SERENA Webinar #3

Simulating the Communication Performance of Active Antenna Systems

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SERENA

gan-on-Silicon Efficient mm-wave euRopean systEm iNtegration plAtform

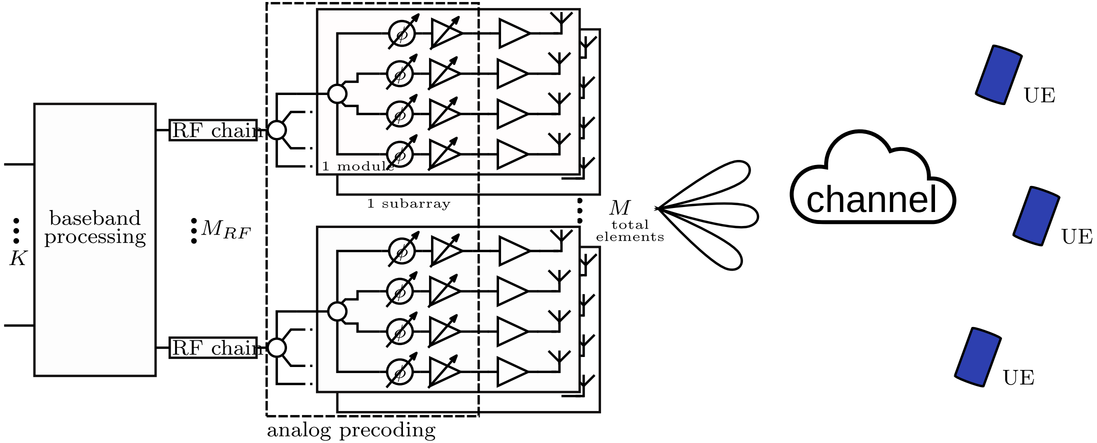
What is the task? What are the goals?

- To have a measure of the communication performance of a system
- To understand the influence of the hardware and the signal processing design choices
- it should be feasible, not every detail can be simulated

⇓

we need to simulate what matters and simplify what does not matter

The SERENA Hybrid Beamforming System



T. Kuehne, X. Song, G. Caire, K. Rasilainen, T. H. Le, M. Rossi, I. Ndip, and C. Fager, "Performance Simulation of a 5G Hybrid Beamforming Millimeter-Wave System," in 24th International ITG Workshop on Smart Antennas (WSA 2020), Hamburg, Germany, Feb. 2020.

Simulation code: https://doi.org/10.5281/zenodo.3971622

Simulation Setup

What we simulate:

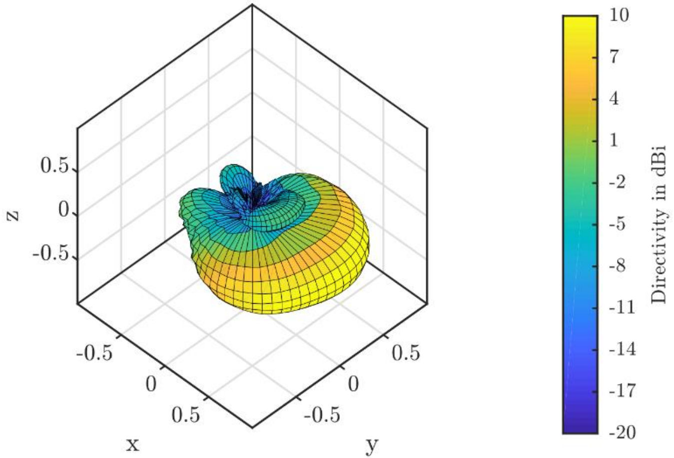
- Hardware: antenna pattern, characteristics of the beamformer, output power
- Wireless channel: a stochastic model → we get averaged results
- Signal Processing: parts related to the hybrid beamforming approach (initial acquisition, precoding)
- As the performance measure: sum spectral efficiency

How: in Mathworks Matlab

What not: Not every signal processing step (e.g., modulation), not every hardware detail (e.g., phase noise)

Hardware

- EM Simulation of the antenna pattern of a single element on the integration package
- Constructed the 16x8 array from the single element pattern
- Output power and NF: 10dBm, 7dB
- For example: the beamformer



3-D view of a single element pattern

```
phase_values = (unique([linspace(-180,0,48) linspace(0,180,48)]));
phase_error = 5;
[~, element_phase_idx] = min(abs(element_phase-phase_array));
element_phase_error = phase_error*(rand()-0.5);
element_factor =    real_element_amplitude*exp(1i*(phase_values(element_phase_idx)+ element _phase_error)/180*pi);
```

