Efficient Modeling of Beam Patterns Using Physics-Based Basis Functions

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Introduction

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- Small difference between actual and predicted beams
  - broken elements
  - beamformer errors
  - element displacement
- Limited number of calibration sources
  → few parameters to describe actual beam
  → proper basis functions needed
- Possible solutions
  - tapered aperture approximation (Craeye)
  - characteristic basis function patterns (this talk)

Characteristic Basis Function Patterns

Maaskant et al., IEEE TAP, 2012, in press

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Current distribution over aperture

- determines far field radiation pattern
- superposition of characteristic basis functions (CBFs)
  → exploited in CBFM to reduce numerical complexity

Definition of CBFP

- far field radiation pattern associated with CBF

Total far field pattern is superposition of CBFPs

Generation of CBFPs

- Using EM-models for expected physical effects
  - primary CBFP: nominal beam (no errors)
  - secondary CBFPs: deviations from "nominal"
    - impedance matching errors
    - beamformer errors
- After instrument characterization: measured CBFPs?
- Efficient representation by superposition of analytic functions saves processing power

Data model / measurement equation

- **Beam model**

$$\mathbf{F}(\theta, \varphi) = \Sigma\, a_m\, \mathbf{G}_m(\theta, \varphi)$$

- **Voltage domain**

$$V_k = \mathbf{F}(\theta_k, \varphi_k) \cdot \mathbf{E}_i(\theta_k, \varphi_k)$$

- **Power domain:**

$$R_{pq} = \langle V_p, V_q^* \rangle$$

$$= \langle \int \Sigma\, a_{mp}\, \mathbf{G}_{mp}(\Omega) \cdot \mathbf{E}_i(\Omega)\, d\Omega, Vq^* \rangle$$

$$= a_p^H\, \mathbf{A}_{pq}\, a_q$$

Example 1: beamformer errors (1)
Maaskant & Ivashina, ICEAA 2012, 2 – 7 Sep. 2012

