Karlsruher Institut für Technologie

Development of a Single-Carrier SM-MIMO Transceiver

Detector Implementation
Channel Estimation & Synchronization

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System Model SC-SM

SM with N_t=2, BPSK

Bits-to-Symbol Mapping		
Input bits	Active antenna	BPSK symbol
00	1	-1
01	1	+1
10	2	-1
11	2	+1

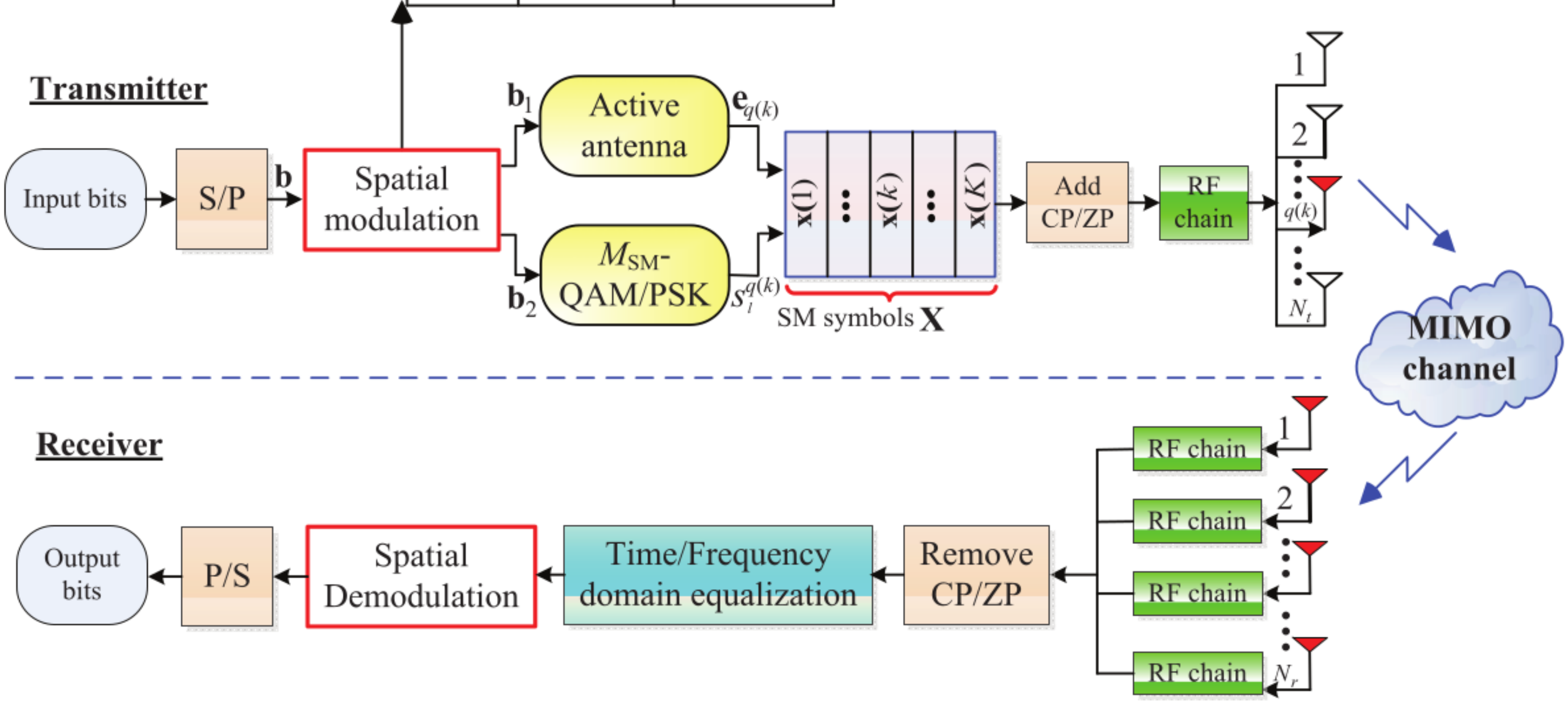

Figure 1: General transceiver structure of SC-SM systems [**1**]

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Low-Complexity Single-Stream ML Scheme

- Based on M-algorithm.
- Single stream ML detection.
- Avoids QR-decomposition.
- **Balanced trade-off: performance/complexity.**
- Scheme approaches ML detector with increasing M.
- Efficient operation even in rank-deficient channel scenarios.