Wireless Channel Model

- geometry-based stochastic channel model:

  QuaDRiGa: Matlab based channel model

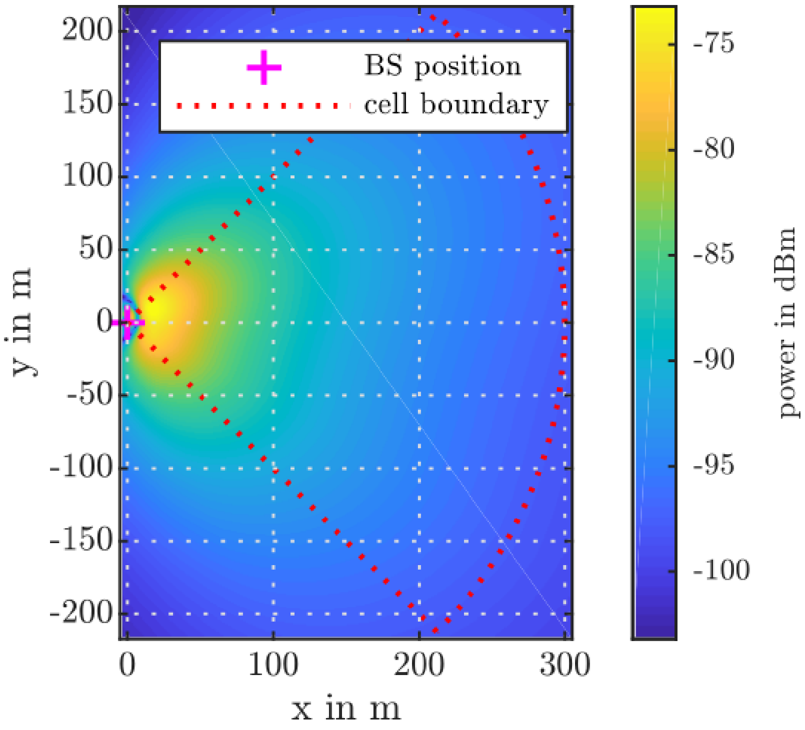
- stochastic model: not 1 but many channels (>2000)
- With a defined cell geometry, antenna configuration and time/frequency setting

S. Jaeckel, L. Raschkowski, K. Börner, L. Thiele, F. Burkhardt and E. Eberlein, ”QuaDRiGa - Quasi Deterministic Radio Channel Generator, User Manual and Documentation”, Fraunhofer Heinrich Hertz Institute, Tech. Rep. v2.6.1, 2021.
https://quadriga-channel-model.de/

Wireless Channel Model

5G based parameters

- 3GPP 38.901 channel model Urban Micro, LOS and NLOS
- 39GHz, 400MHz bandwidth, 120kHz subcarrier spacing
- cell size: 300m, horizontal angular range -45° to 45°



Signal Processing

- Only the parts which are special/unique for the hybrid beamforming architecture
- Initial acquisition / beam alignment:
  - estimating the angle of departure/arrival (AoD/AoA)
- Hybrid precoding:
  - Using the AoD / CSI information to transmit data to multiple users in the same time/frequency block
  - Result: SNR and interference per user and time/frequency block

