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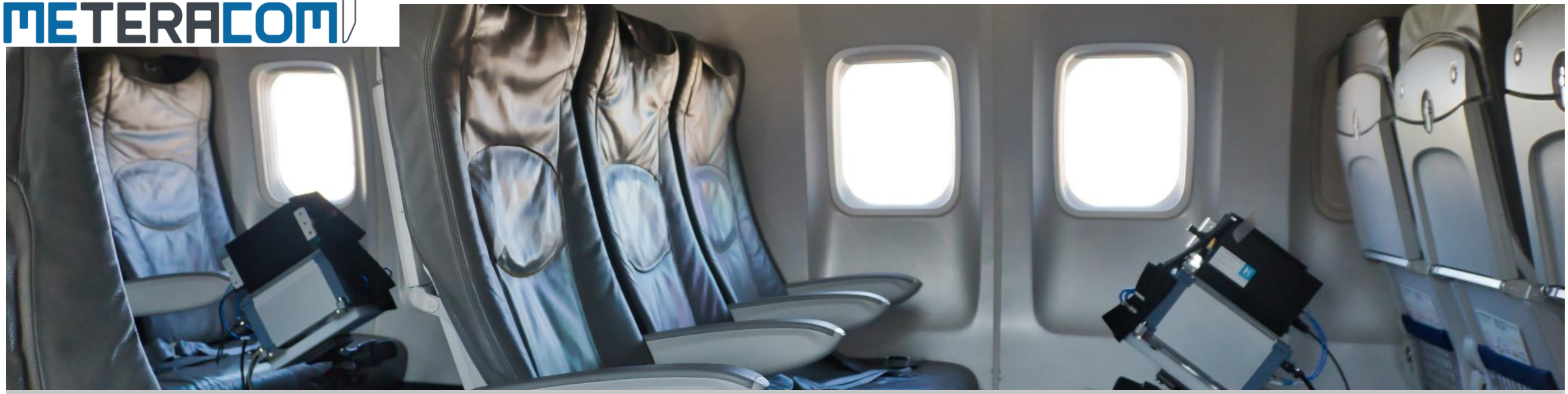
FOR 2863 Meteracom
Metrology for THz Communications

METERACOM



How image reconstruction can improve THz communications
A compressed sensing-assisted device discovery approach

Tobias Doeker

1st International Workshop on Metrology for THz Communications, Braunschweig, 28 June 2022

Outline

- Motivation
- Introduction to device discovery
- Why compressed sensing?
- Improvements of device discovery
- Outlook