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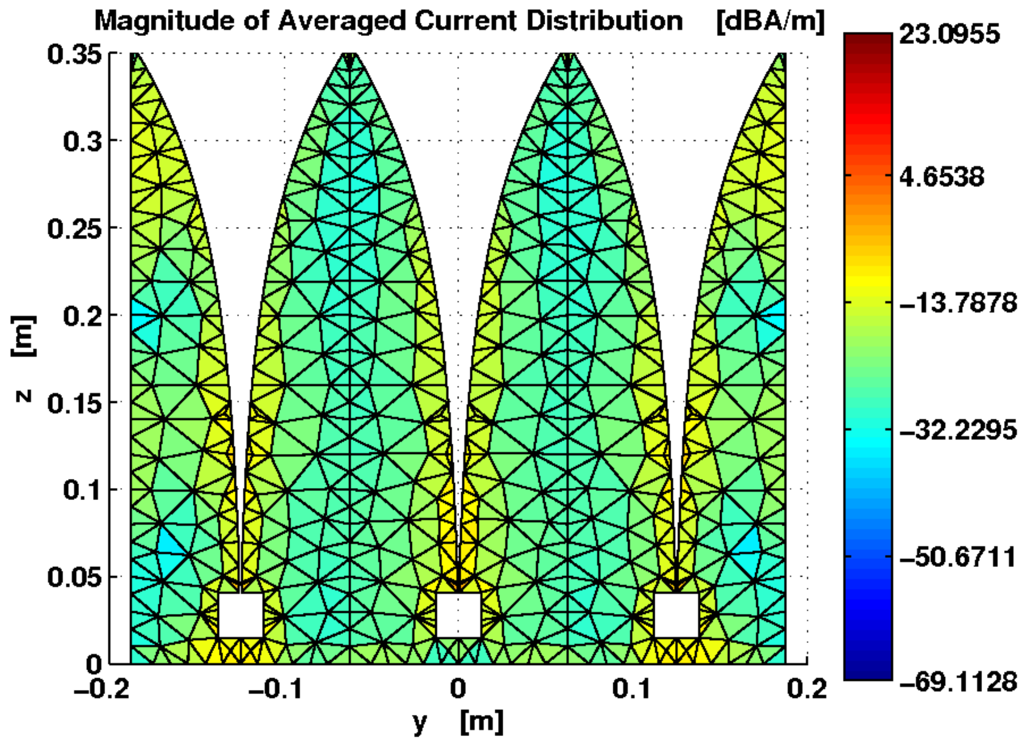
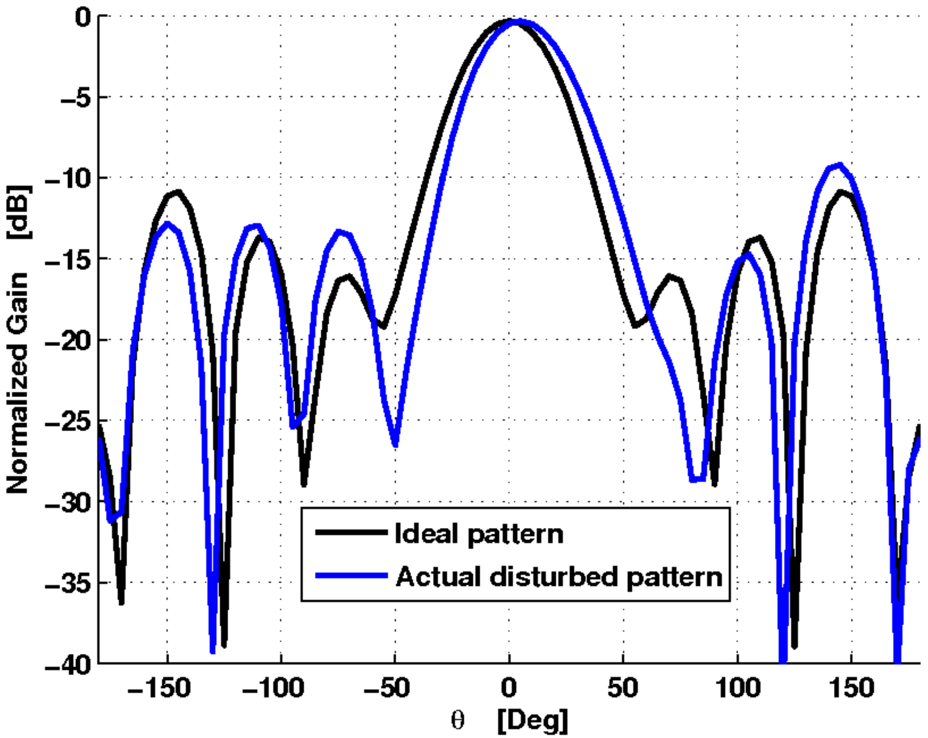
Scenario: 3-element Vivaldi array with 5° mis-pointing





Example 1: beamformer errors (2)

