IGG

UNIVERSITÄT BONN

EUREF AC Workshop 2019

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GNSS antenna calibration in the anechoic chamber

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presented by: Christof Völksen

Key points and questions

- **Brief description of the calibration procedure**
- **Precision/accuracy of chamber calibrations?**
- **Consistency between chamber and robot calibrations?**
- **Precision/accuracy of chamber type-means?**

The anechoic chamber

- Designed and established during PhD of Philipp Zeimetz (2010)

  ‚Zur Entwicklung und Bewertung der absoluten GNSS-Antennenkalibrierung im HF-Labor‘

  DGK-Reihe C, Nr. 682, München 2012

- Cooperation with District Government Cologne (Geobasis NRW)

  GEObasis.nrw Bezirksregierung Köln

  ⟹ Responsible for parts of the German SAPOS network (*www.sapos.de*)

Currently…

- one member of technical staff in charge of antenna calibrations (amongst other things)
- no member of scientific staff involved in chamber calibrations
- no scientific research in the field of antenna calibration

The anechoic chamber

Chamber calibrations used by IGG for:

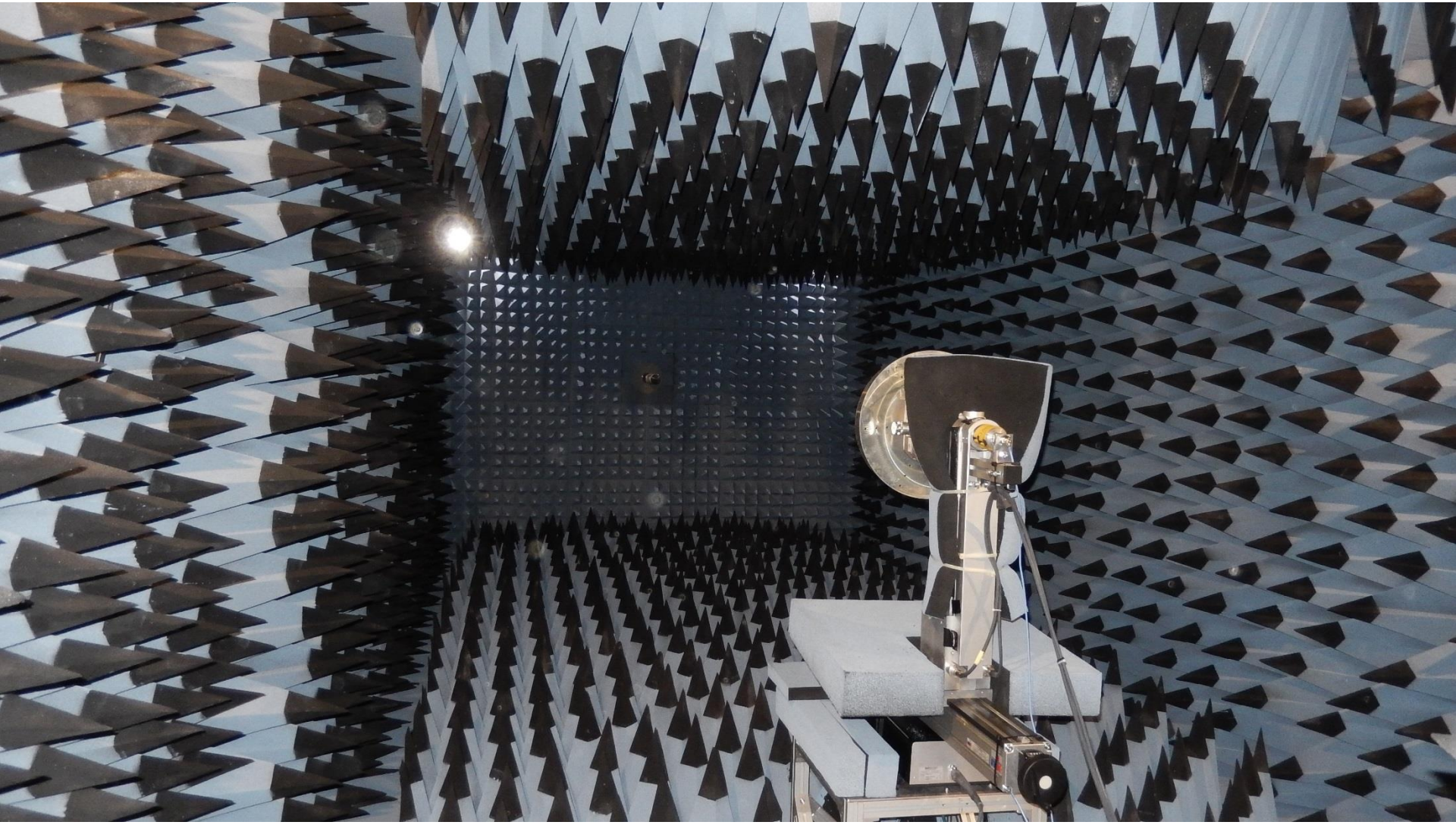
– High-precision static and kinematic short baseline applications (<1km)
  – Accuracy requirements at a few millimeters to submillimeter range

– Experimental calibrations

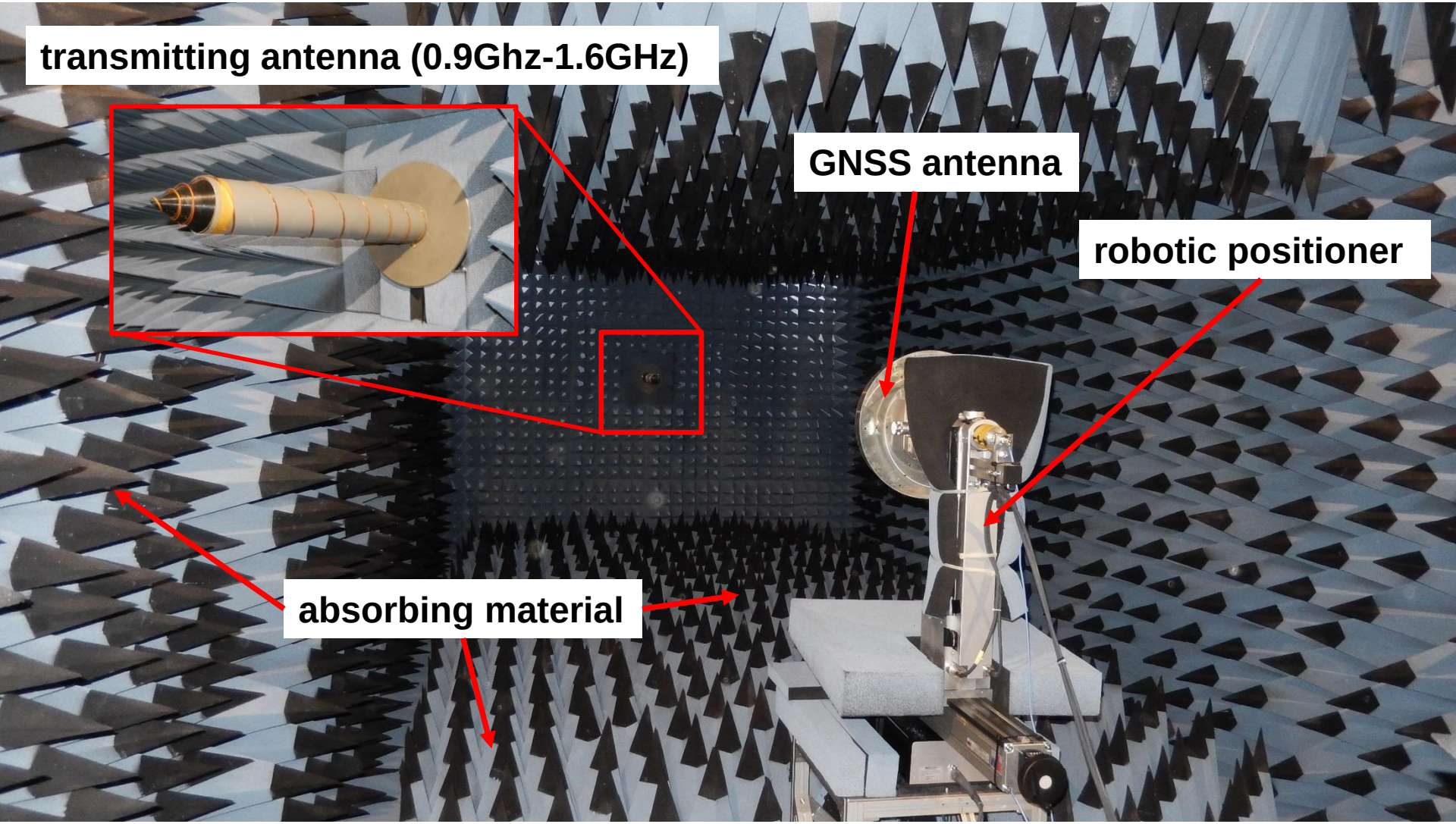
Chamber calibrations used by District Government for:

