references

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3. D-T Phan-Huy et al., "Connected Vehicles that Use Channel Prediction Will Fully Take Advantage of 5G," *22nd ITS World Congress*, Bordeaux, France, October 2015.
4. D-T Phan-Huy et al., "Making 5G Adaptive Antennas Work for Very Fast Moving Vehicles," *IEEE Intelligent Transportation Systems Magazine*, Summer, 2015, pp. 71-84.
5. D-T Phan-Huy et al., "5G on Board: How Many Antennas Do We Need on Connected Cars?," *IEEE Globecom 2016 Workshop on 5G RAN Design*, Washington DC, USA, December 2016.
6. D-T Phan-Huy et al., "Adaptive Massive MIMO for fast moving connected vehicles It will work with Predictor Antennas!," *International ITG Workshop on Smart Antennas (WSA)*, Bochum, Germany, March 2018.