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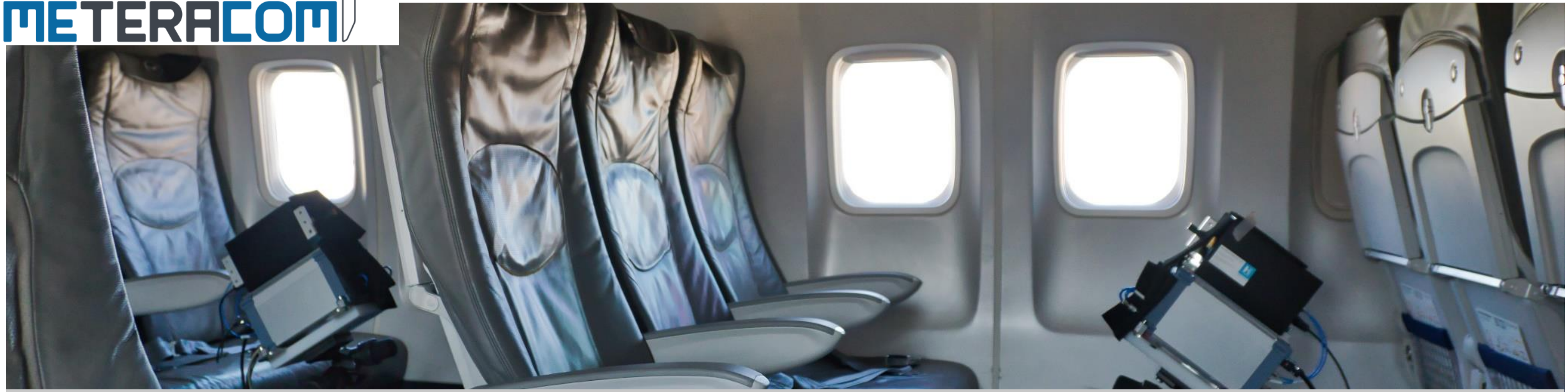

Calibration and Verification of Multidimensional Channel Sounder for THz Applications

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Goal and Motivation

Goal
- Realize an OTA artifact

Purpose
- Test the calibration of a channel sounder
- Test resolution capabilities of a channel sounder
- Validate the performance of its full chain (i.e., hardware and signal processing)

Features
- OTA to include the antennas
- Designed to generate multipath components with **varying** directions, delay times and (Doppler shifts)