Maaskant & Ivashina, ICEAA 2012, 2 – 7 Sep. 2012

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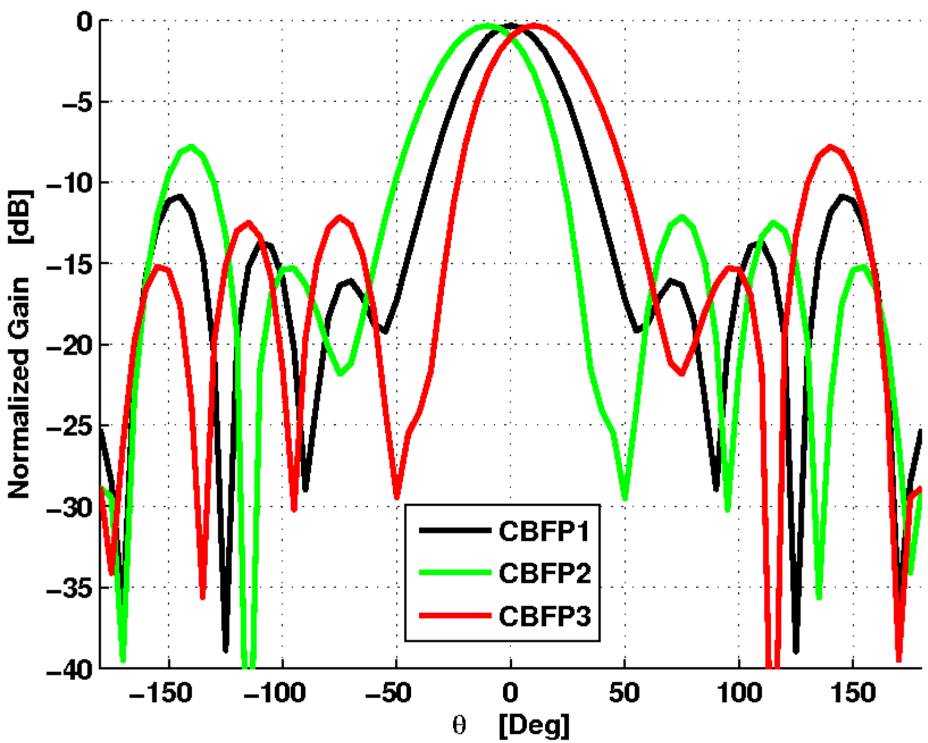
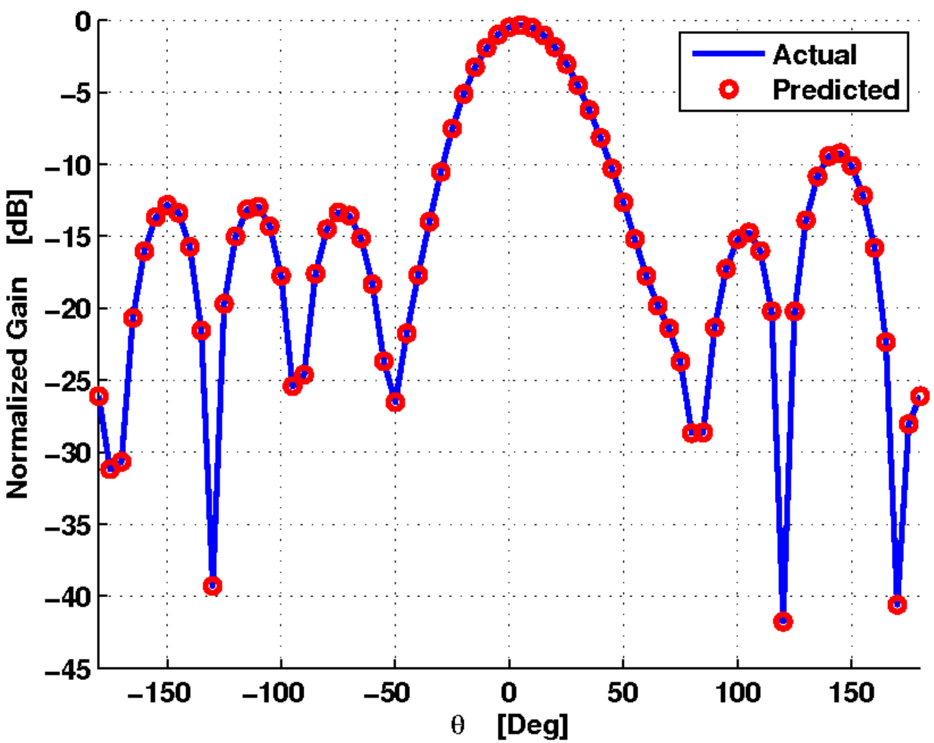
CBFPs: nominal beam and ±10° mis-pointed beams

CBFPs provide very accurate beam prediction





Example 2: impedance mismatch (1)