– SAPOS permanent station network
  – Accuracy requirements 5mm horizontal, 8mm vertical

The anechoic chamber

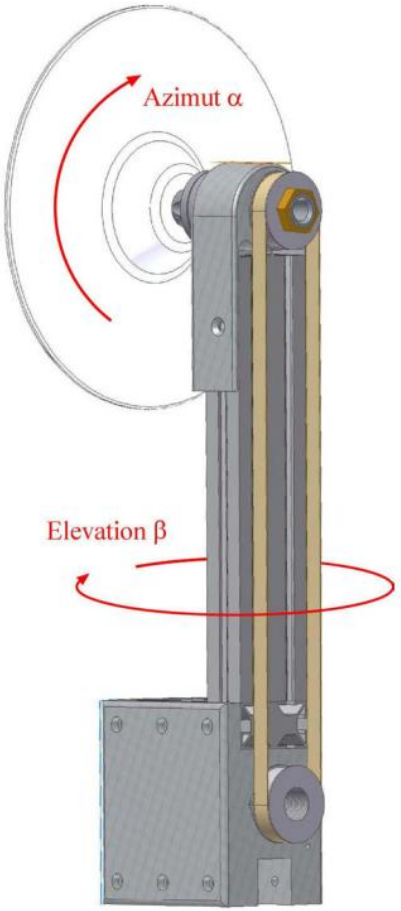


The anechoic chamber



Calibration procedure

- **Network analyzer (NWA)** performs frequency sweap between 1.15GHz and 1.65GHz (sinusoidal signal)
- **Signal is attenuated** by 30-40dB to avoid an overload of the amplifier in the receiving antenna
- **NWA measures phase shift** of received signal at every antenna position
- **Antenna is rotated** in 5 degree steps in elevation and azimuth
  1. Elevation 0° ⟹ azimuth 0°…360°
  2. Elevation 5° ⟹ azimuth 0°…360°
  3. …

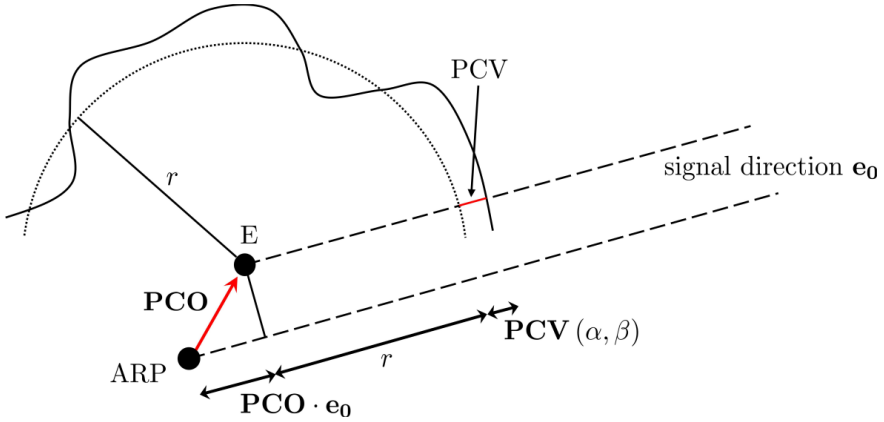


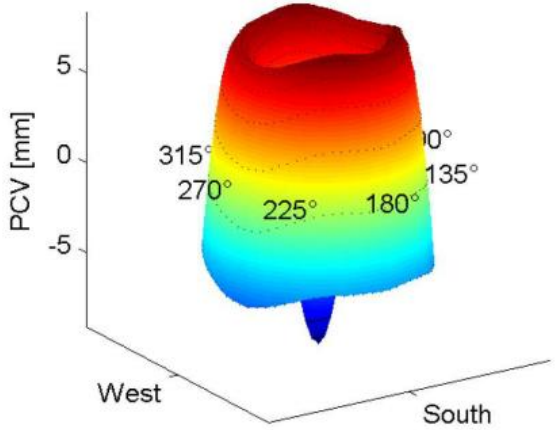
Calibration procedure

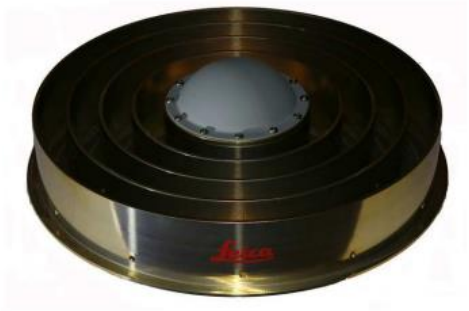
– sphere fit to NWA measurements

➡ center of sphere defines **PCO**

➡ residuals to fitted sphere define **PCV**







Calibration procedure

Pros

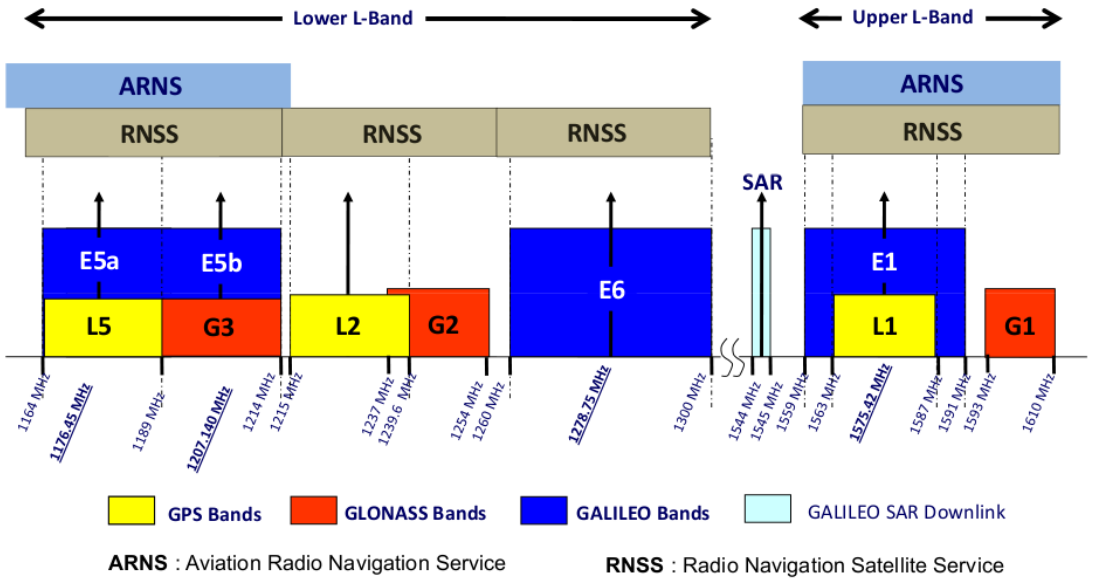
– GNSS frequency spectrum completely available