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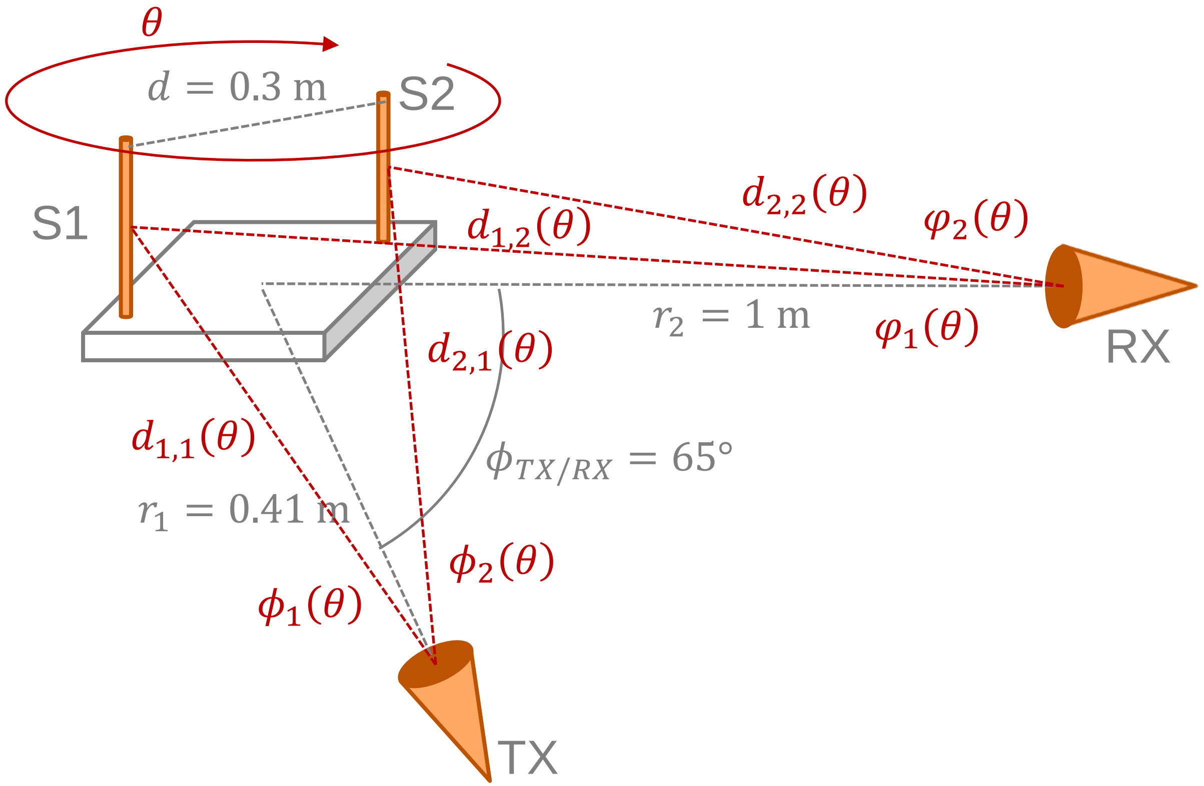
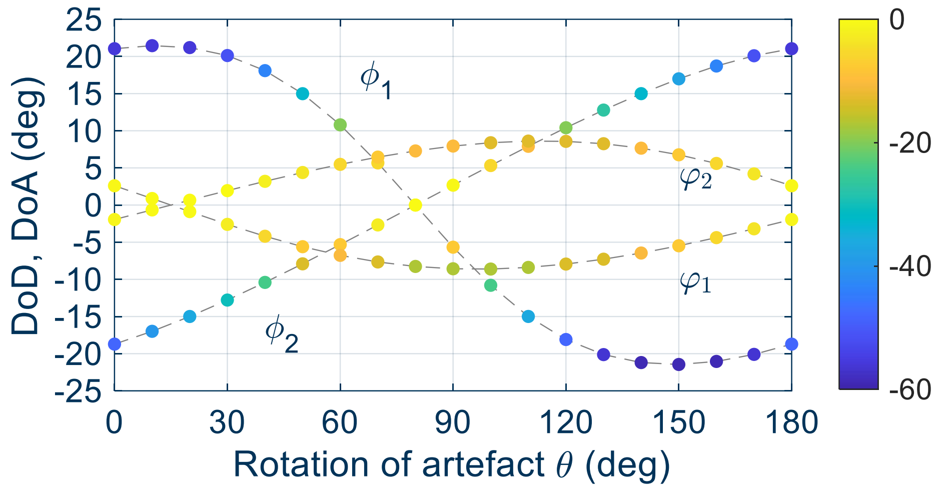
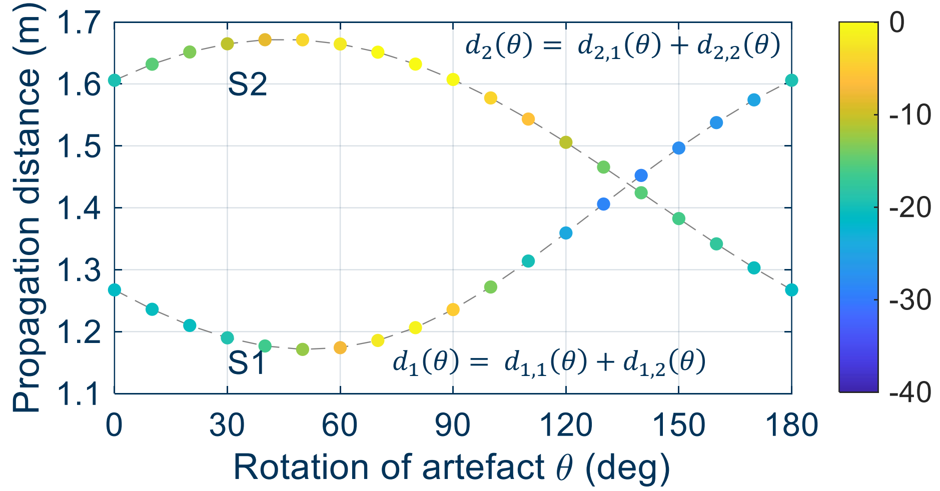
OTA Multipath Artifact and Ground Truth







