

# Development of a Single-Carrier SM-MIMO Transceiver

Channel Estimation & Synchronization  
Complete System Analysis

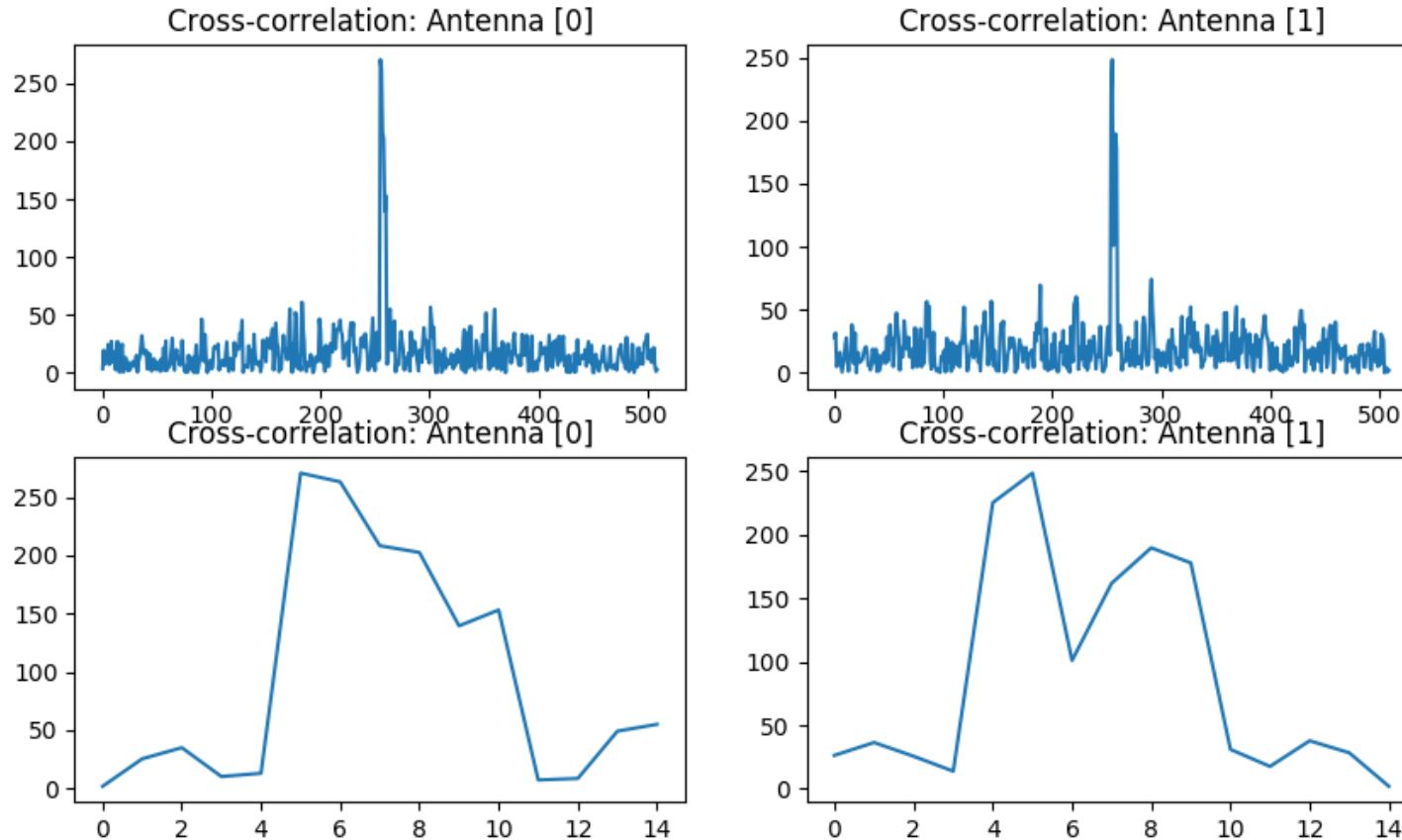
Communications Engineering Lab  
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# Classic Channel Estimation scheme