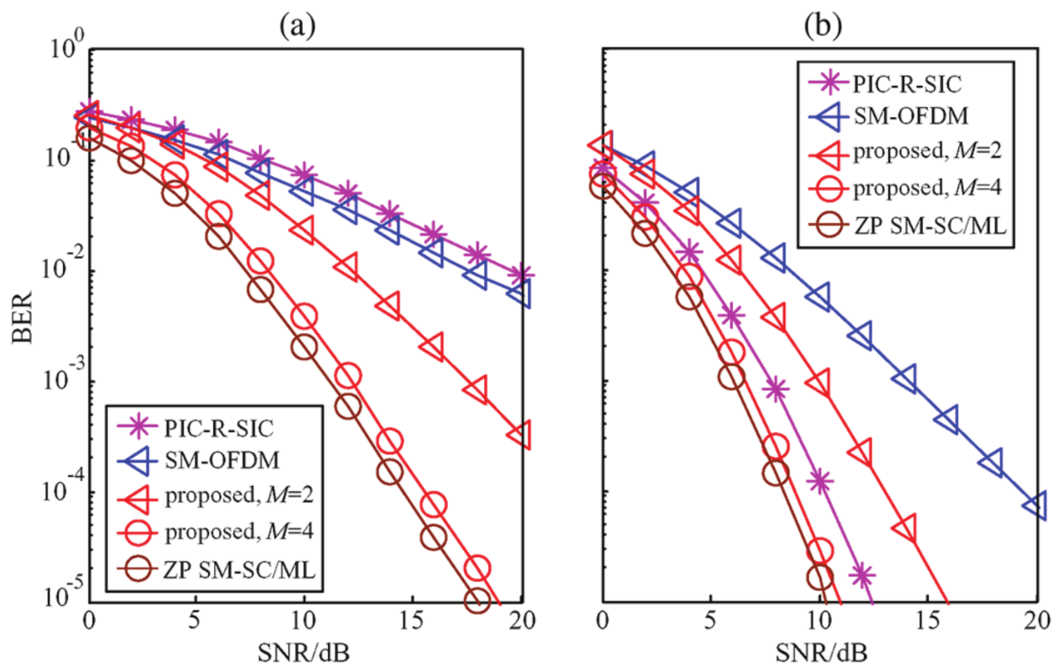

Figure 2: BER of ZP-aided SM-SC and SM-OFDM with different receiver antennas: (a) N_r = 1; (b) N_r = 2 [**1**]

Detector Implementation – Practical Solutions

- Module & class-based approach:
  - sc_sm_transceiver.py – transceiver, LSS-detector classes.
  - channel.py – uniform frequency-selective rayleigh fading channel class.
  - modulation.py – linear modulation classes.
- Spatial modulation symbol creation, e.g. [0, -1].
- Debug:
  - Correctly store metrics & estimated symbols.
  - Correct norms and variances.
  - Add true final detection over M candidates.
- Look into / validate Zero-Prefix.
- Improve scripts for testing & plotting.

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Detector Implementation – Simulation Results