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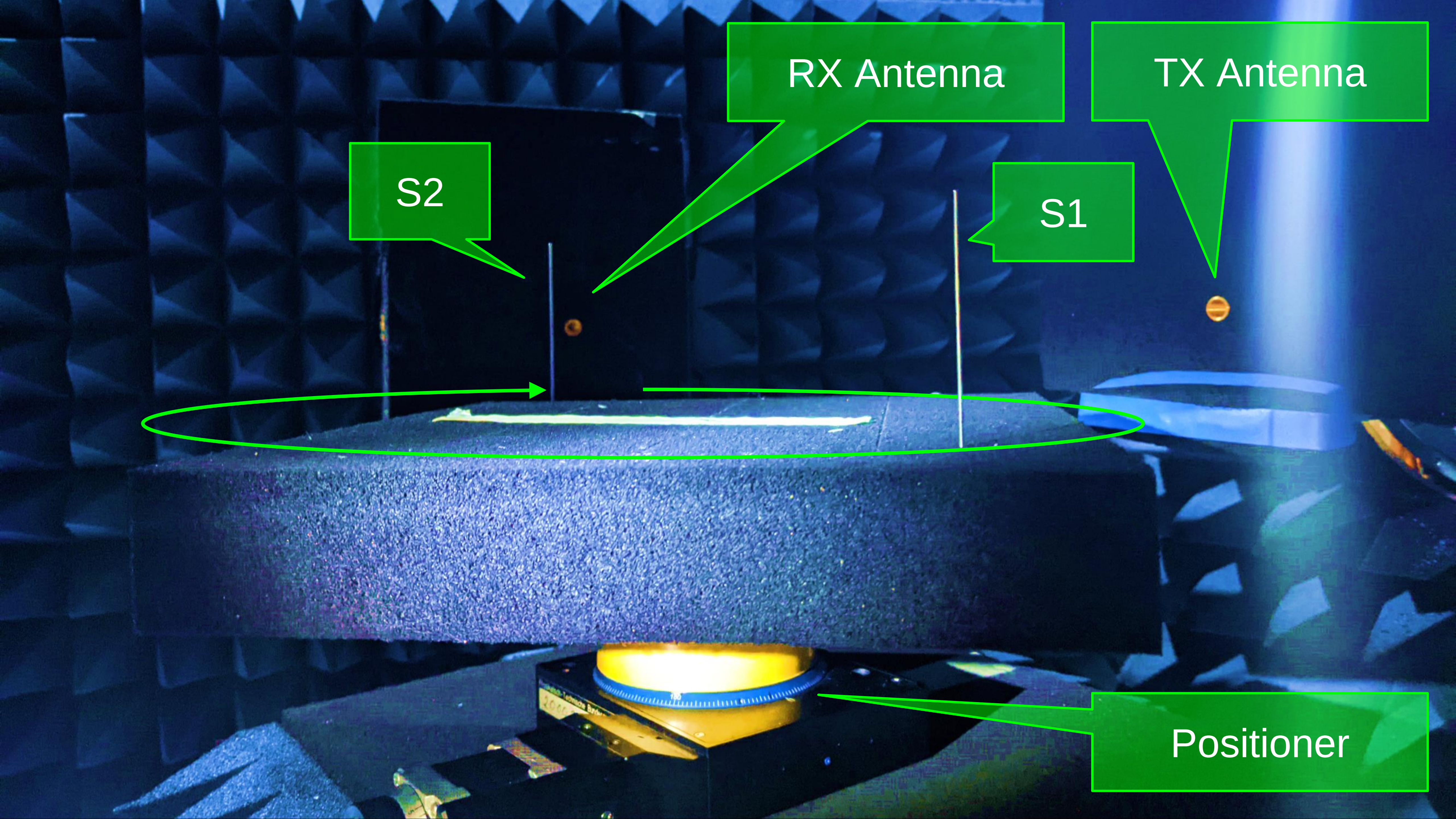

RX Antenna
TX Antenna
S2
S1
Positioner

TUIL Dual-polarized UWB THz Channel Sounder

Baseband

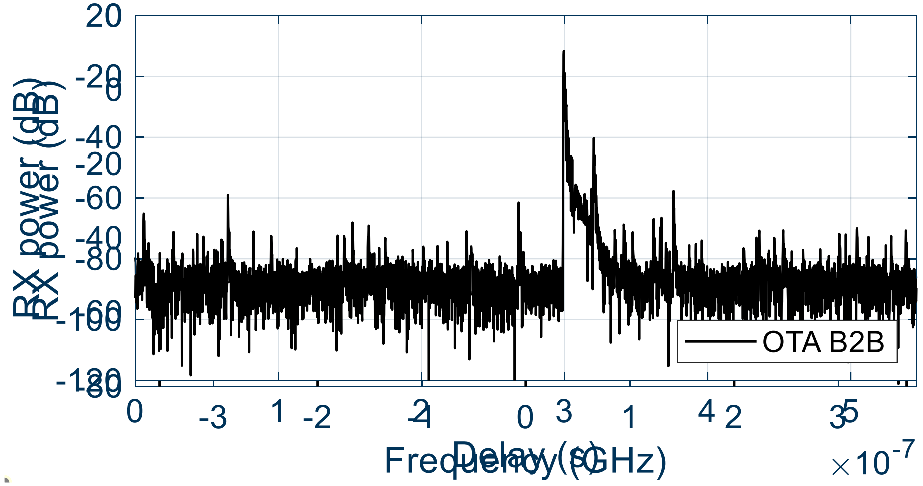
- UWB 12-bit MLBS M-Sequence baseband units
- **7.5 GHz** bandwidth (null-to-null) → **4 GHz after frequency response calibration**
  - Imperfections (e.g., notch) in the frequency response of the system $H_{OTA}(f)$
  - Spurious peaks in the time domain $h_{OTA}(\tau)$