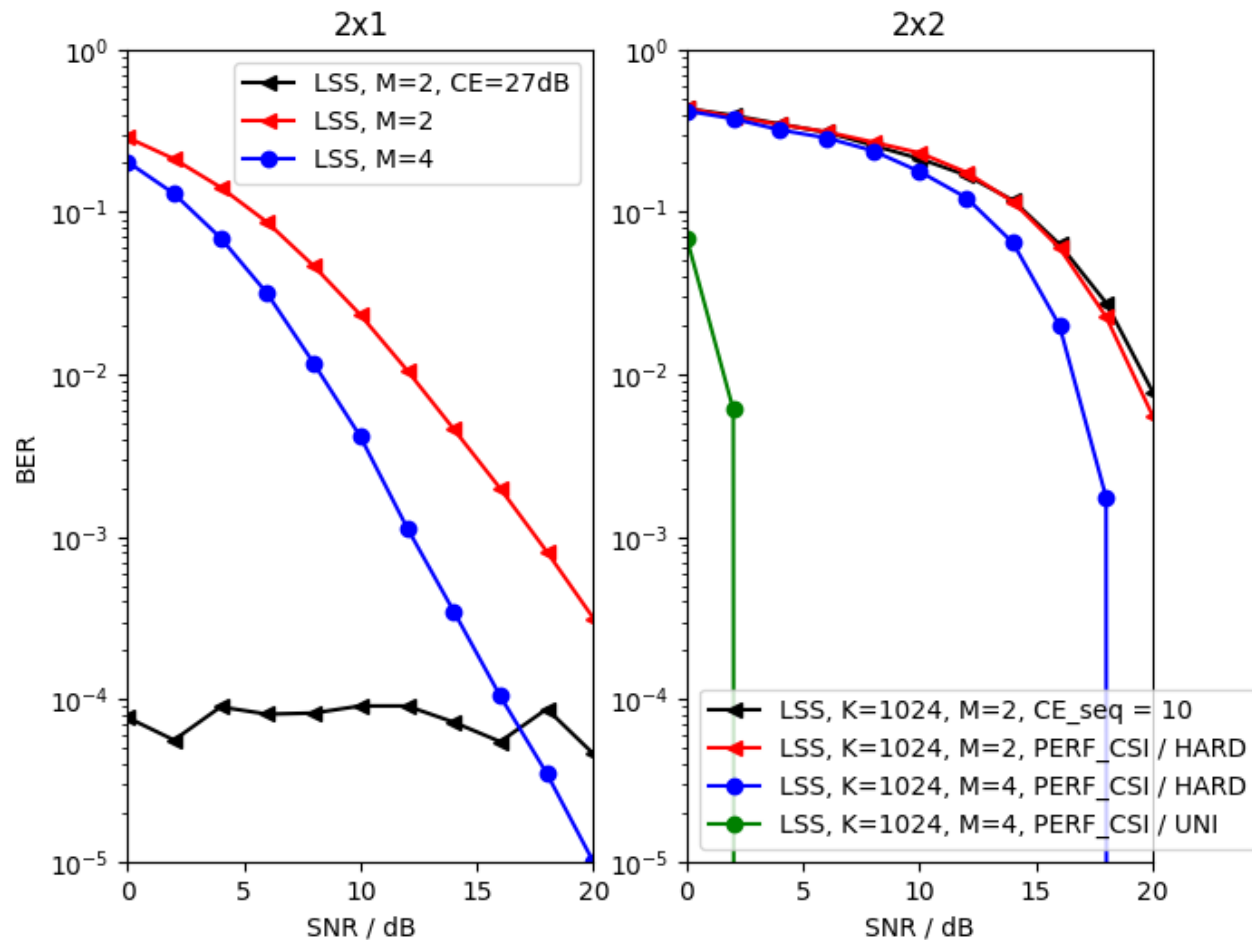
- For each transmission antenna: send training sequence.
- Using Gold Sequences: no multi-path effects for different antennas.
  - A frame can contain multiple antenna sequences.
- Correlate with the corresponding sequence at the receiver.
  - Channel Impulse Response for each transmit antenna.
- Reconstruct channel matrix with impulse responses.
  
- Performance trade-offs:
  - Longer sequences → lower threshold for reconstruction & more overhead.
  - More  $N_t$  → more index information & more overhead.
  - More  $N_r$  → lower channel estimation SNR needed.