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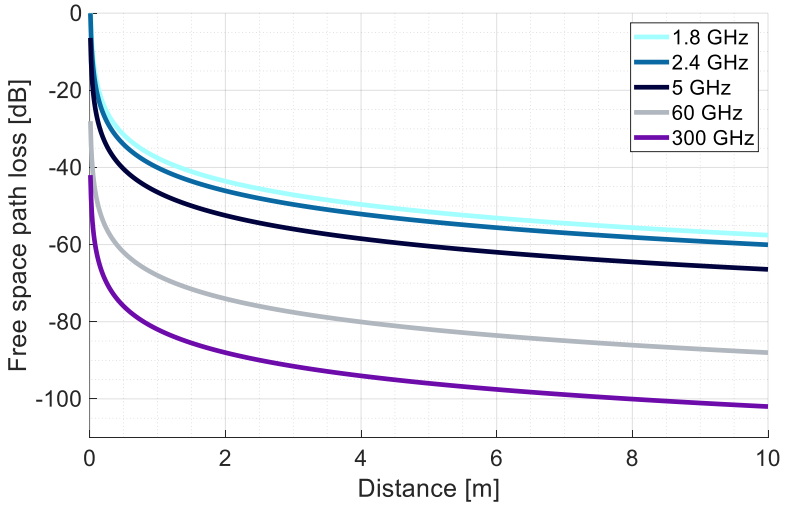
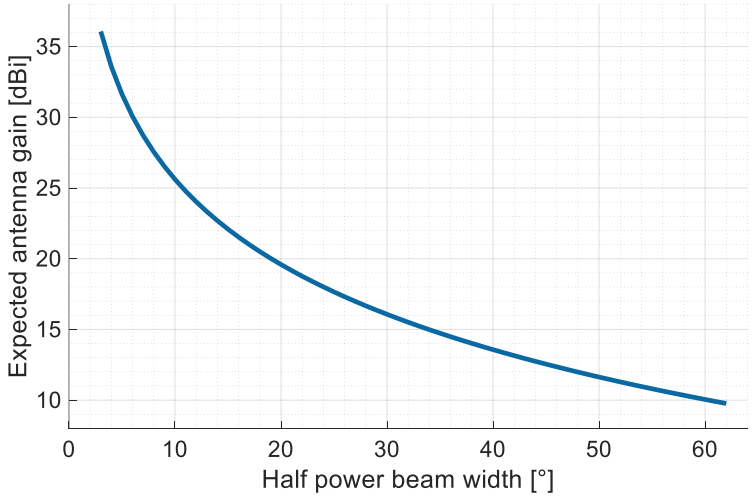
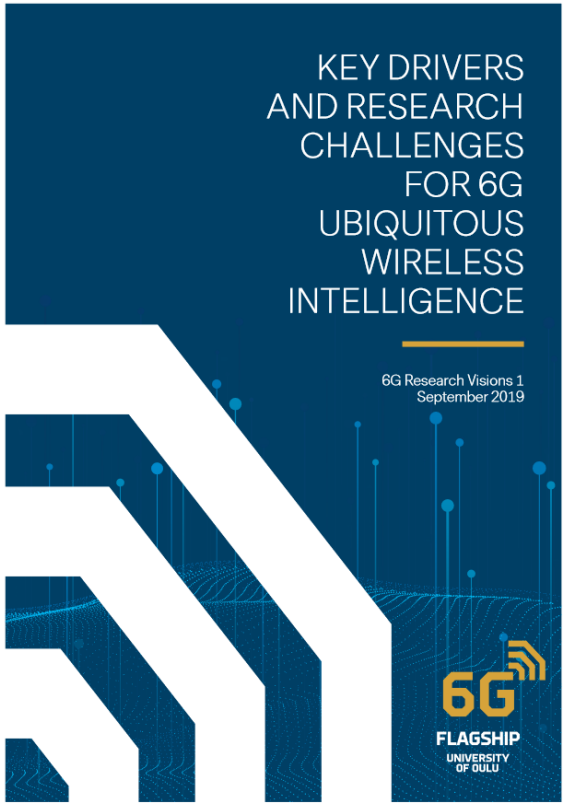
Motivation

- " …6G research should look at the problem of transmitting up to 1 Tbps per user. This is possible through the efficient utilization of the spectrum in the THz regime…."
- THz communications needs highly directive antennas due to the high path loss
- Precise alignment between TX and RX necessary → *device discovery* crucial







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Two step approach

T. Doeker, P. Reddy Samala, P. S. Negi, A. Rajwade and T. Kürner, "Angle of Arrival and Angle of Departure Estimation Using Compressed Sensing for Terahertz Communications," *15th Eu. Conf. Ant. Propag. (EuCAP)*, 2021, pp. 1-5, doi: 10.23919/EuCAP51087.2021.9411406.

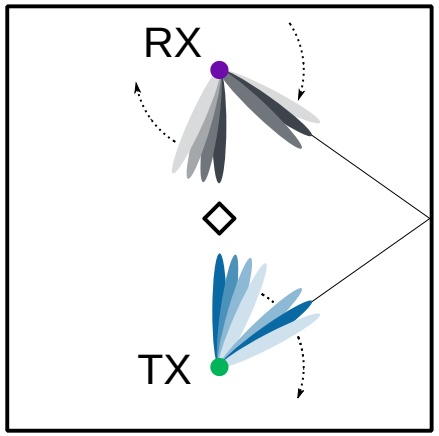
1. Scanning environment with low angular resolution