The Performance Measure

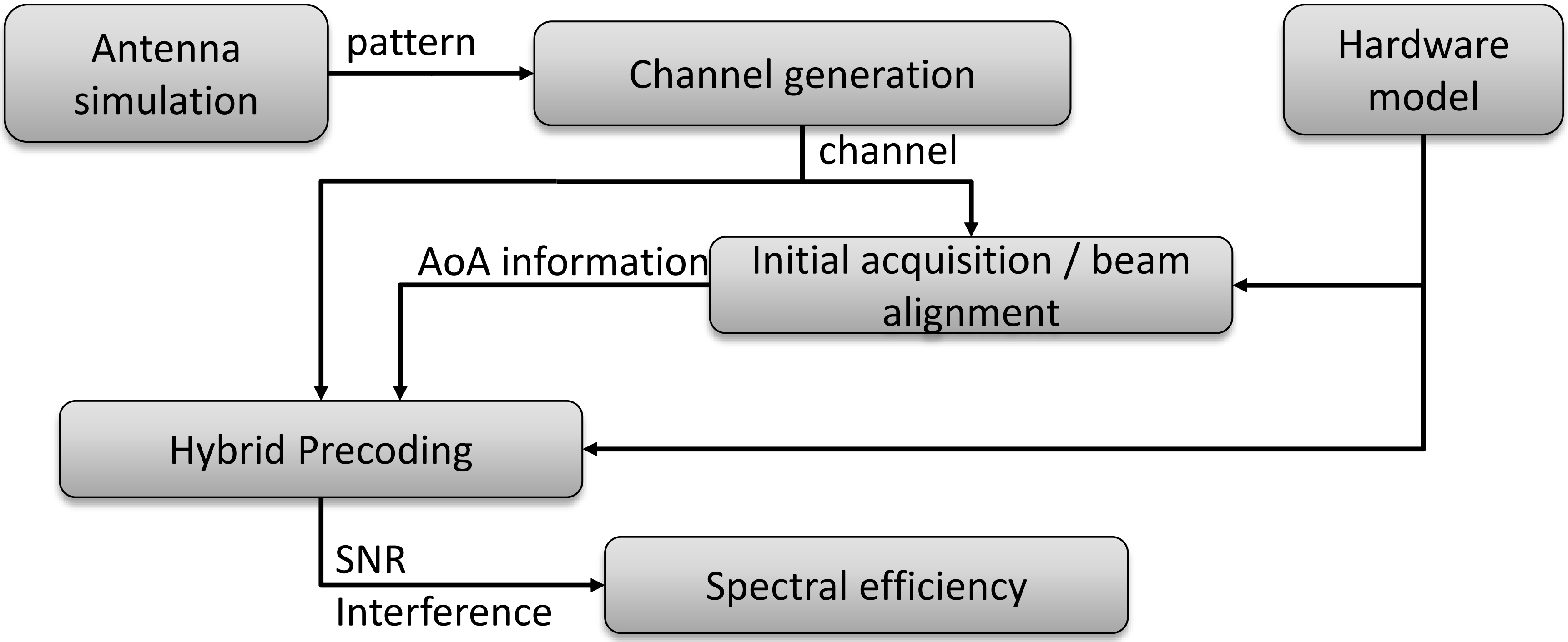
- Achievable asymptotic ergodic spectral efficiency
- Independent of the modulation or the coding etc. →what a system could achieve
- When interference by other users is treated as noise
- Each user knows its own channel coefficients
- For the k-th user

$$R_k = \mathbb{E}\left[\sum_{\omega} \log_2\left(1 + \frac{P_{k,\omega}\left|\mathbf{v}_k^{\mathrm{H}}\mathbf{H}_{k,\omega}(t)\mathbf{u}_{k,\omega}\right|^2}{\left|\sum_{k'\neq k}\sqrt{P_{k',\omega}}\mathbf{v}_k^{\mathrm{H}}\mathbf{H}_{\boldsymbol{k}',\omega}(t)\mathbf{u}_{\boldsymbol{k}',\omega}\right|^2 + N_0}\right)\right]$$

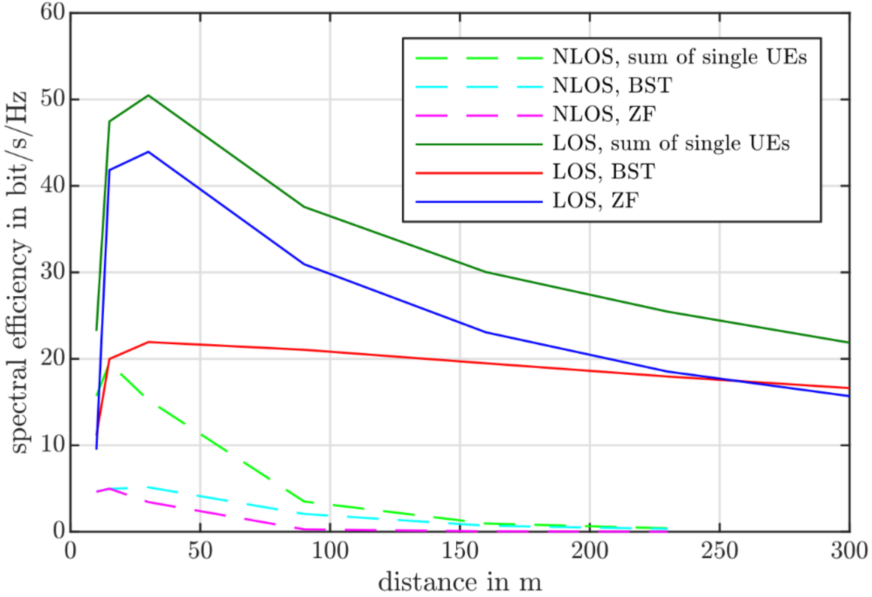
- And the sum rate:

$$R_{\mathrm{sum}} = \sum_{k=1}^{K} R_k$$

Complete Simulation



Example Result:



Average sum spectral efficiency over the UE distance

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