# Simulation Results: Classic Approach (1)



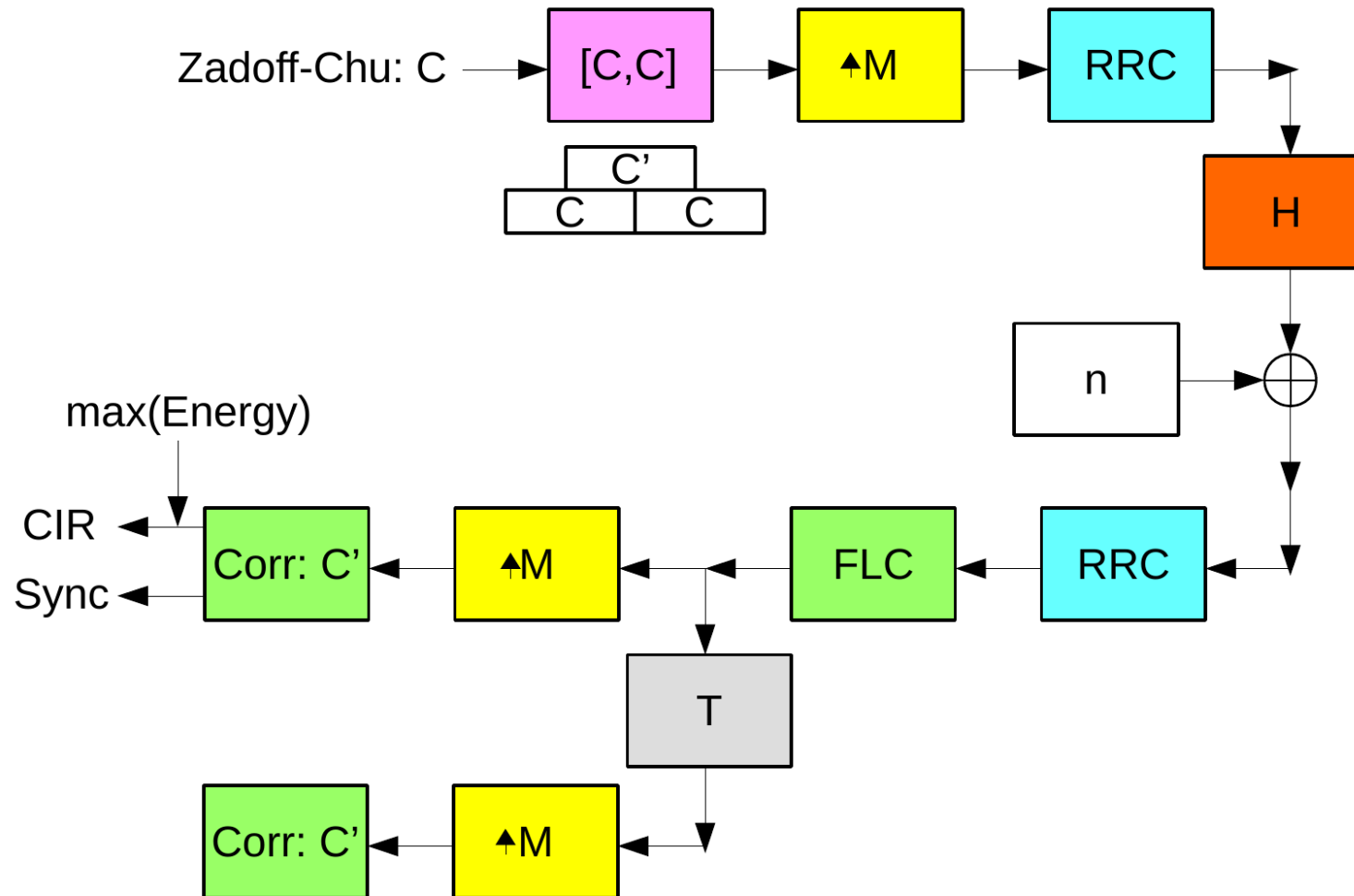
**Figure 1:** Results of correlation: Channel Impulse Response for different sending antennas [ $N_r = 2$ ;  $N_r = 2$ ; hard coded].

# Simulation Results: Classic Approach (2)



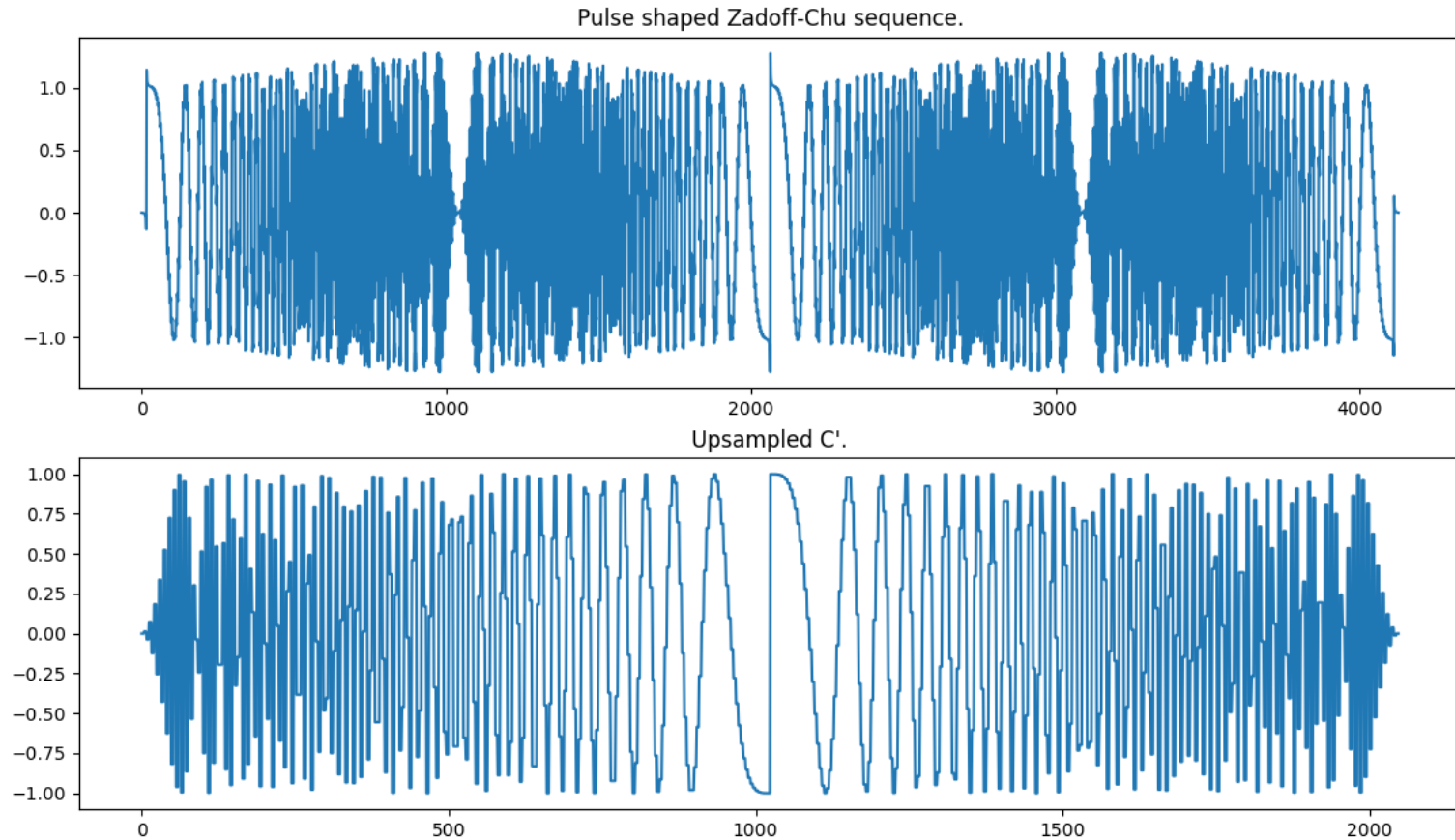
**Figure 2:** Classic SC-SM Channel Estimation scheme.