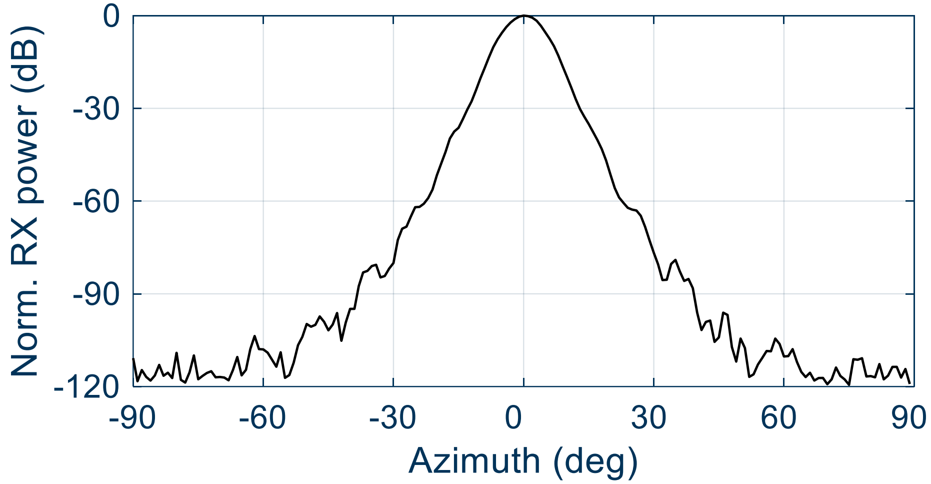
RF

- Up- and Down-converters at 190 GHz
- Two parallel RX channels to simultaneously sample the two polarizations
- A switch at the TX to alternatively transmit the different polarization

Antennas

- Dual-polarized 15° HPBW horn antennas at both sides





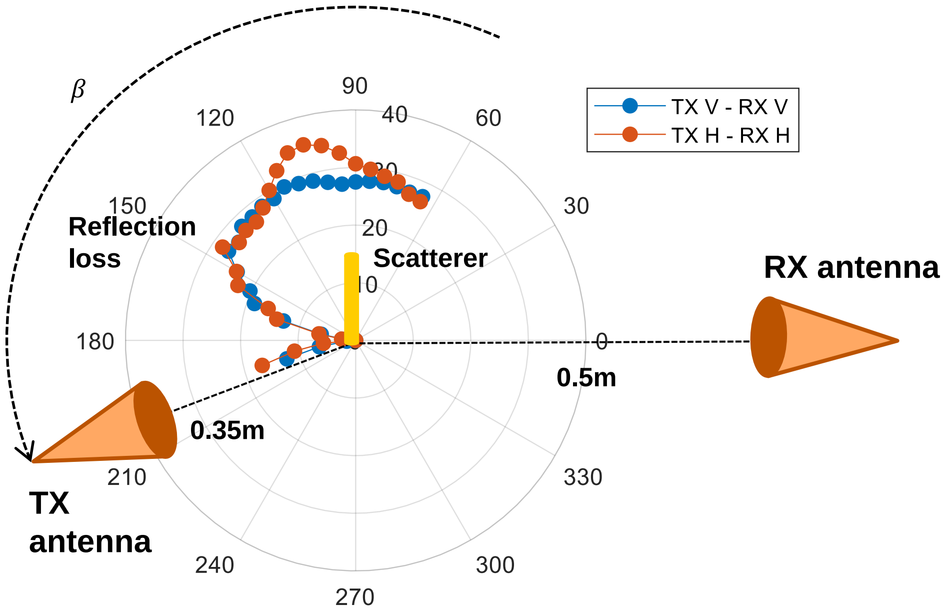
Characterization of the Reference Scatterers

Point scatterer
- Ideal: sphere (polarization independent) → Hard to implement
- Practical: wires (polarization dependent)

Scatterers: metal wires
- 1.5 mm diameter ≈ λ
- 10 cm length

Measurements
- Dual-polarized measurements of the reflection loss of the scatterers
- Illumination angle β changed from 60° to 145°

Results
- Mean reflection loss of approx. 27.5 dB
  - Constant in **vertical polarization**
  - Illuminating angle dependence in horizontal polarization



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Signal Processing and Parameter Estimation

FFT-based processing (non-parametric): peak-detector

- Inherent resolution of the measurement system → Resolution of MPCs depends on the bandwidth
- Sensitive to the quality of the **frequency response calibration** → spurious peaks, side-lobes, etc.

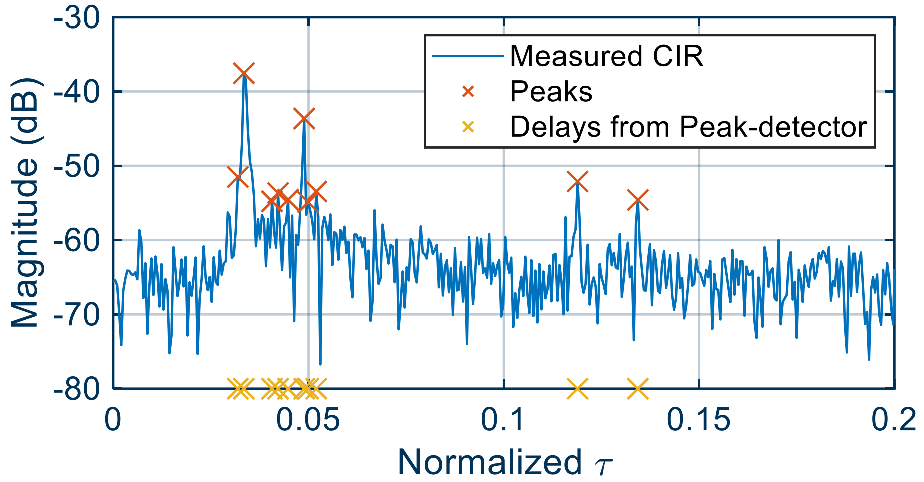
Model-based processing (parametric) → RiMAX