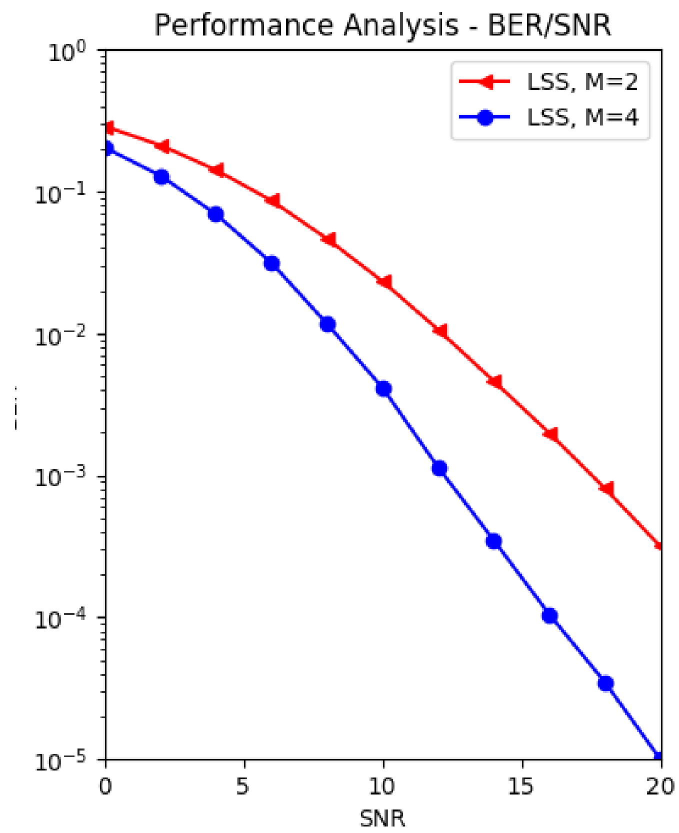

Figure 3: BER of ZP-aided SM-SC with receiver antenna: N_r = 1

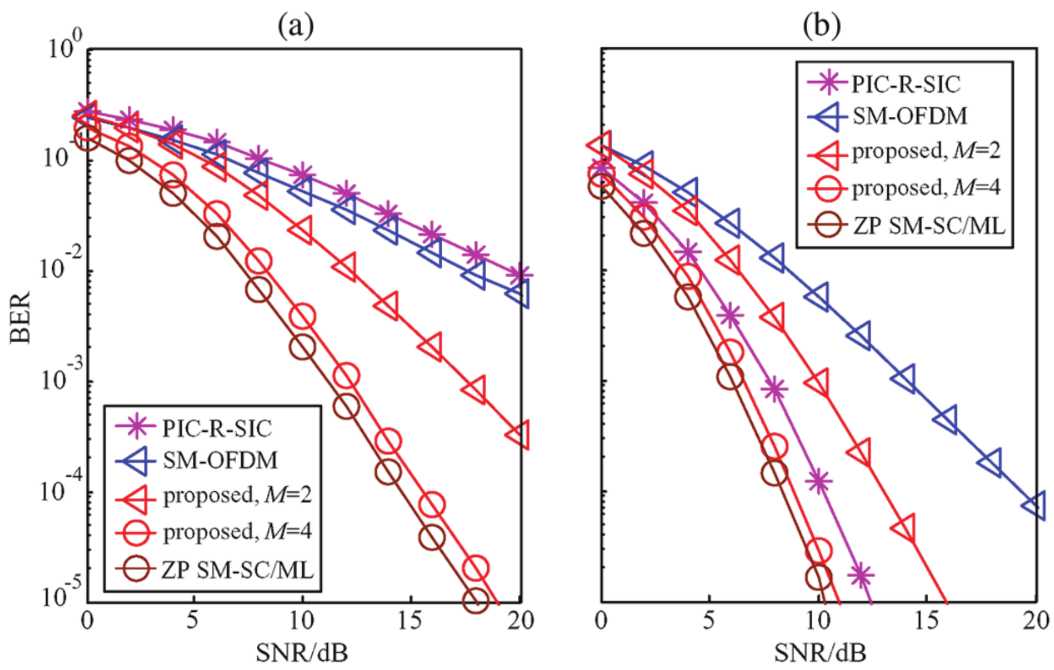

Figure 4: BER of ZP-aided SM-SC and SM-OFDM with different receiver antennas: (a) N_r = 1; (b) N_r = 2 [**1**]

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Detector Implementation – Simulation Results