Maaskant et al., IEEE TAP, 2012, in press

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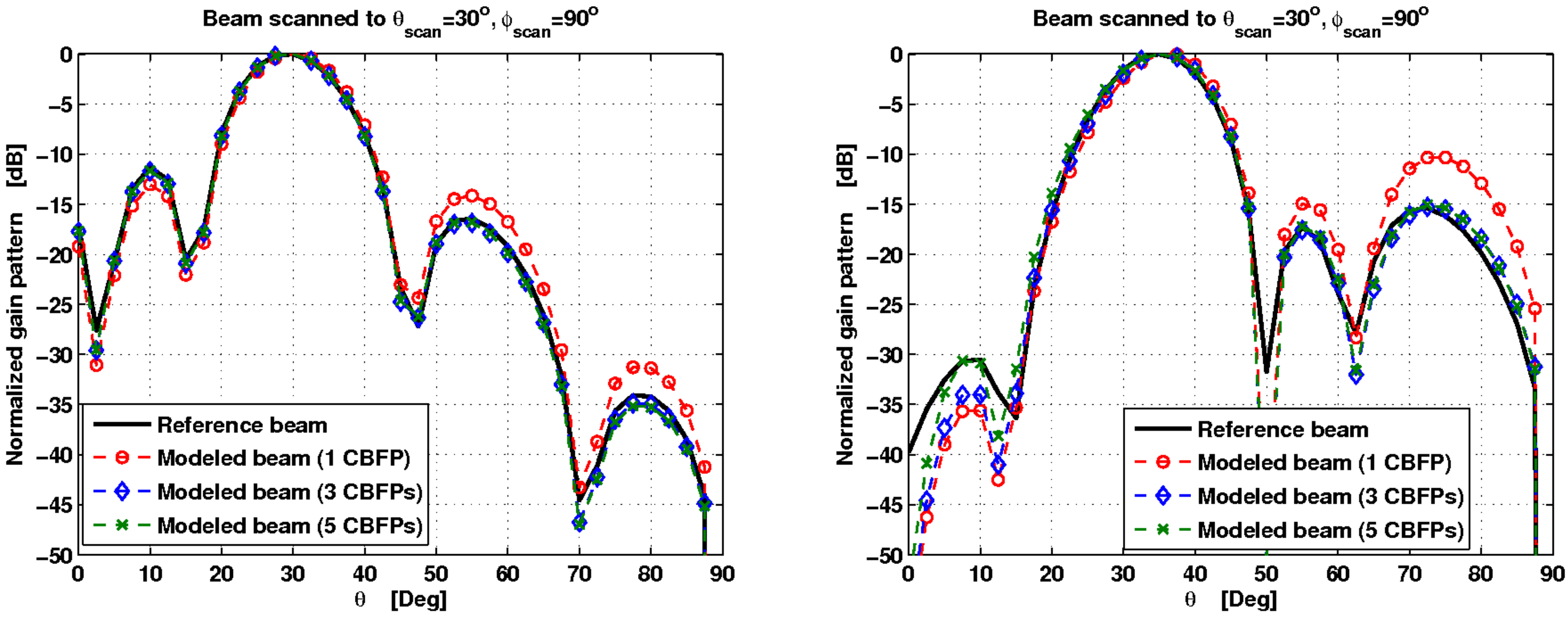
Scenario: 11-elem ULA with impedance mismatch

CBFPs: shifted copies of EEP neighboring elements



Example 2: impedance mismatch (2)