– fast calibration procedure

⇒ duration ≈ 1-2 hours

– not influenced by atmospheric effects or satellite errors

– ‚controlled' measurement environment



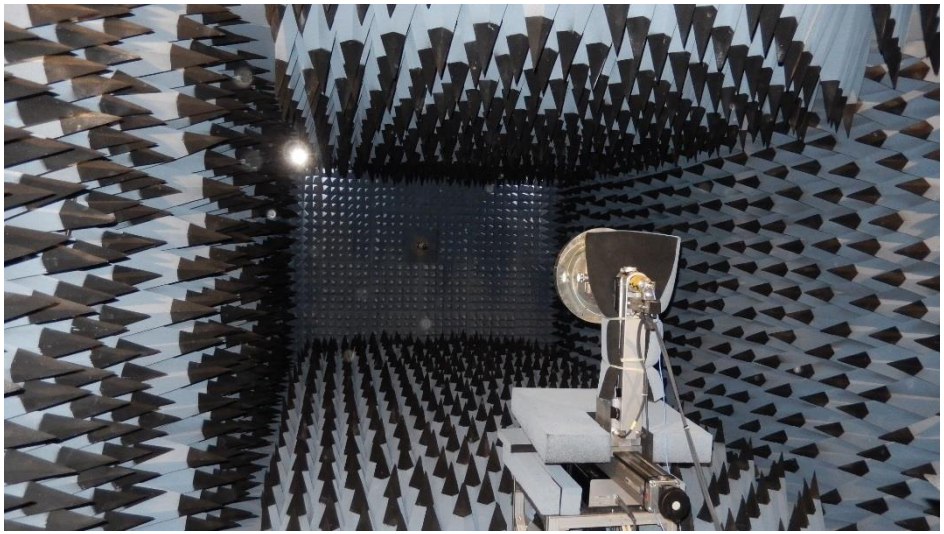
Calibration procedure

Cons

– Assumption of a parallel wave front

⇒ short distance between transmitting and receiving antenna (≈ 6.5m)

⇒ theoretically fulfilled



– absorbers perfectly working?

⇒ no influence of reflected signals?

⇒ effectivity depends on incidence angle

– Identification of systematic errors extremely difficult

– common ‚near-field' problem

Key points and questions

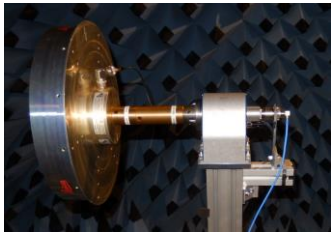
- Brief description of the calibration procedure
- **Precision/accuracy of chamber calibrations?**
- Consistency between chamber and robot calibrations?
- Precision/accuracy of chamber type-means?

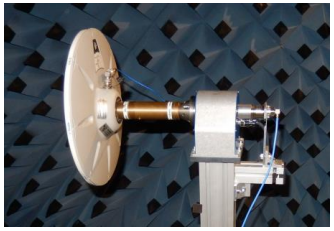
Precision of chamber calibration patterns

How accurate/precise are chamber calibration patterns?

Antenna 1: TRM55971.00_NONE (24 repeated calibrations)

Antenna 2: LEIAT504GG_NONE (8 repeated calibrations)





Analysis:

– Determination of PCC (phase center corrections) for each antenna and calibration pattern

$$PCC\,(\alpha,\beta) = \mathbf{PCO}\cdot\mathbf{e_0}\,(\alpha,\beta) + PCV\,(\alpha,\beta)$$

– Determination of standard deviations $\sigma_{PCC}\,(\alpha,\beta)$ for each antenna

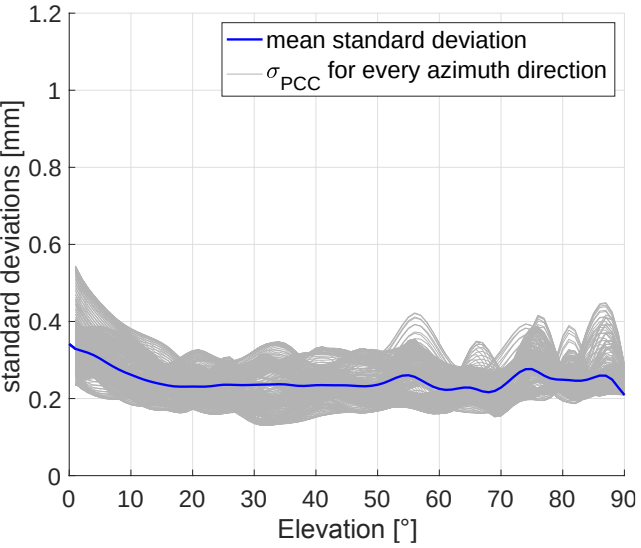
– Results for frequencies

- G01 (1575.42 MHz) ⟹ identical to E01/S01/J01
- G02 (1227.60 MHz) ⟹ identical to J02
- G05 (1176.45 MHz) ⟹ identical to E5a/S05/J05/I05

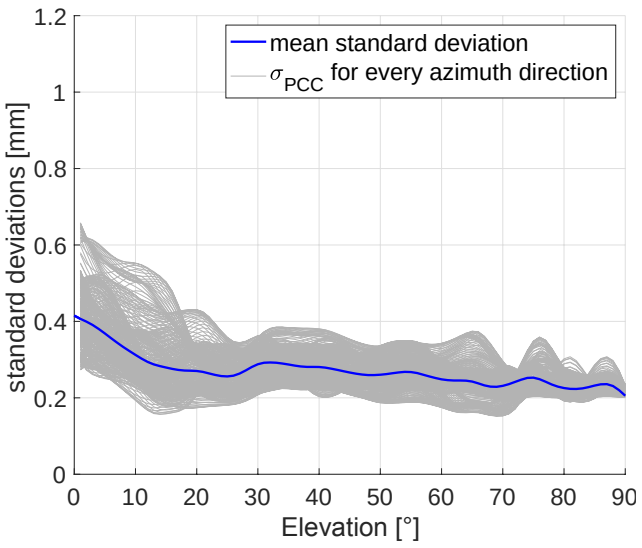
Precision of calibration patterns

(TRM55971.00_NONE - 24 calibrations)