# Simultaneous Frame Synchronization and Channel Estimation scheme



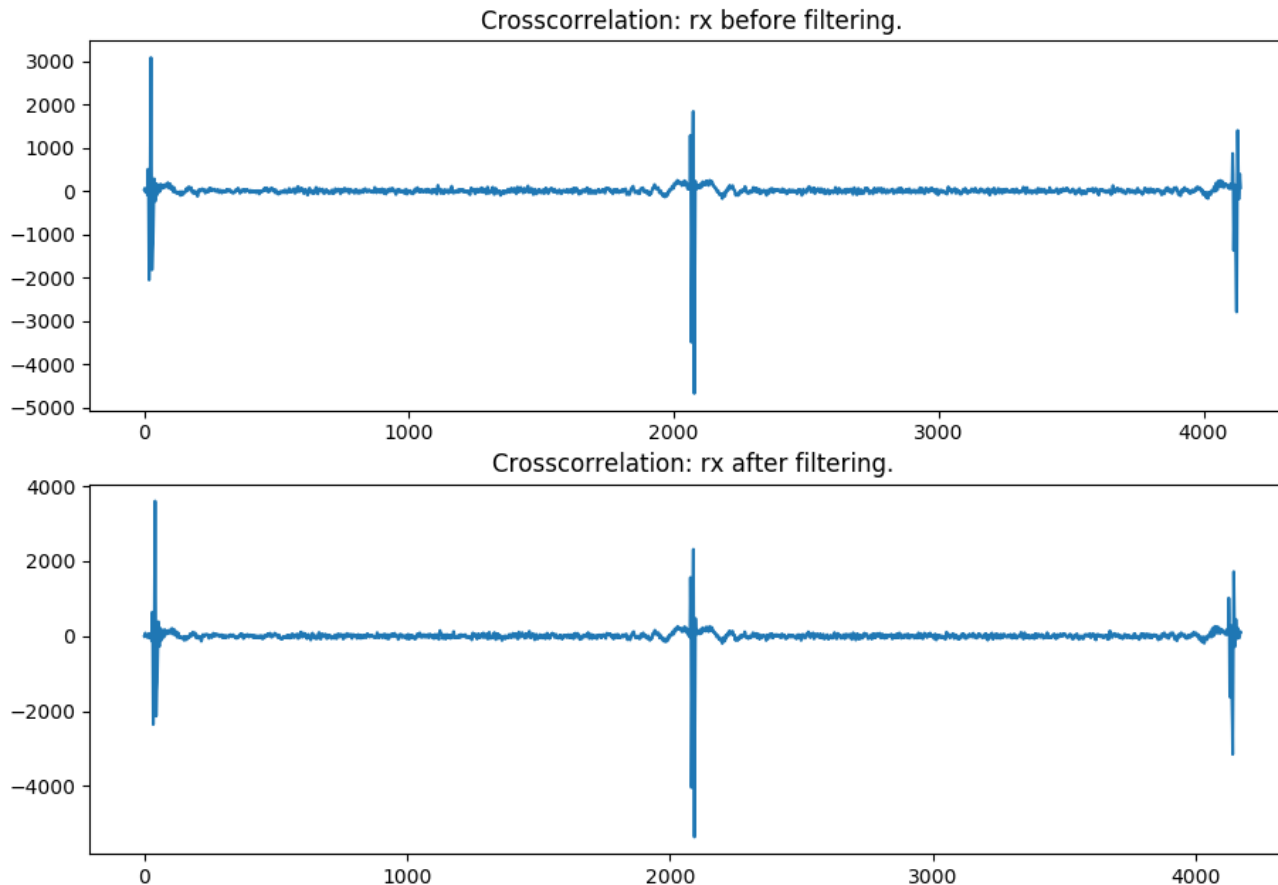
**Figure 3:** Proposed Synchronization & Channel Estimation scheme.