Maaskant et al., IEEE TAP, 2012, in press

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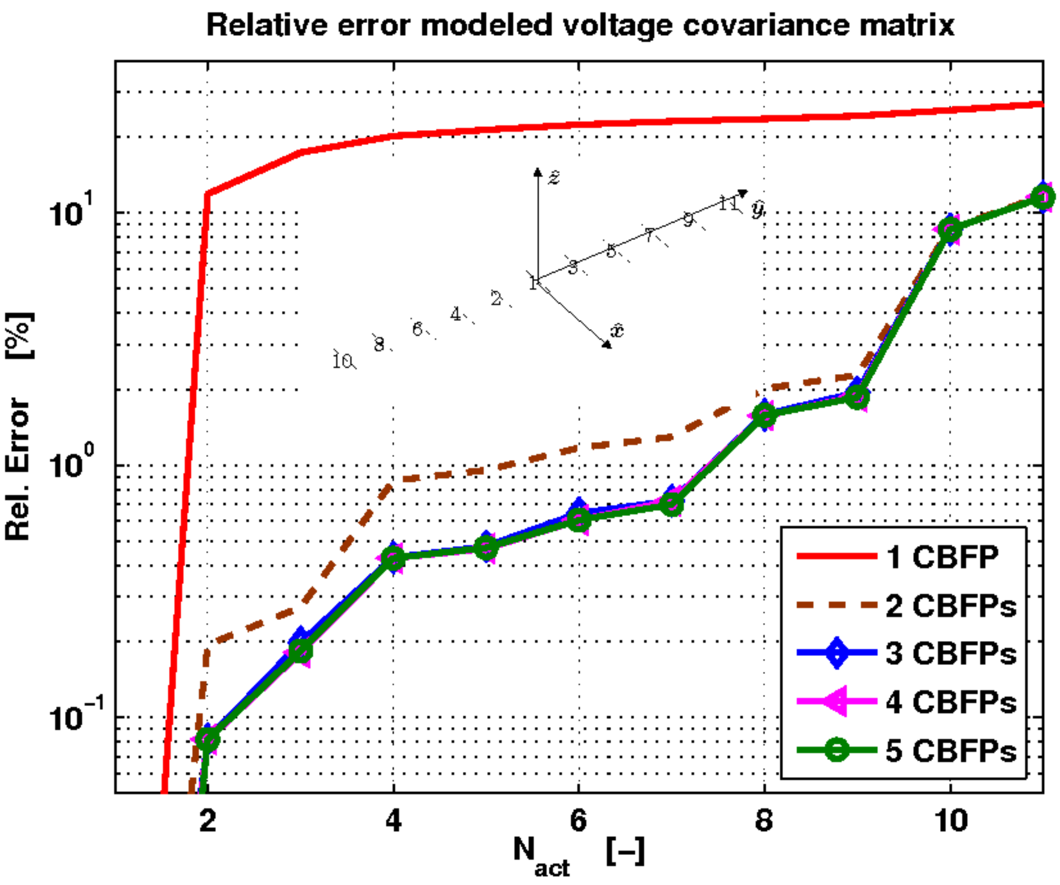
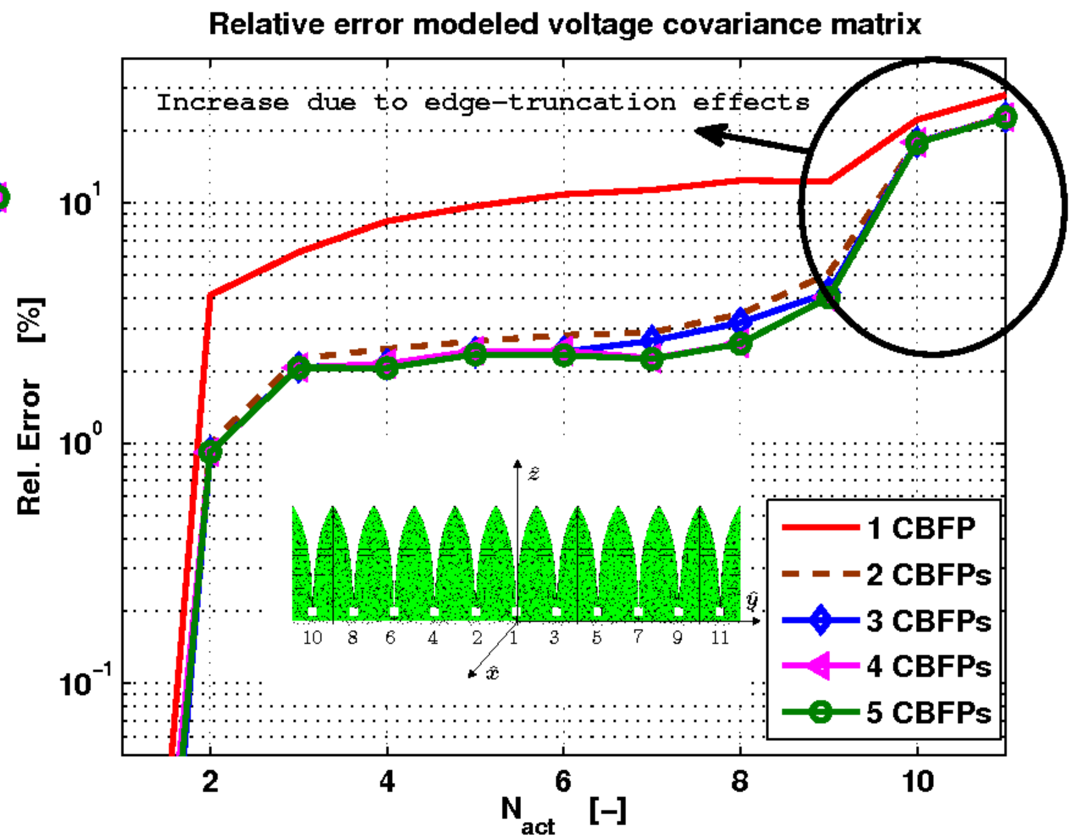
Rel. error as function of #elements used for fitting

11-element dipole array (left) and Vivaldi array (right)





Example 2: impedance mismatch (3)