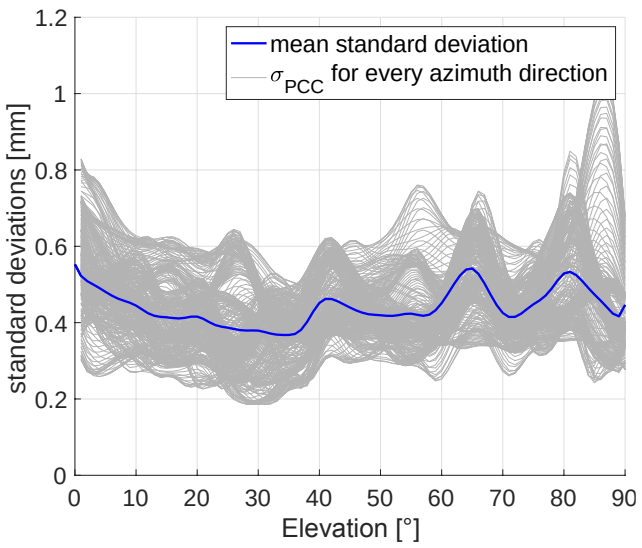
G01 (1575.42 MHz)

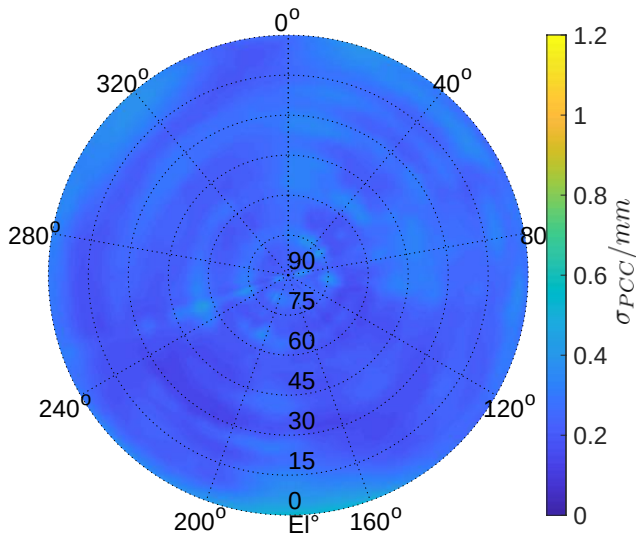


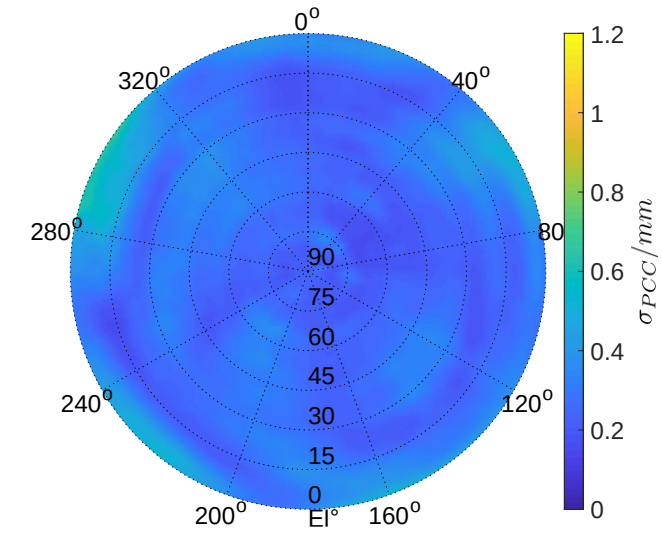
G02 (1227.60 MHz)

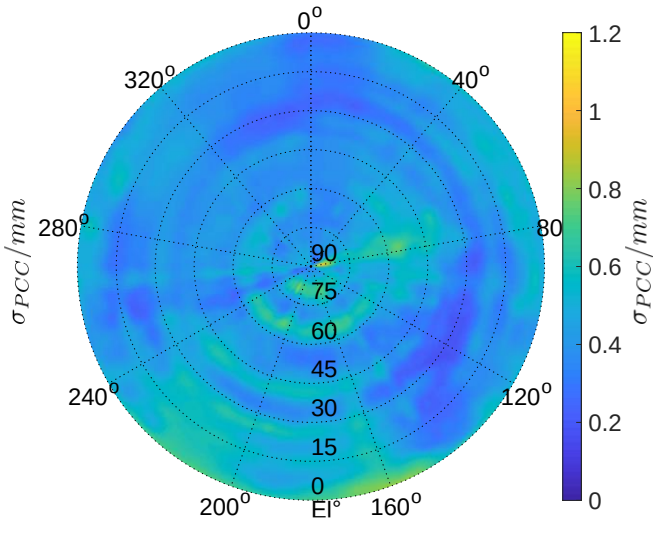


G05 (1176.45 MHz)





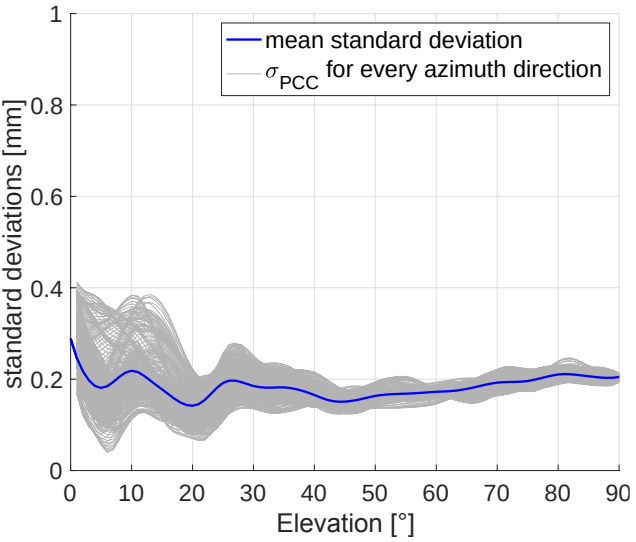


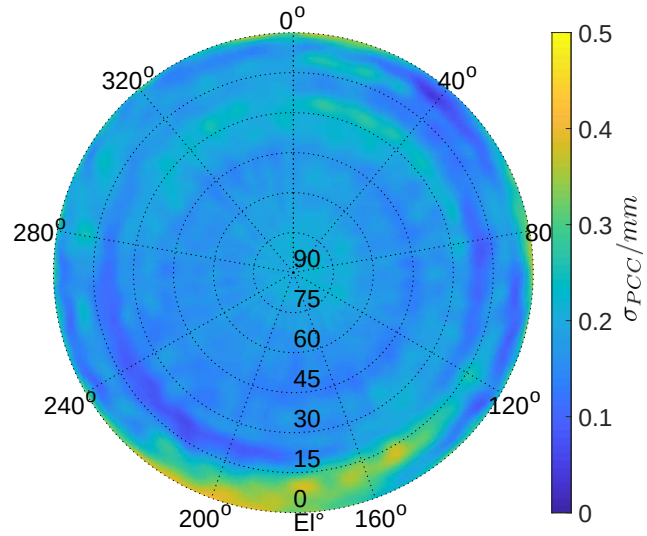


Precision of calibration patterns

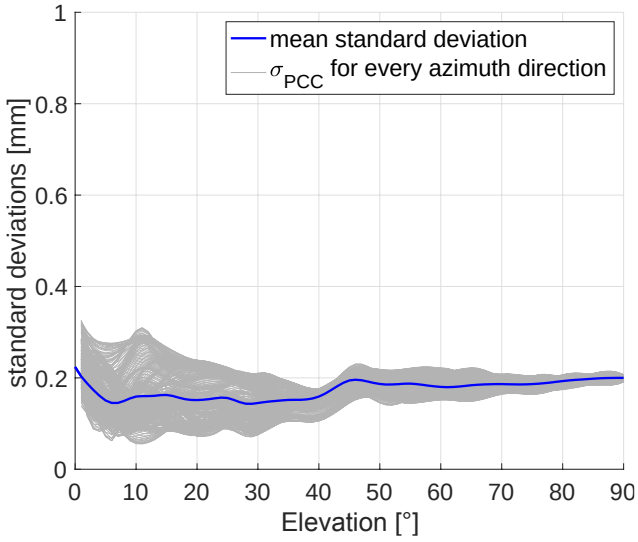
(LEIAT504GG_NONE - 8 calibrations)