# Simulation Results: SISO (1)



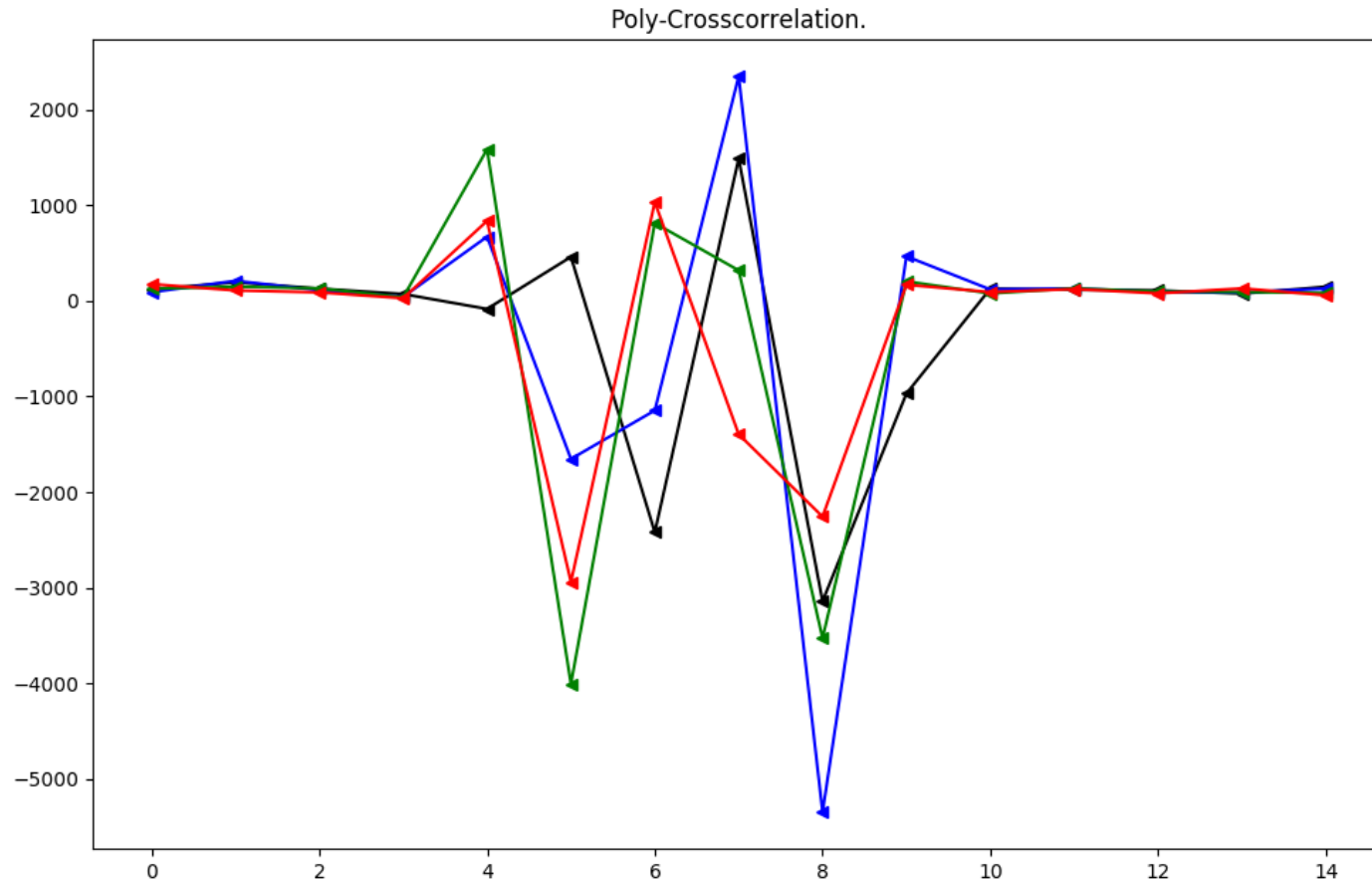
**Figure 4:** Upsampled frames:  $C$  and  $C'$ .