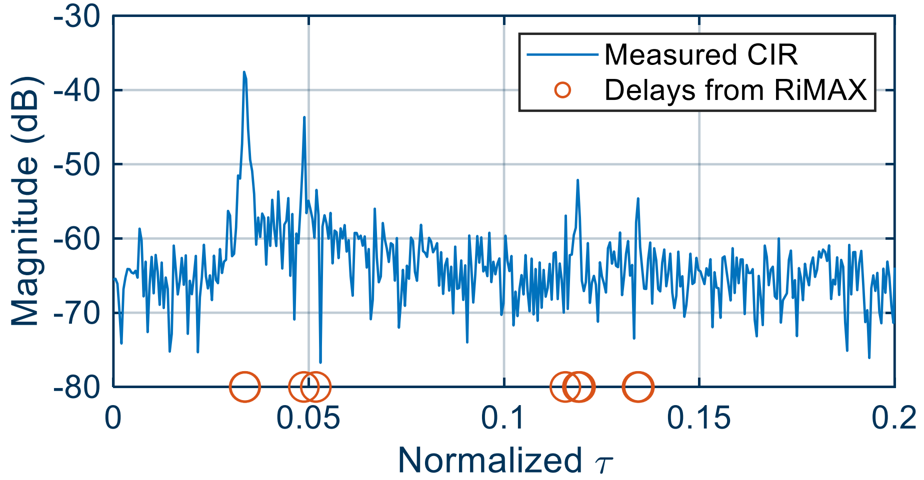
- Modified implementation of RIMAX: **the system frequency response $H_{OTA}(f)$ is incorporated in the data-model $H(f)$**
- Performance depends on the data model

$$\sum_{l=1}^{L} \gamma_l\, \delta(\tau - \tau_l) + n(\tau) \;\rightarrow \sum_{l=1}^{L} \gamma_l\, h_{\mathrm{OTA}}(\tau - \tau_l) + n(\tau) \;\circ\!\!-\!\!\bullet\; H(f)$$

$$H(f) = \sum_{l=1}^{L} \gamma_l\, H_{\mathrm{OTA}}(f) \exp(j2\pi f \tau_l) + n(f)$$

$$\min_{L,\gamma_l,\tau_l,l\leq L} \| H(f) - H_{\mathrm{meas}}(f) \|_2^2$$





Frequency Response Calibration

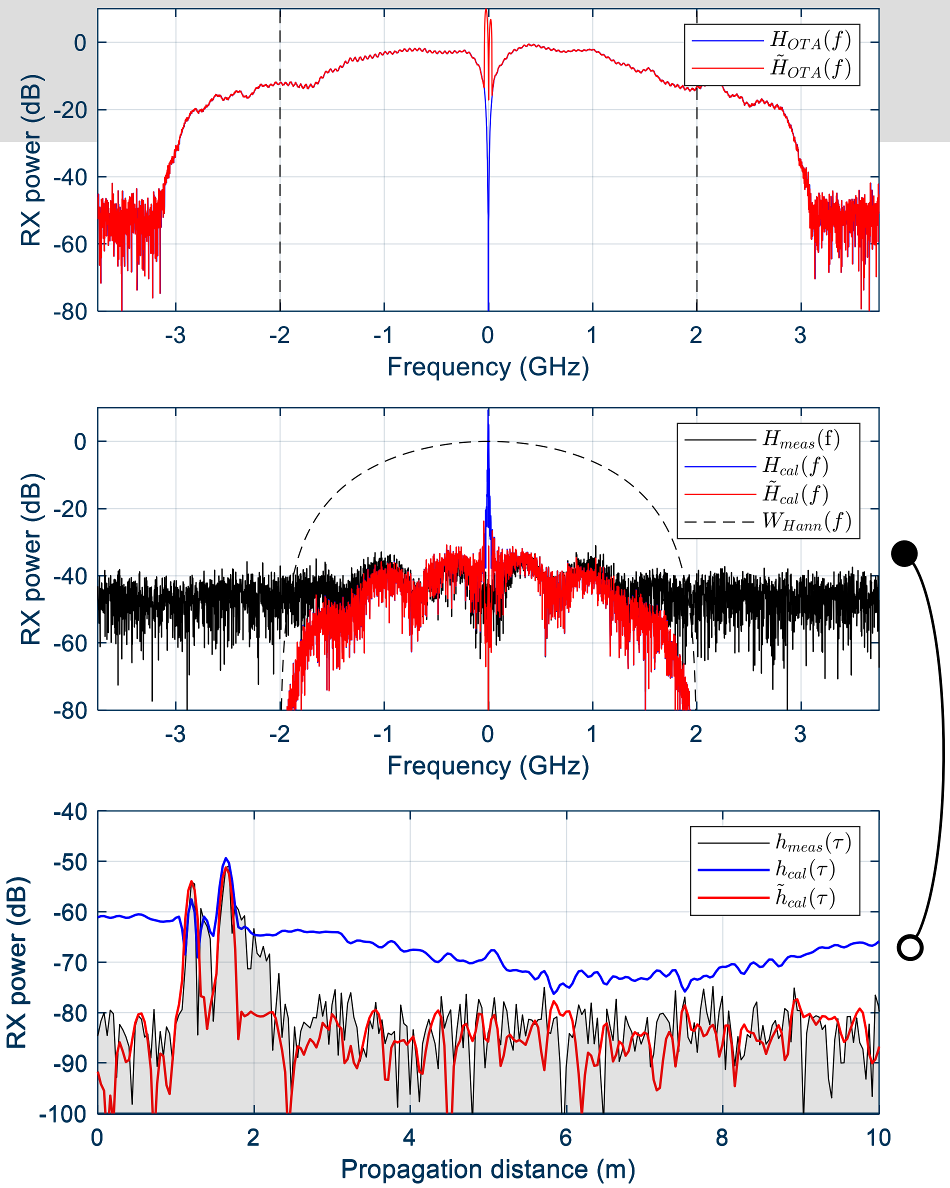
- Calibration by deconvolution carried out in the frequency domain with reference OTA back-to-back frequency response measurement $H_{\mathrm{OTA}}(f)$ in pure LOS (in anechoic chamber at TX – RX distance d_{ref})