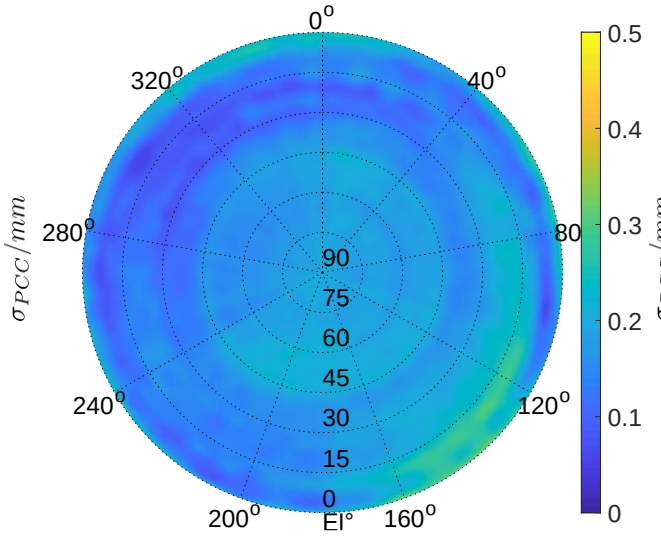
G01 (1575.42 MHz)



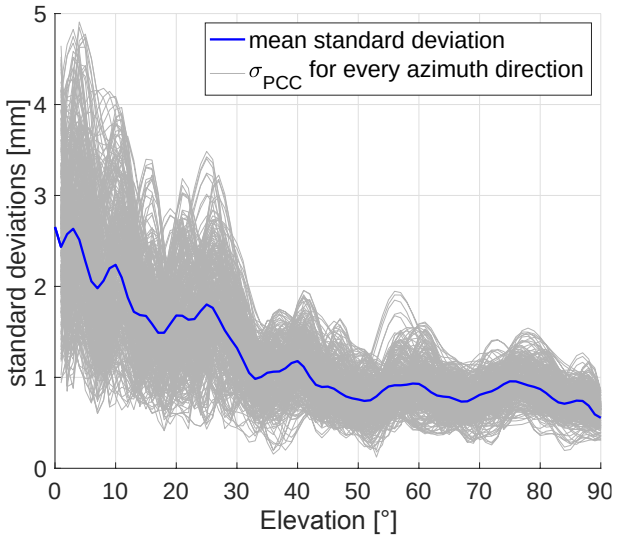


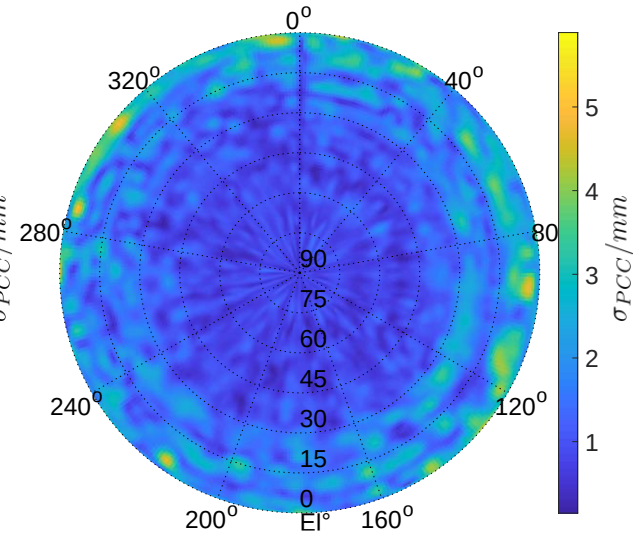
G02 (1227.60 MHz)





G05 (1176.45 MHz)