# Simulation Results: SISO (2)



**Figure 5:** Cross-correlation of the received frame with  $C'$ .

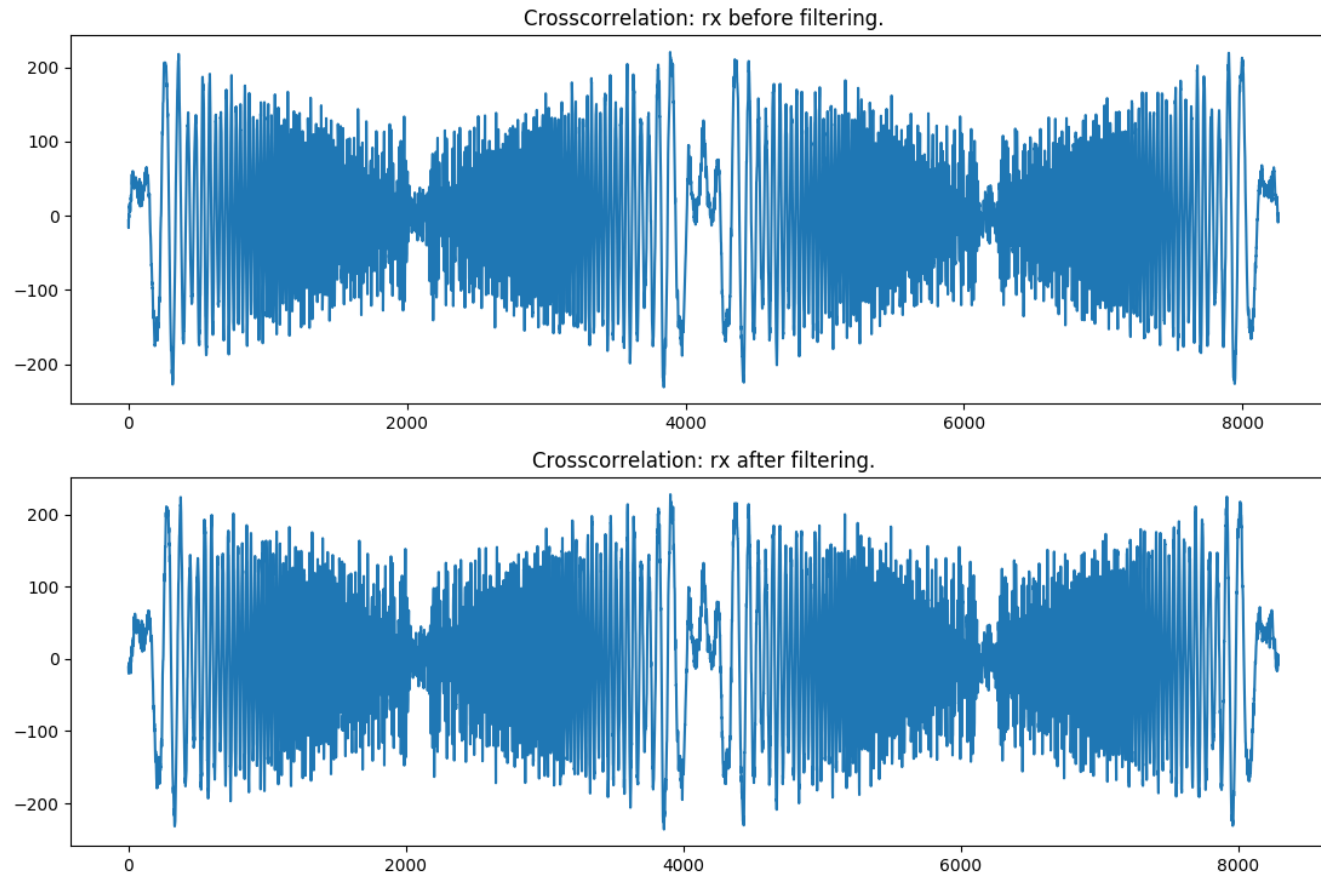
# Simulation Results: SISO (2)