- Raw $H_{\mathrm{OTA}}(f)$

$$H_{\mathrm{cal}}(f,\theta) = \frac{H_{\mathrm{meas}}(f,\theta)}{H_{\mathrm{OTA}}(f)} \exp\left(-j2\pi f \frac{d_{\mathrm{ref}}}{c_0}\right) W(f) \bullet\!\!-\!\!\circ \; h_{\mathrm{cal}}(\tau,\theta)$$

- Spline interpolated $\tilde{H}_{OTA}(f)$ (to minimize the effects of the notch)

$$\tilde{H}_{\mathrm{cal}}(f,\theta) = \frac{H_{\mathrm{meas}}(f,\theta)}{\tilde{H}_{\mathrm{OTA}}(f)} \exp\left(-j2\pi f \frac{d_{\mathrm{ref}}}{c_0}\right) W(f) \bullet\!\!-\!\!\circ \; \tilde{h}_{\mathrm{cal}}(\tau,\theta)$$



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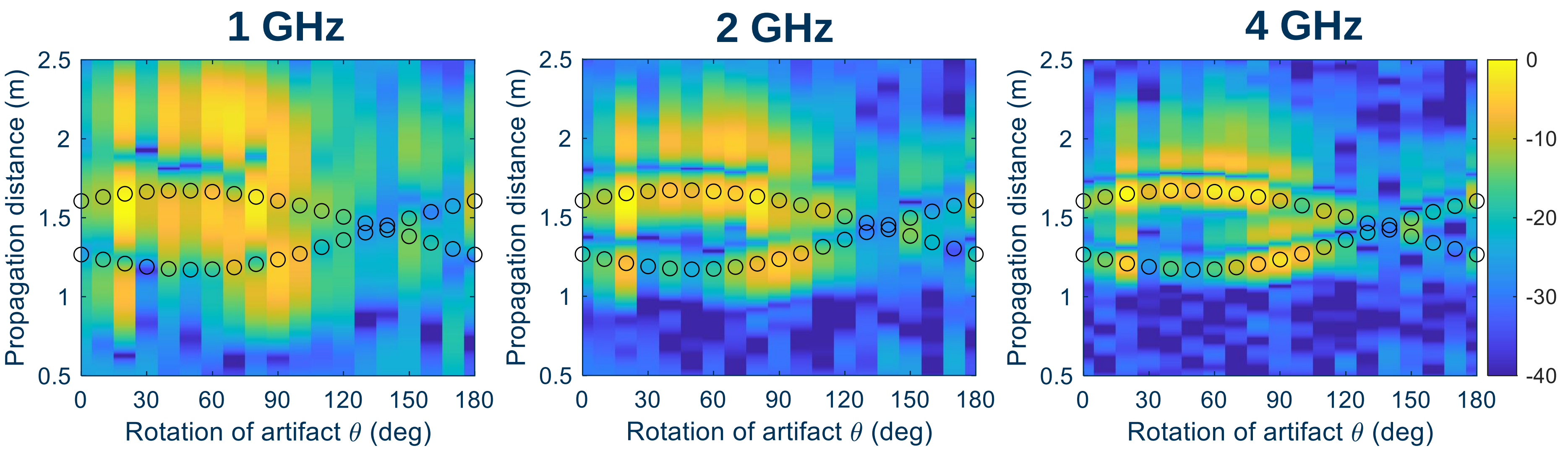
Raw Measurements