Maaskant et al., IEEE TAP, 2012, in press

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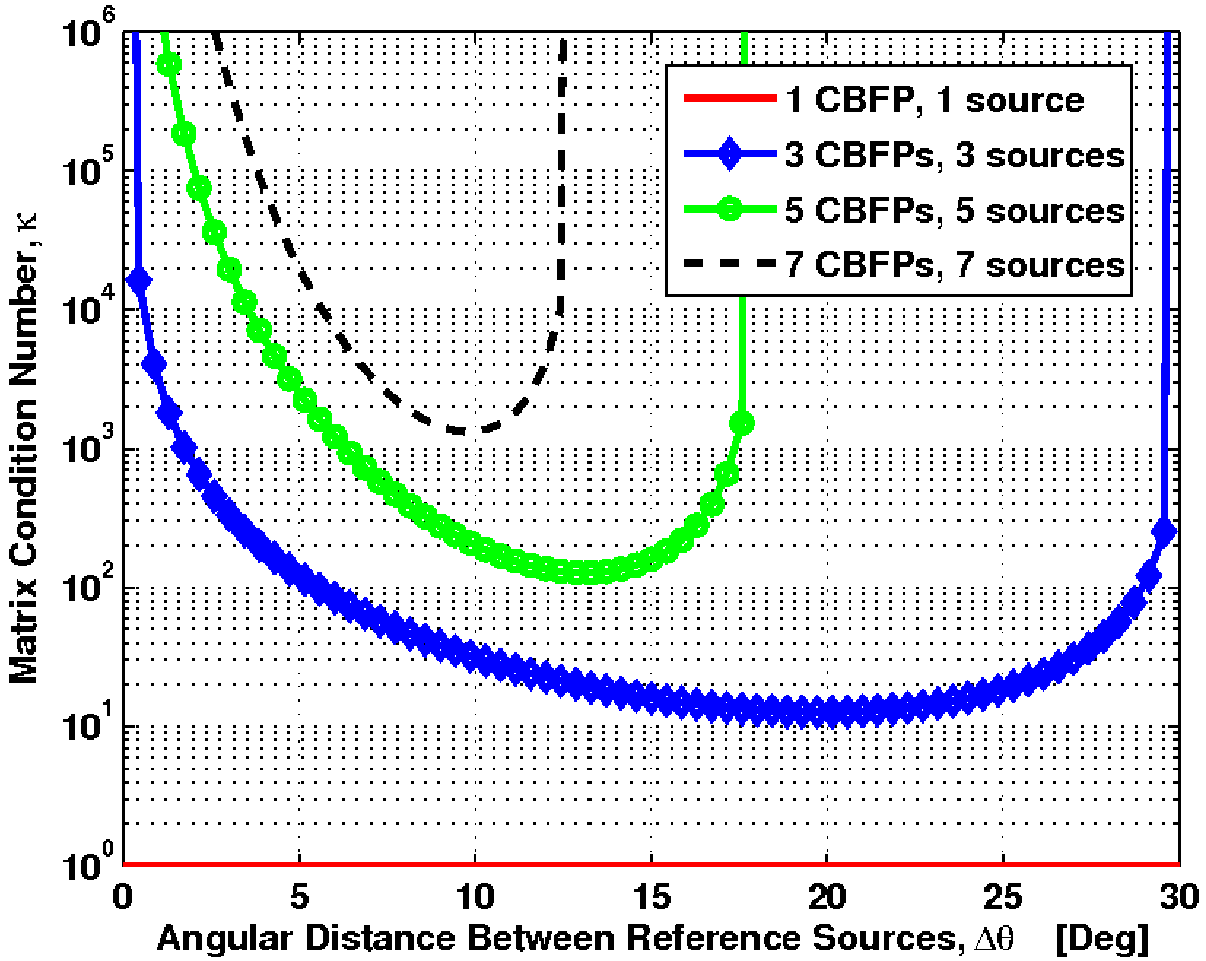
Analysis of reconstructability: condition number as function of #CBFPs and angular separation



Future work

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- **Definition of scenarios**
  - CBFPs should describe deviations in array
- **Dealing with phase / unitary ambiguity**
  - non-unique solution for coefficients
  - use of reference antenna?
  - **however:** power patterns seem accurate
- **Algorithm optimization**
  - CBFPs as superposition of basis functions (instead of tabulation)
  - sparse reconstruction with multiple dictionaries

Conclusions

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Characteristic Basis Function Patterns

- radiation patterns **associated with CBFs**
- **precomputed** based on specific scenarios
- provide **efficient description** of beam pattern