**Figure 6:** Polyphase-cross-correlation of the received frame with  $C'$ .

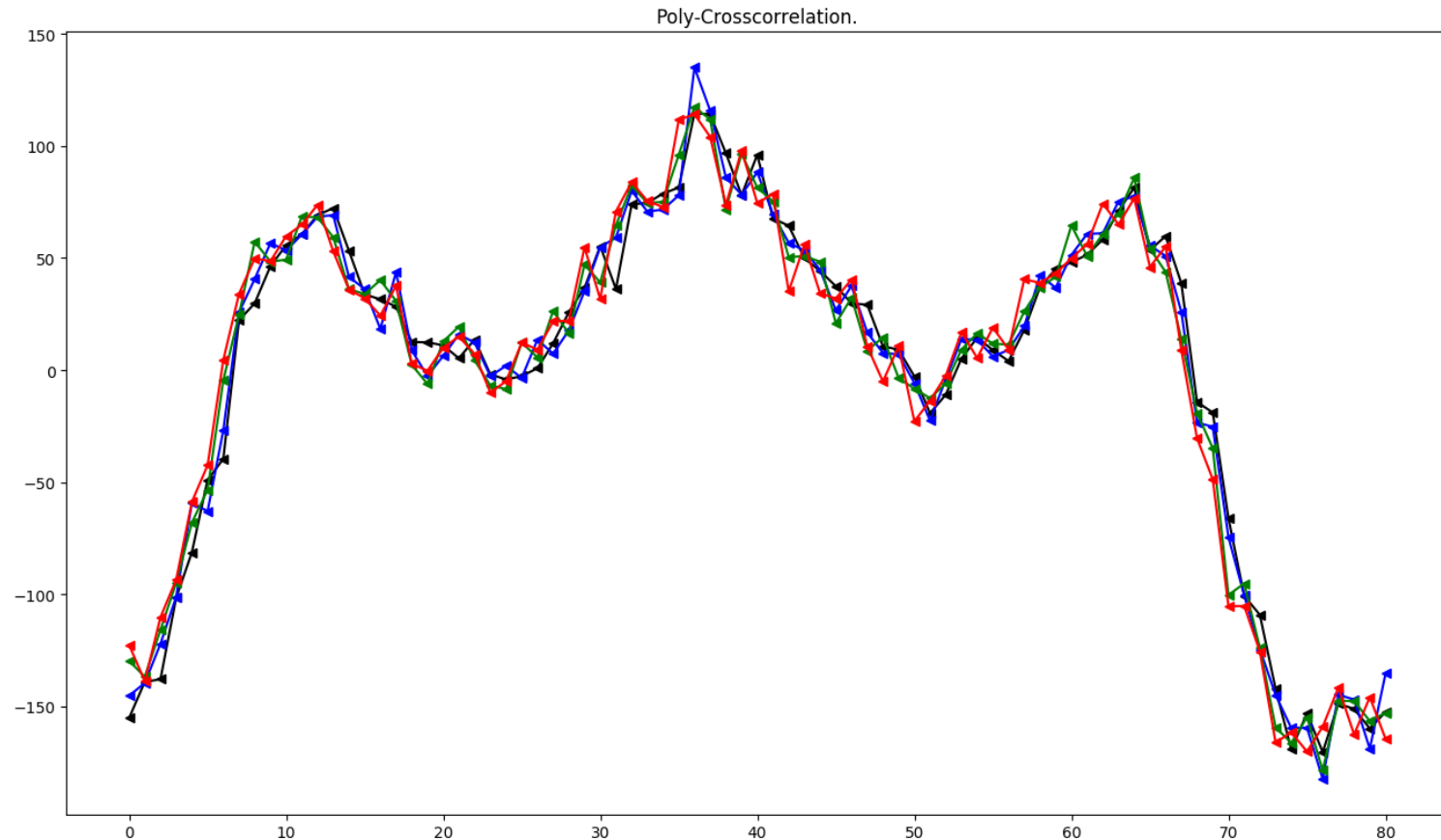


# Simulation Results: SIMO (1)



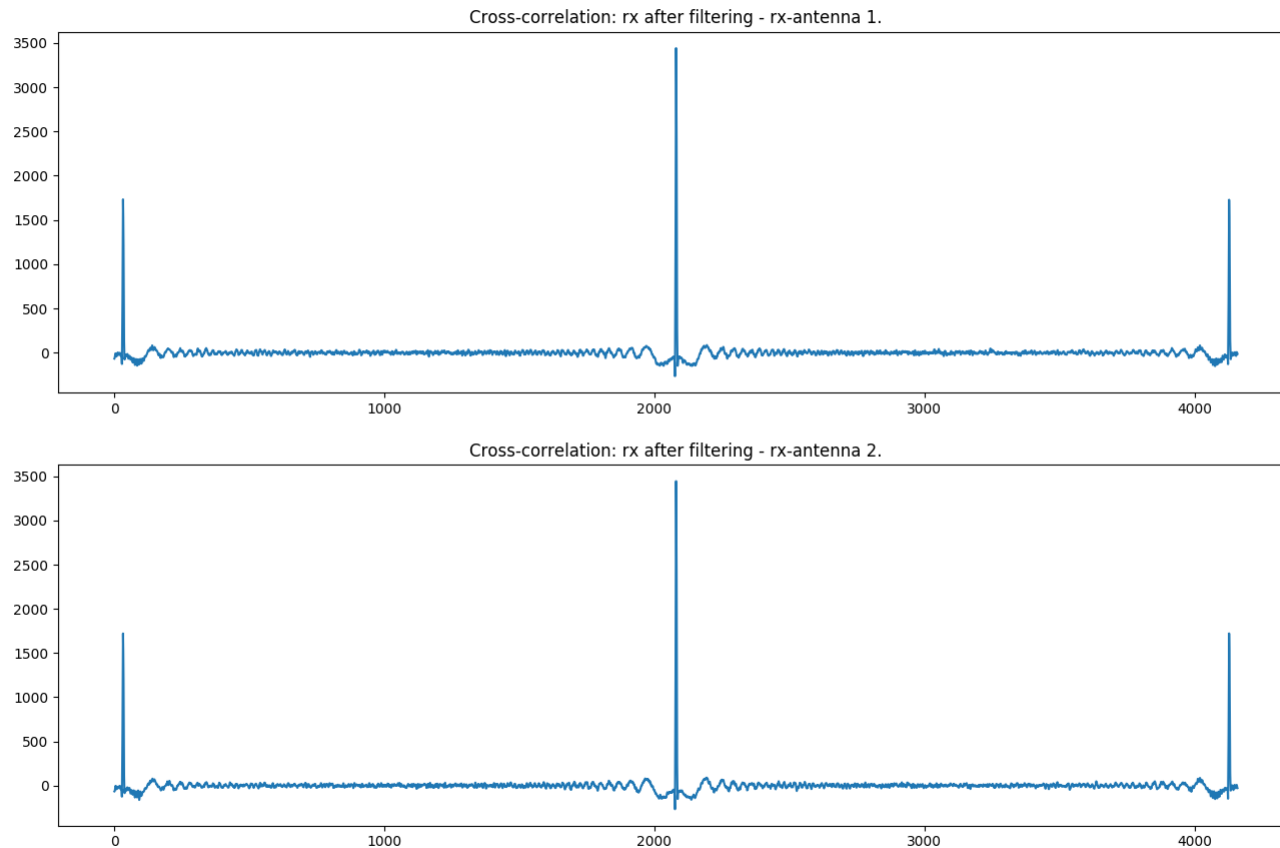
**Figure 7:** Cross-correlation of the received frame with  $C'$ .