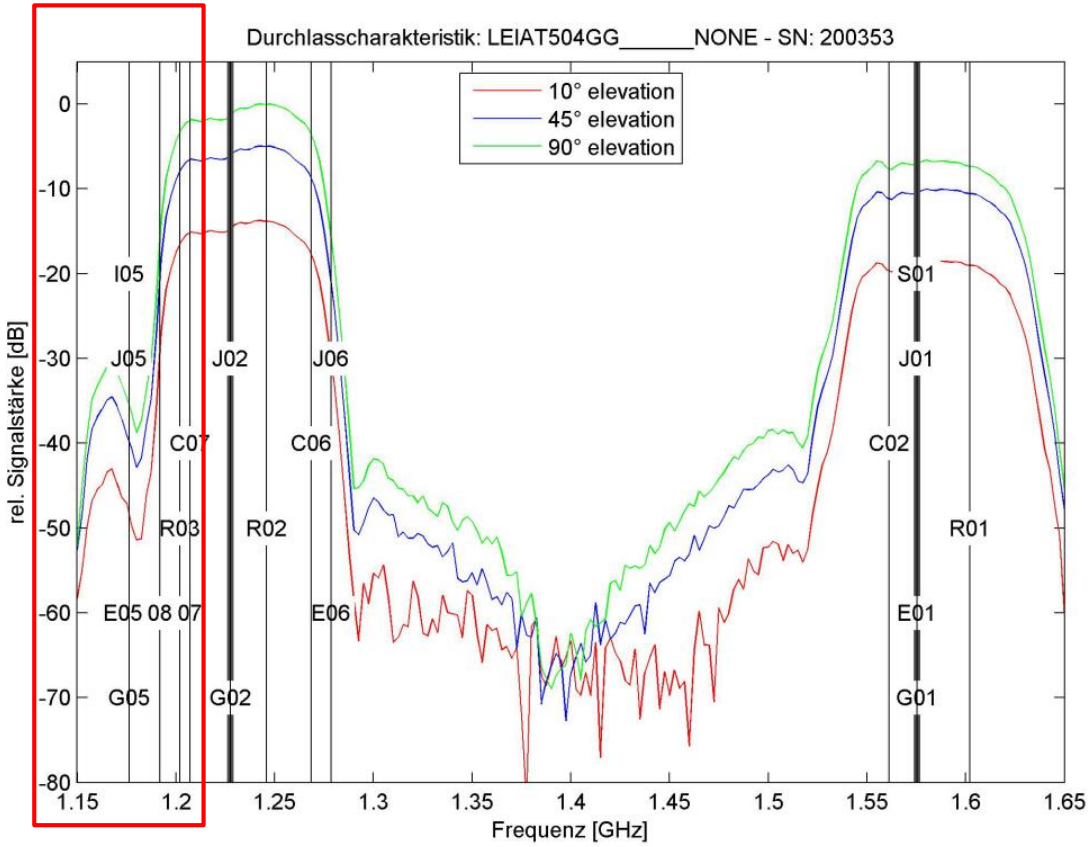




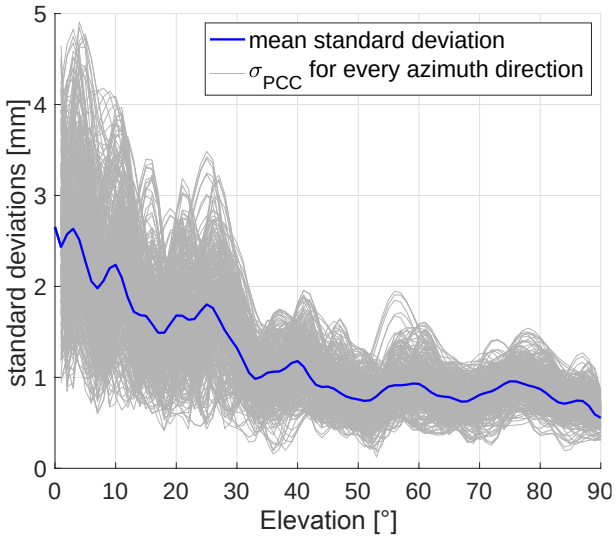
Precision of calibration patterns

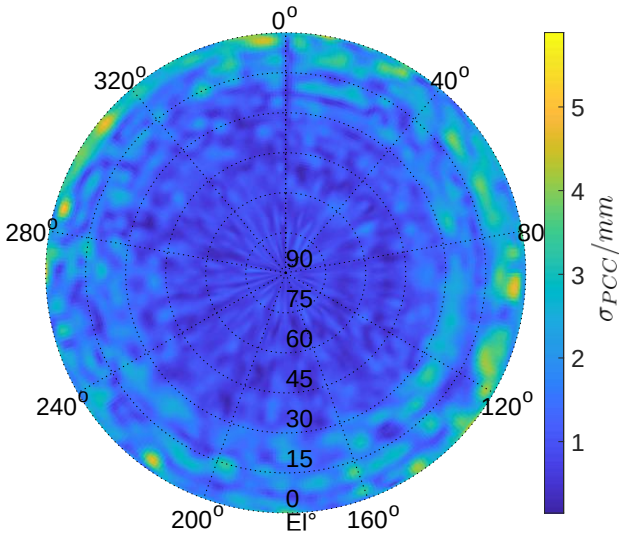
(LEIAT504GG_NONE - 8 calibrations)

G05 frequency attenuated due to transmission characteristics of antenna



G05





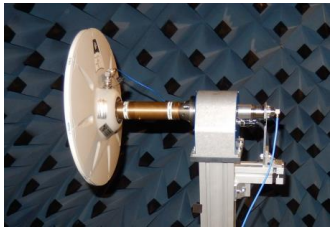
Key points and questions

- Brief description of the calibration procedure
- Precision/accuracy of chamber calibrations?
- **Consistency between chamber and robot calibrations?**
- Precision/accuracy of chamber type-means?

Chamber vs robot calibration

Consistency between robot and chamber calibration patterns?

Antenna: TRM55971.00_NONE



Individual antenna calibrations available from

– Geo++ (robot)

– IfE Hannover (robot)

– IGG (chamber)

Analysis:

– Determination of PCCs for every calibration pattern

– Determination of PCC differences $\Delta PCC\,(\alpha, \beta)$

– Results for frequencies

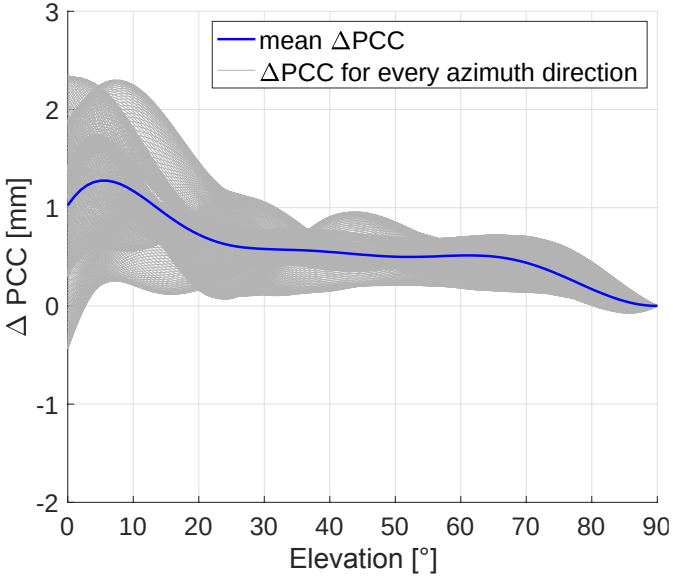
  – G01 (1575.42 MHz)

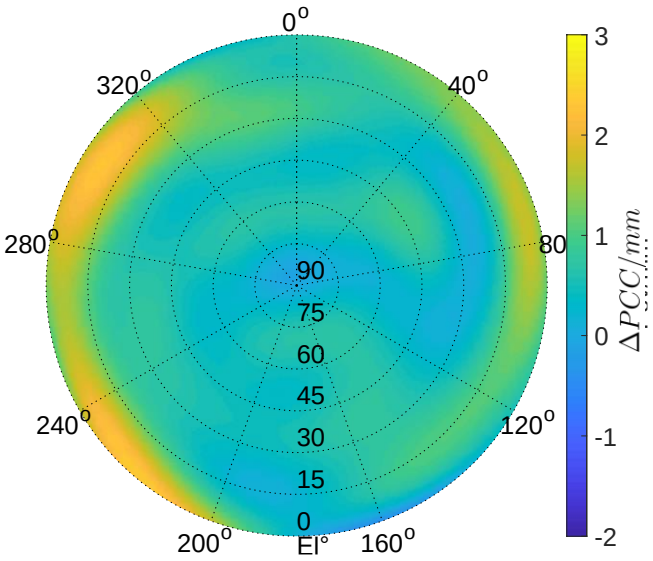
  – G02 (1227.60 MHz)

robot (Geo++) vs. robot (IfE)

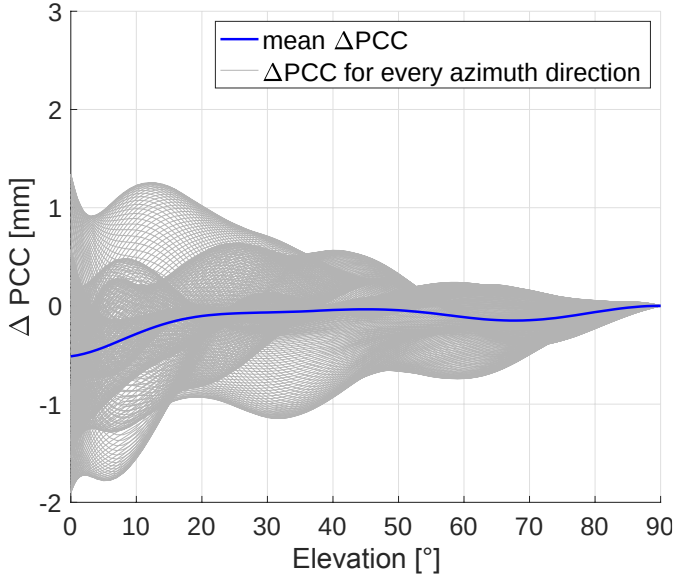
(TRM55971.00_NONE)