   → Finding sector with highest received power

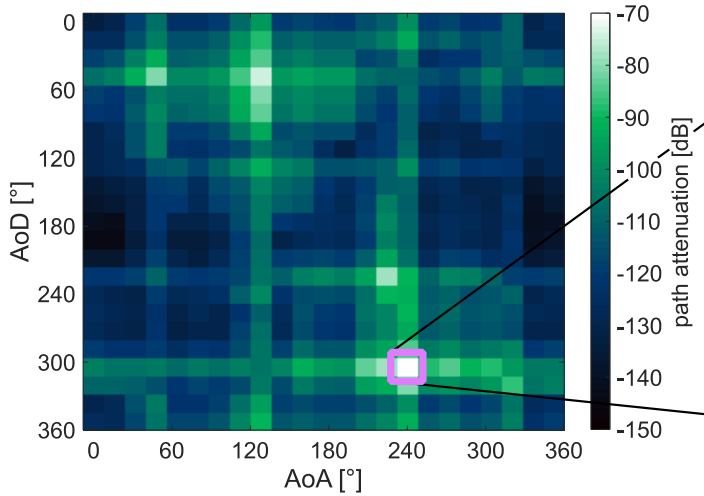
2. Scanning environment in dedicated sector with high angular resolution

   → Finding angle of departure (AOD) / angle of arrival (AOA) combination with highest received power

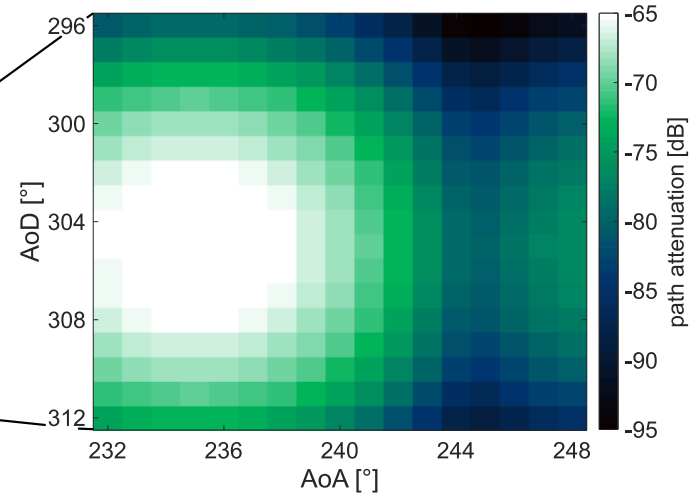
$$N = \left\lceil \frac{360^\circ}{\Delta\varphi_{\text{init}}} \right\rceil^2 + \left\lceil \frac{\Delta\varphi_{\text{init}}}{\Delta\varphi_{\text{final}}} \right\rceil^2$$



Exemplary Setup



Power angular profile (PAP)
Scanning Step



PAP – Aligning Step

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Compressed sensing

- Method to reconstruct unknown signal vector $\boldsymbol{x}$ from known measurement vector $\boldsymbol{y}$
- Known from signal processing and image reconstruction

$$\mathbf{y} = \mathbf{A}\mathbf{x}$$

$$\mathbf{x} \in \mathbb{R}^n \qquad \mathbf{y} \in \mathbb{R}^m$$

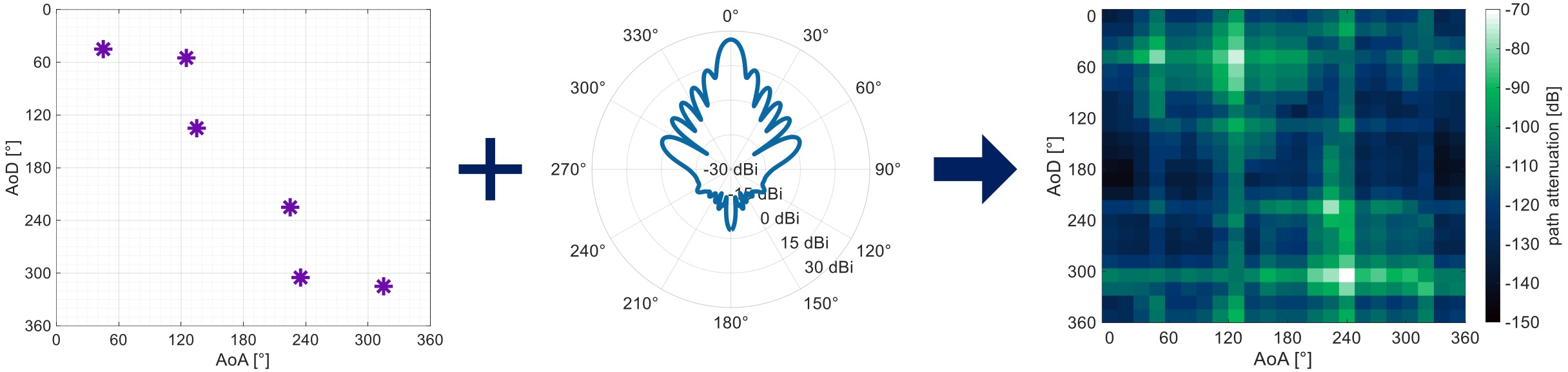
- $\boldsymbol{A}$ is the measurement matrix

$$\mathbf{A} \in \mathbb{R}^{m \times n}$$

- Due to dimension constraints, conventional techniques fail
- Prerequisite: Sparsity of $\boldsymbol{x}$