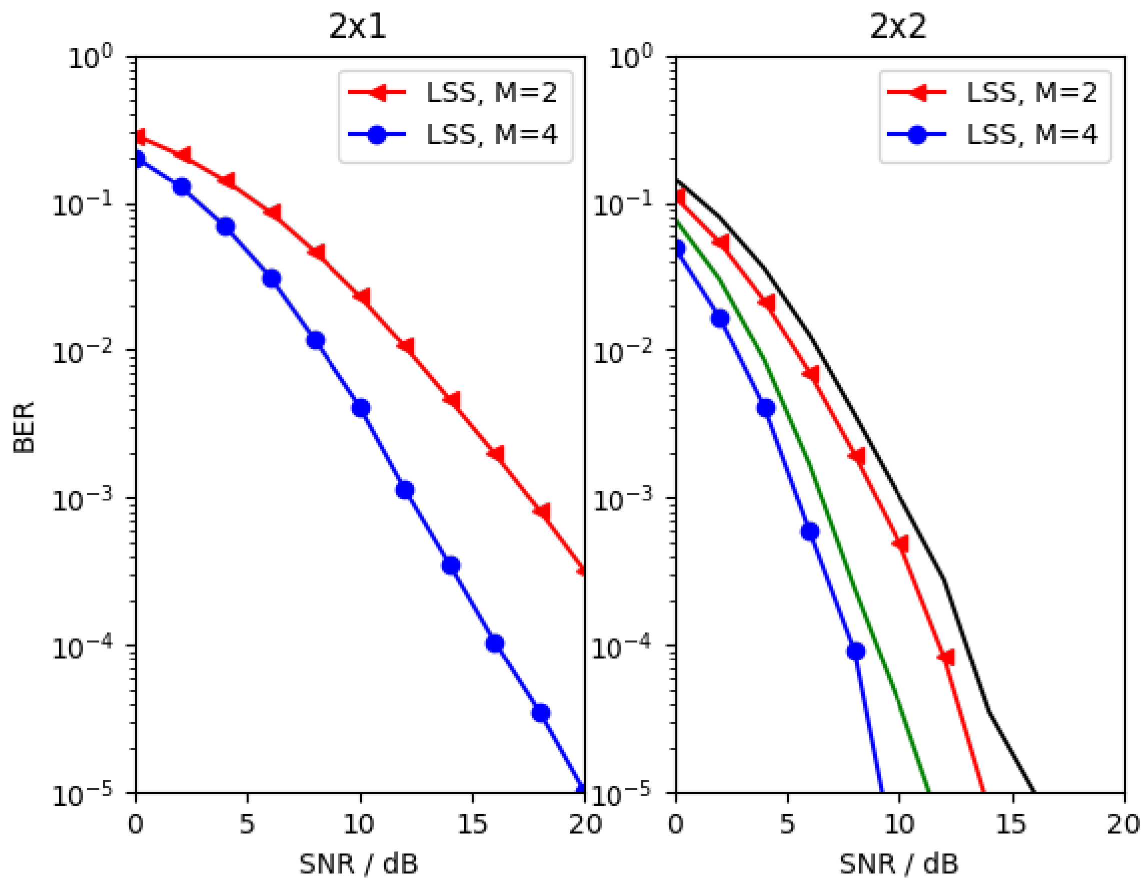

Figure 5: BER of ZP-aided SM-SC with different receiver antennas: N_r =1; N_r = 2

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Channel Estimation & Preamble Design

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- Common approach: Use pilot signals (or preambles) and correlate.
- Conventional preamble sequences may hurt advantages of SC-SM:
  - Sparse structure of SC-SM symbols not taken into account.
  - Prone to estimation errors – small-scale SM more robust than V-BLAST.
  - Not investigated in large-scale SC scenarios.
- Special training sequences using cyclic right-shifting method:
  - May not be suitable for high rates: Power efficiency loss, pilot overhead
- Ternary-like pseudo-random sequences promising candidates.
- Reducing pilot overhead:
  - Semi-blind iterative detection techniques.
  - Advanced training optimization techniques.
  - Differentially encoded designs.

Practical Channel Estimation - TCCE/CCE

- Implement small-scale approach: Hybrid between conventional channel estimation and transmission cross channel estimation.
- Estimate whole MIMO channel by sending pilots through 1 TA.
- High channel correlation: Gain of 7.5 dB.