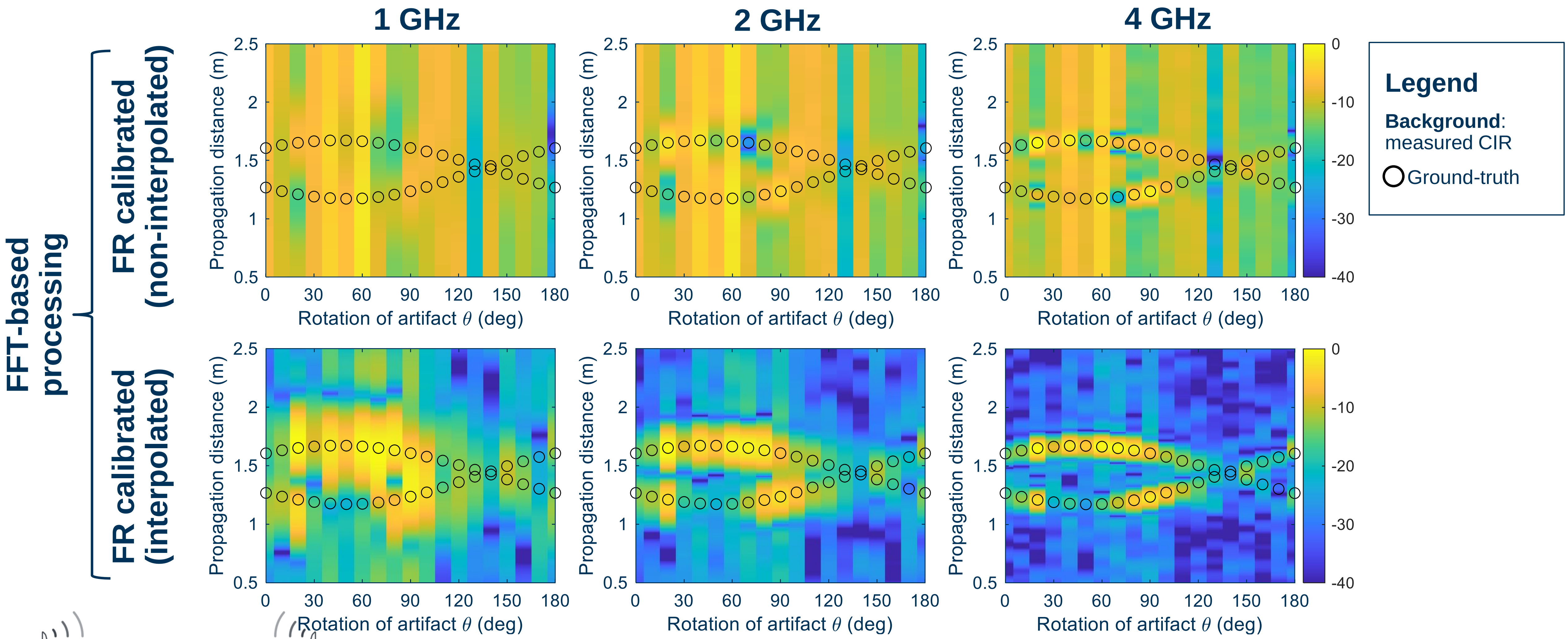


Legend

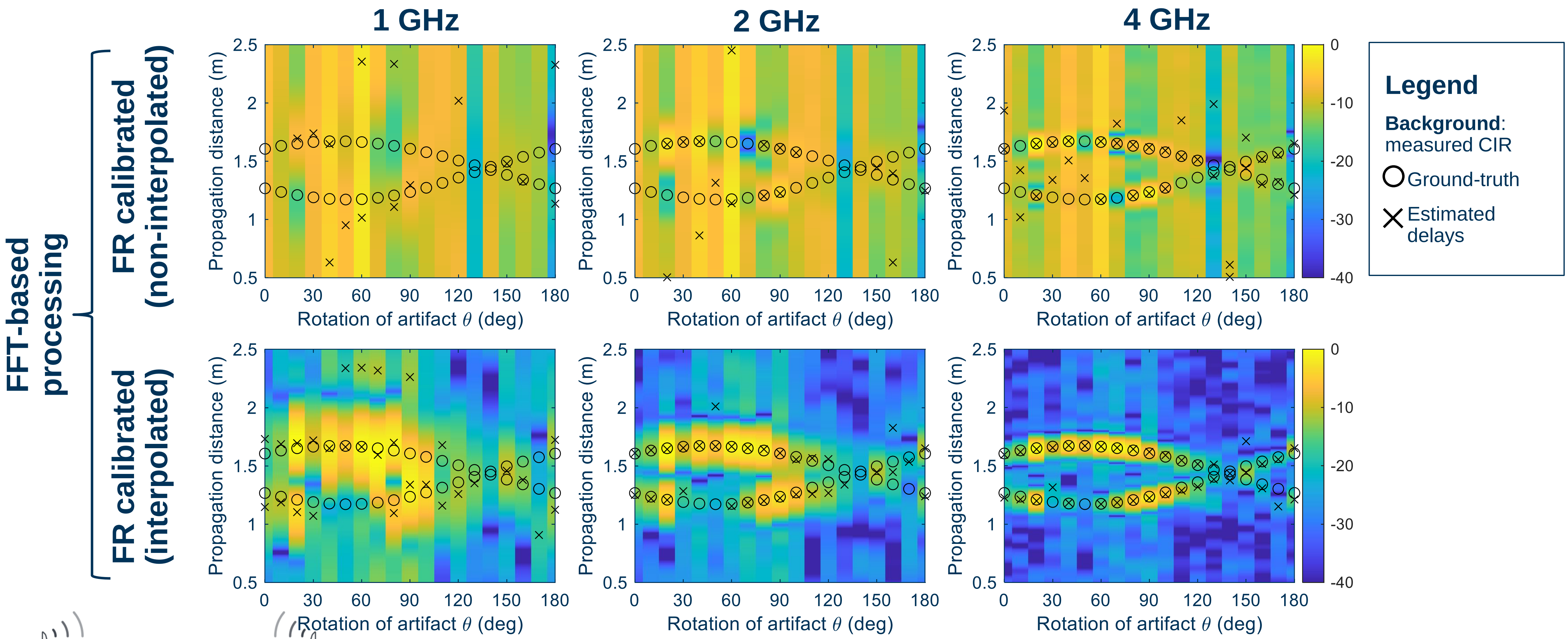
Background: measured CIR

○ Ground-truth

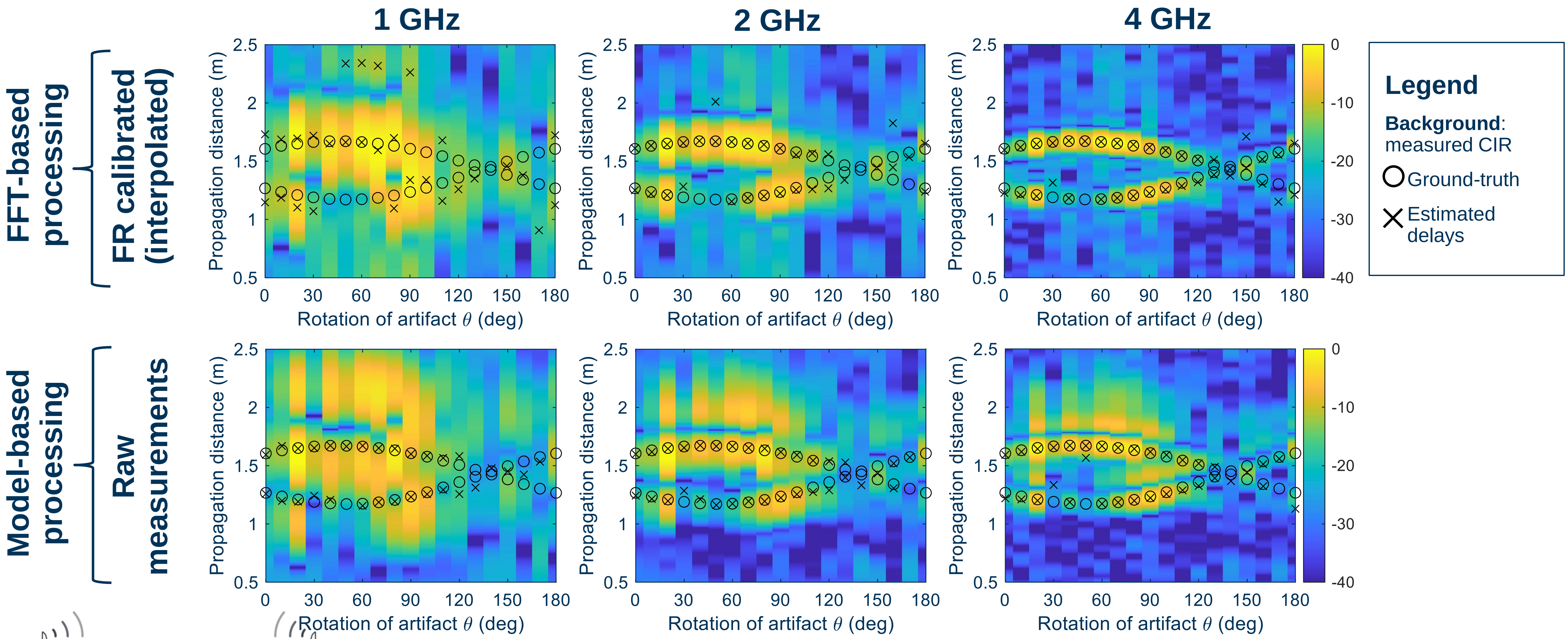
Verification of the FR Calibration



FFT-based Estimation: Peak Detector



FFT-based and Model-based Estimation



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Conclusions

OTA multipath artifact

- Can be used to test the channel sounder calibration and validate its performance

FFT-based processing (non-parametric)

- Very sensitive to the frequency response calibration
- Resolution highly depends on the measurement bandwidth

Model-based (parametric estimation)

- More accurate
- Less sensitive to bandwidth

Future work

- Extension to Doppler and DoA/DoD

Thank you very much for your Attention

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