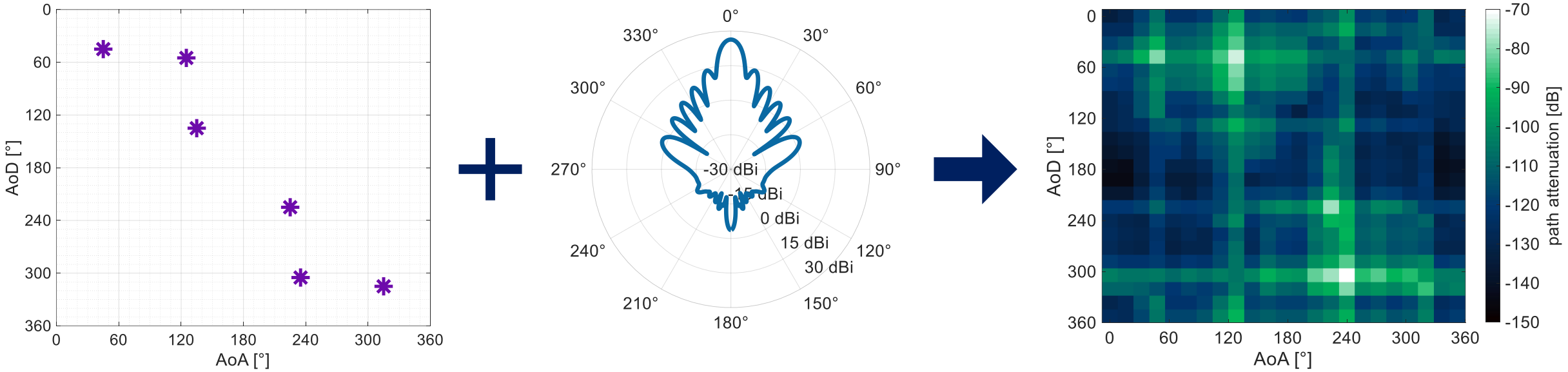
$$m \ll n$$

Power angular profile



- Multipath components (vectorized) = signal vector
- Antenna Diagram (with different orientations) are basis for measurement matrix
- Power angular profile (vectorized) = measurement vector