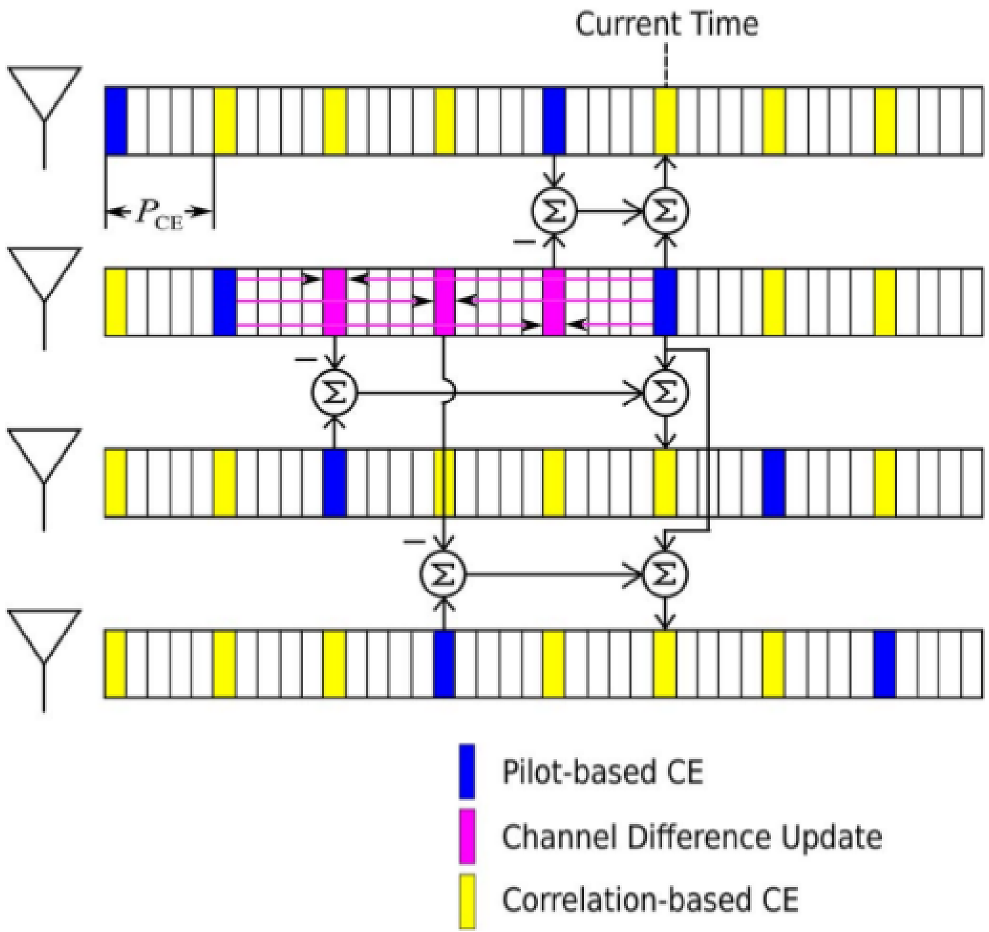

Figure 4: Block diagram of TCCE for SM with N_t = 4. [**2**]

Practical Channel Estimation – Other schemes

- Semi-blind joint channel estimation and data detection for STSK:
  - Uses initial least square channel estimate.
  - Then low-complexity single-stream ML.
  - Few iterations sufficient to approach ML with perfect CSI.
  - Lower bound: number_of_training_blocks > N_t / number_of_time_slots.

- Reduced-complexity joint channel estimation and data detection:
  - Based on the above-mentioned scheme.
  - Channel coefficients estimated according to MMSE criterion.
  - Achievable BER performance improves at the expense of an increased decoding complexity (increases linearly with number of iterations).

- Reduced-complexity ML detection and capacity-optimized training:
  - Optimal power allocation between data & training blocks (capacity bound).
  - Same SER performance as iterative data-detection/channel-estimation algorithm.

Prospects

- Solve 1 dB offset for 2x2 scenario.
- Implement different channels (COST, LTE).
- Implement and analyze channel estimation scheme(s).
- Implement synchronization.

- Proof of concept with GNU Radio

Any questions?

- Sources

  - [1] L. Xiao, D. Lilin, Y. Zhang, Y. Xiao, P. Yang and S. Li, "**A low-complexity detection scheme for generalized spatial modulation aided single carrier systems**," *IEEE Commun. Lett.*, vol. 19, no. 6, pp. 1069-1072, Jun. 2015

  - [2] X. Wu, H. Claussen, M. Di Renzo and H. Haas, "**Channel estimation for spatial modulation**," *IEEE Trans. Commun.*, vol. 62, no. 12, pp. 4362-4372, Dec. 2014