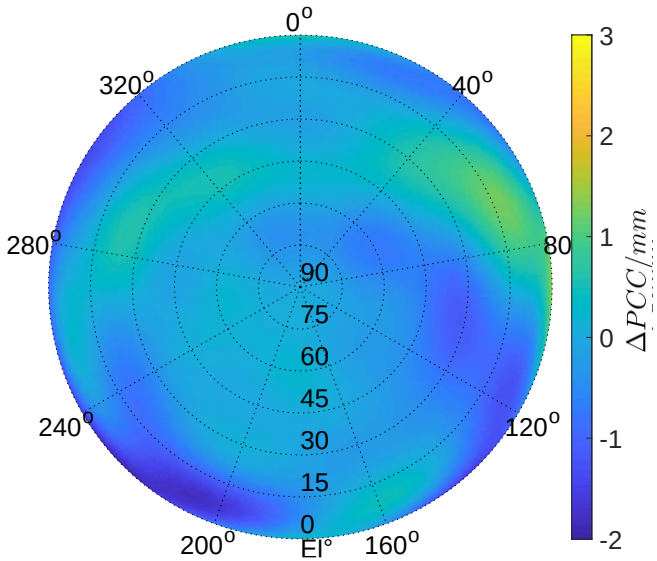
G01





G02

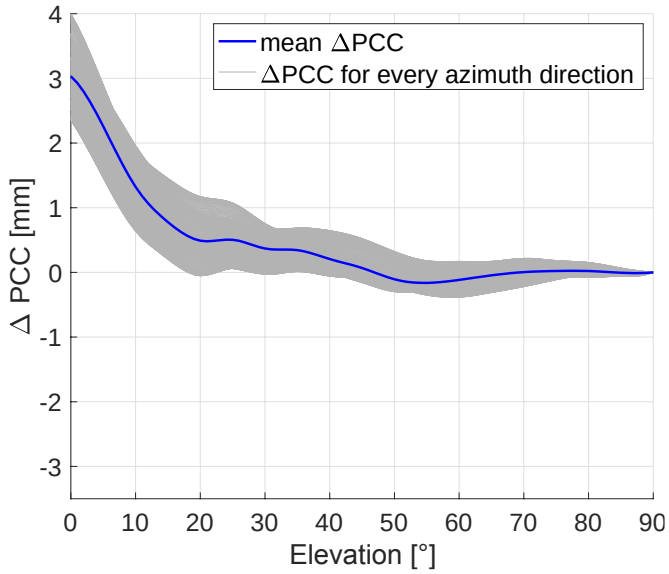


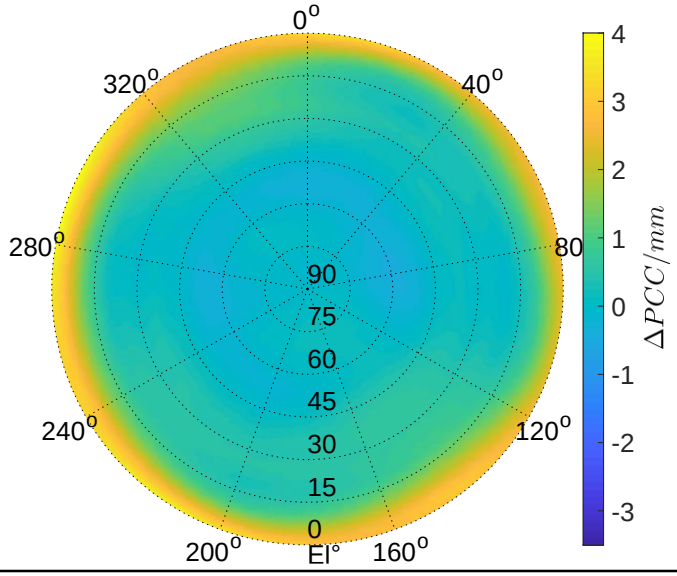


robot (Geo++) vs. chamber (IGG)

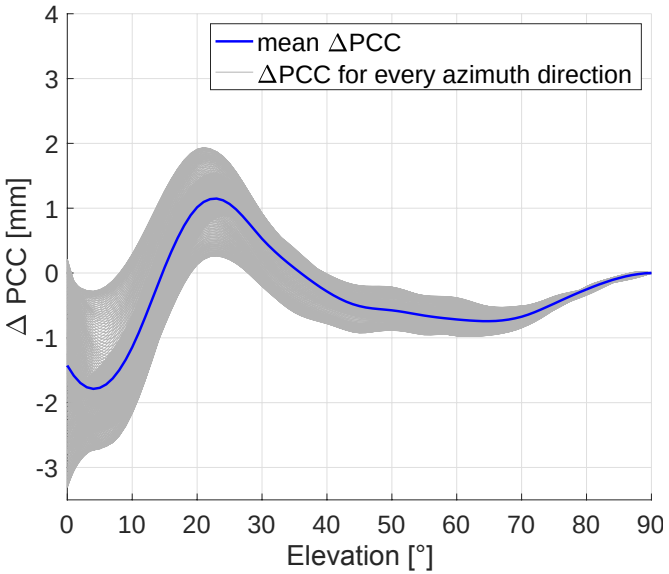
(TRM55971.00_NONE)

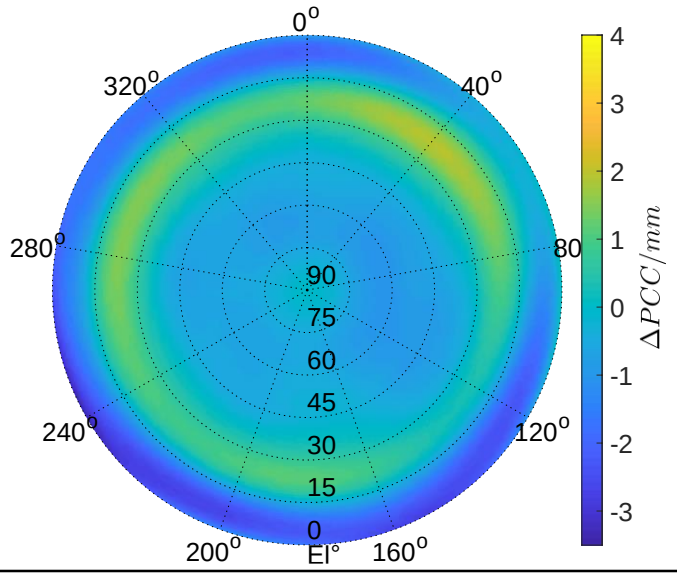
G01





G02





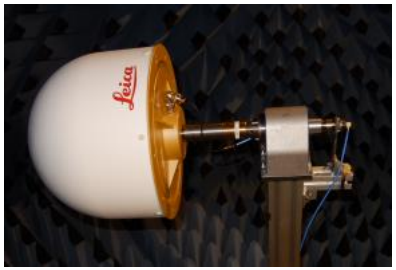
Key points and questions

- Brief description of the calibration procedure
- Precision/accuracy of chamber calibrations?
- Consistency between chamber and robot calibrations?
- **Precision/accuracy of chamber type-means?**

Precision of chamber type-means

Precision of chamber calibration type-means?