Power angular profile



Compressed sensing

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First results

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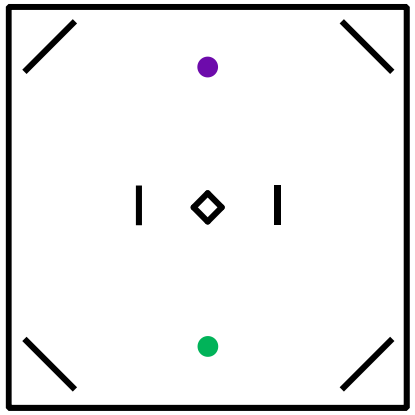
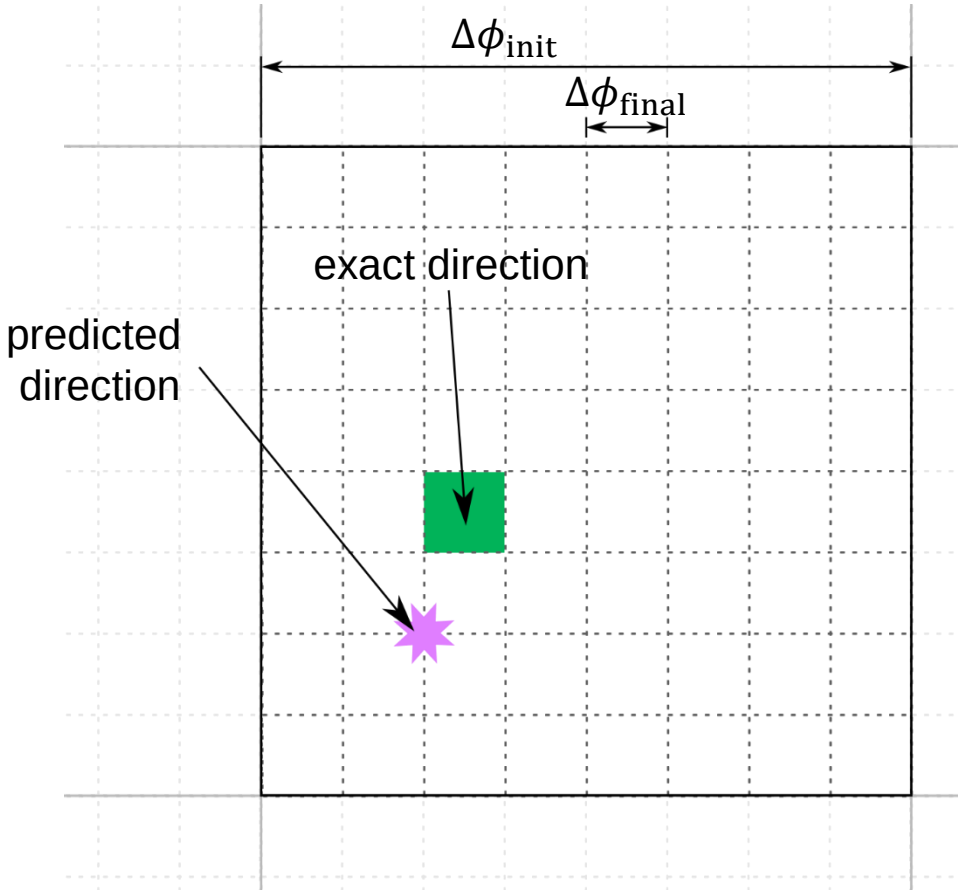
- Ray-tracing based simulations
- Four different scenarios [line-of-sight (LOS) and non line-of-sight (NLOS) with each few and many multipath components (MPCs)] are investigated
- Six different angular resolutions
- Comparison between exact and predicted direction (error with respect to the angular resolution γ)



Simulation setup



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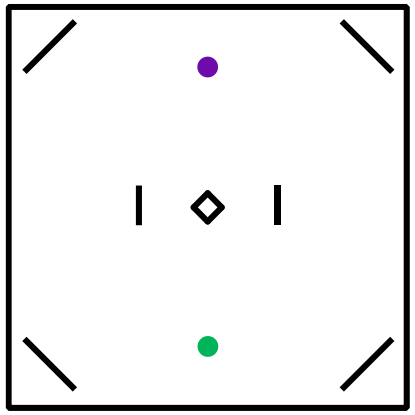

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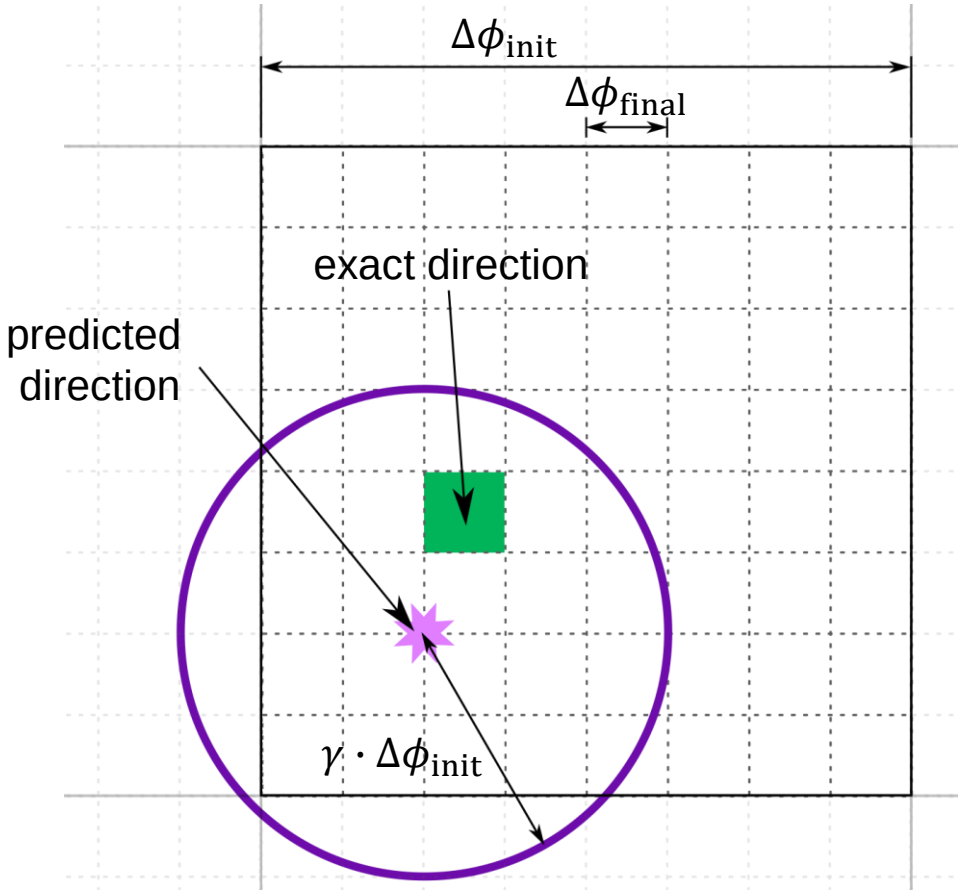

