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

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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- Problem with outdated info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Outdated channel information

- Outdated information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

- Full
- Some info
- No info
• Encounter same position twice
• Predicts the channel at the second time
• Horizon limited by antenna distance
• \( h_{\text{main}}(\text{pos}) = a h_{\text{pred}}(\text{pos}) \), \( a \) - coefficient
• Encounter same position twice
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• $h_{\text{main}}(\text{pos}) = a h_{\text{pred}}(\text{pos})$, $a$ - coefficient
Predictor antenna performance


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8 ms predictions (1λ)


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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
• One subcarrier in an OFDM FDD system
• Limit of 10 ms prediction horizon in this example
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Predictor antenna for FDD

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- Time

- Position

- Main antenna

- Predictor antenna

- Latest prediction

- 25 cm
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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Time

0 1 2 3 4 5 6 7 8 9 10 [ms]

Main antenna

Predictor antenna

25 cm

Position

Latest prediction

Predictor antenna measurement

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Predictor antenna for TDD

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Time

0 1 2 3 4 5 6 7 8 9 10 [ms]

Position

Main antenna

Predictor antenna

25 cm

Predictor antenna measurement

Latest prediction
Kalman smoothing

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

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Kalman filtering/prediction  Backwards Kalman prediction
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- Used for forward filtering/prediction
- Used for backward predictions

Optimally weighted average
Results

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

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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.