# Simulation Results: SIMO (2)



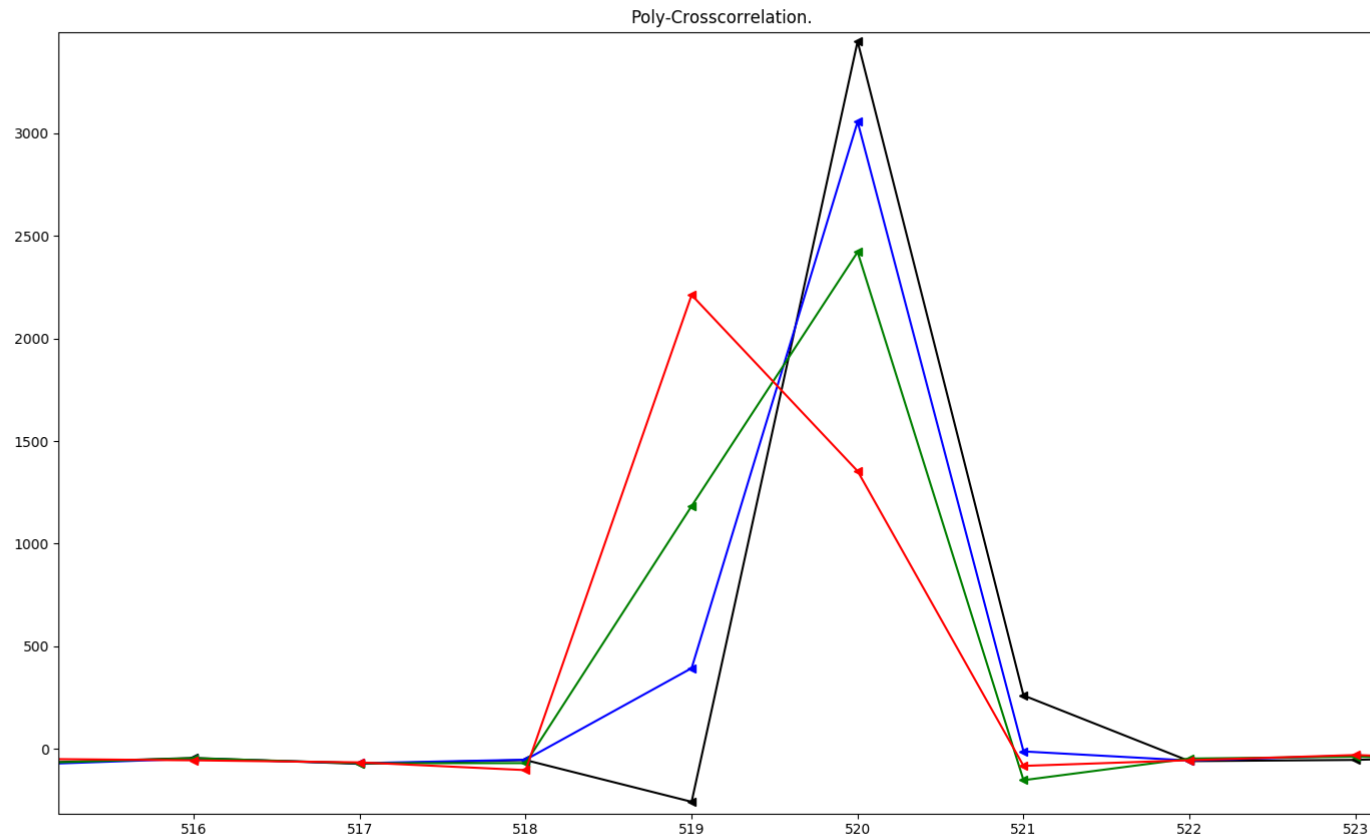
**Figure 8:** Polyphase-cross-correlation of the received frame with  $C'$ .

# Simulation Results: SIMO/Split (1)



**Figure 9:** Cross-correlation of the received frame with C' - split reception antennas.

# Simulation Results: SIMO/Split (2)



**Figure 10:** Polyphase-cross-correlation of the received frame with C' - split reception antennas – antenna 1.

# Concrete Issues

- Fix / adapt SIMO-simulation.
- Specify special channel simulations.
- Generalize current training setup.
  - Slice given Block-Toeplitz into transmit antenna Vector-Toeplitz matrices.
  - Find relevant correlation points and extract channel.

# Prospects

- New:
  - Implement frequency and phase synchronization.
  - Exhaustive tests and comparisons
  
- Persisting issues:
  - Solve 1 dB offset for 2x2 scenario.
  - Implement different channels (COST, LTE).
  
- Near future:
  - Proof of concept with GNU Radio
  - Start writing

# Any questions?

## ■ Sources

- Roth M. et al., 2017