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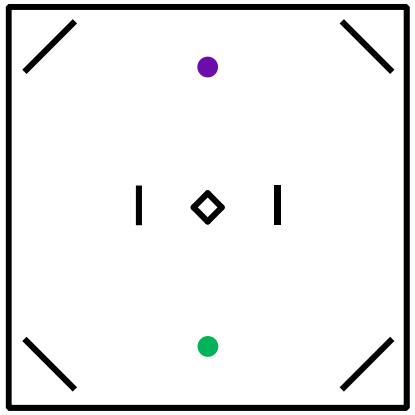

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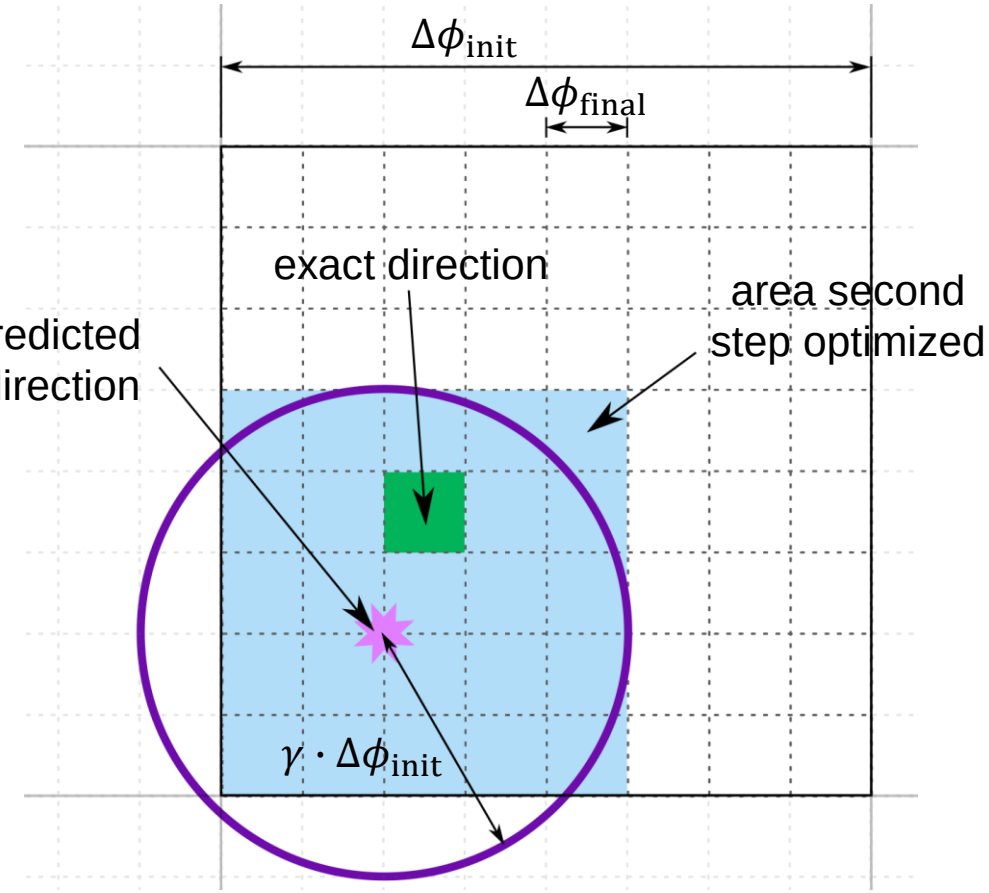
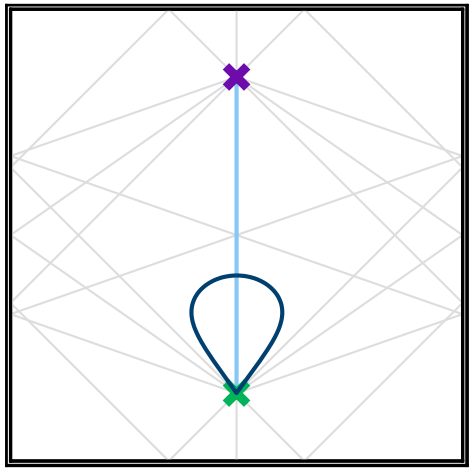


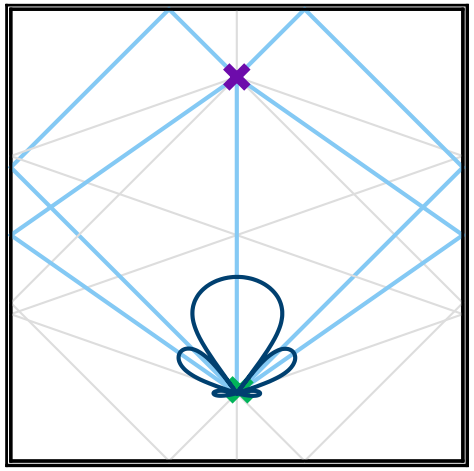
Influence of the antennas

T. Doeker and T. Kürner, "Influence of the Initial Antenna Orientation on the Performance of Compressed Sensing-assisted Device Discovery," *2021 Kleinheubach Conference*, 2021, pp. 1-4, doi: 10.23919/IEEECONF54431.2021.9598425.

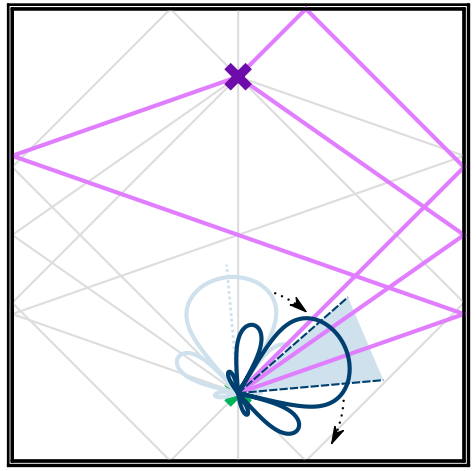
- PAP / angular spread depends on antenna pattern and initial antenna orientation



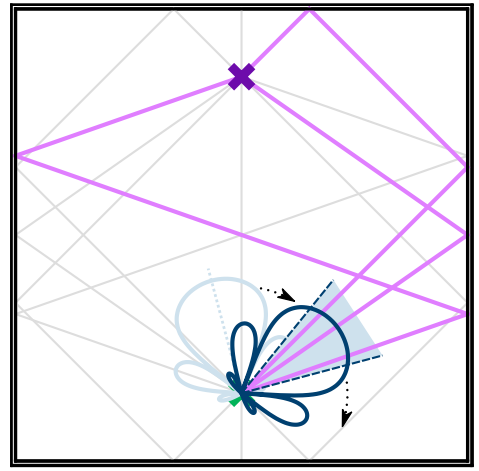
no side lobes



with side lobes



initial antenna orientation
$\alpha_0 = -5°$



initial antenna orientation
$\alpha_0 = -15°$

- Same simulation scenarios as before
- Three different antennas (no / few / strong side lobes)
- Changing initial antenna orientation

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Outlook

- Compressed sensing can assist device discovery
- Full potential from compressed sensing approach currently not exploited

- Possibilities for improvements:
  - Different solver
  - Multiple information (MIMO)
- Acceleration of processing (e.g., segmentation of reconstruction)

Thank you very much for your Attention

E-Mail: t.kuerner@tu-bs.de

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