Antenna: LEIAR25.R4_LEIT (34 calibrations)



Analysis:

– Determination of PCC (phase center corrections) for each calibration pattern

– Determination of type-mean calibration pattern

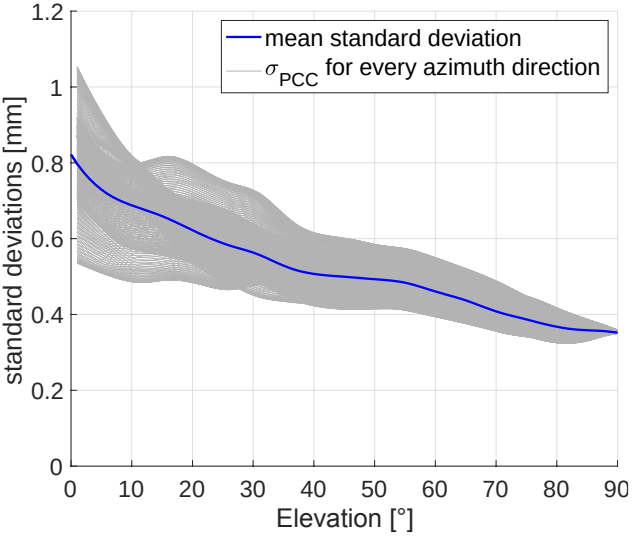
– Determination of differences to type-mean pattern

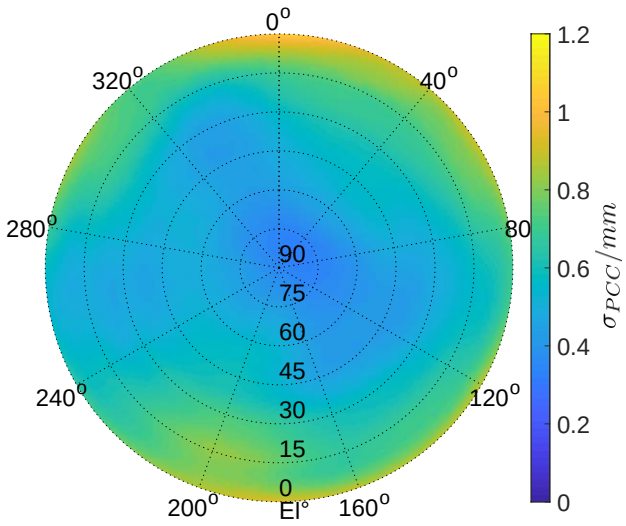
– Analysis of standard deviations $\sigma_{PCC}(\alpha, \beta)$ of differences

Precision of chamber type-means

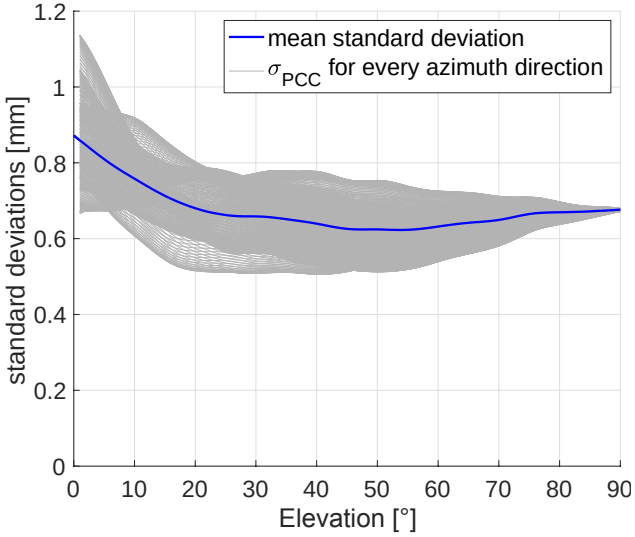
(LEIAR25.R4_LEIT - 34 calibrations)

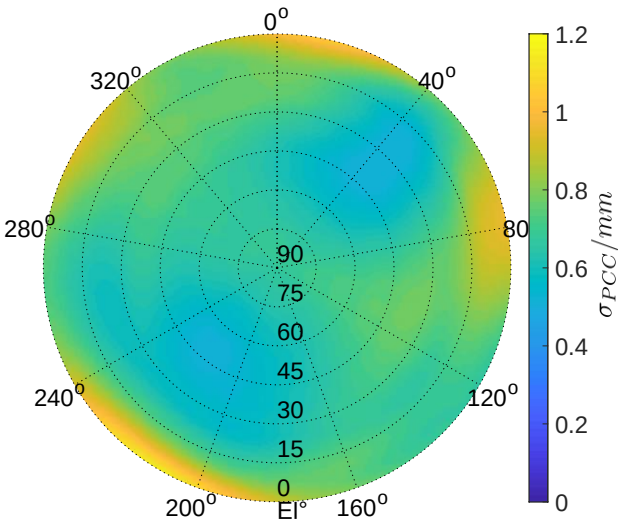
G01



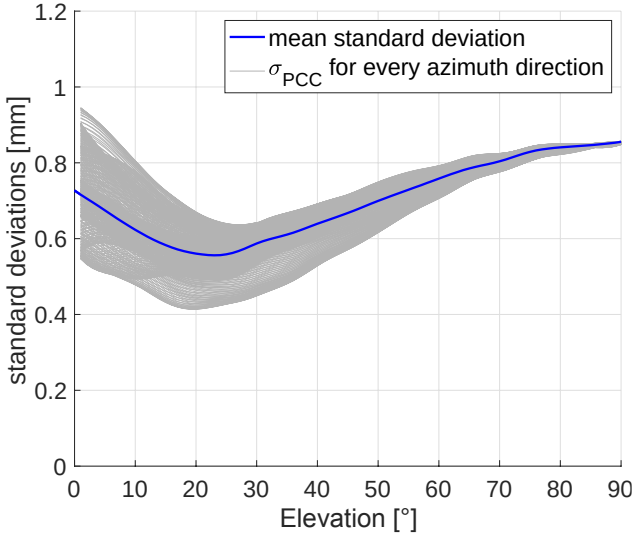


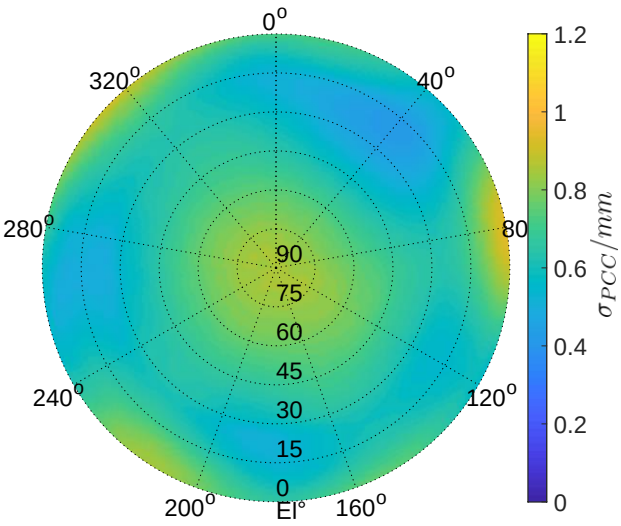
G02





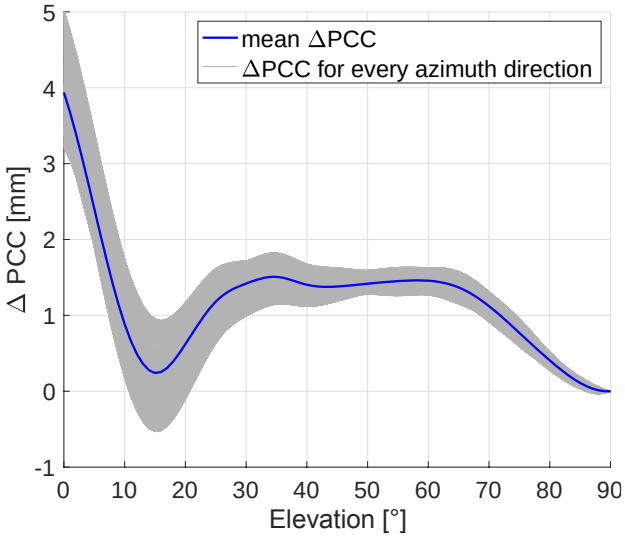
G05

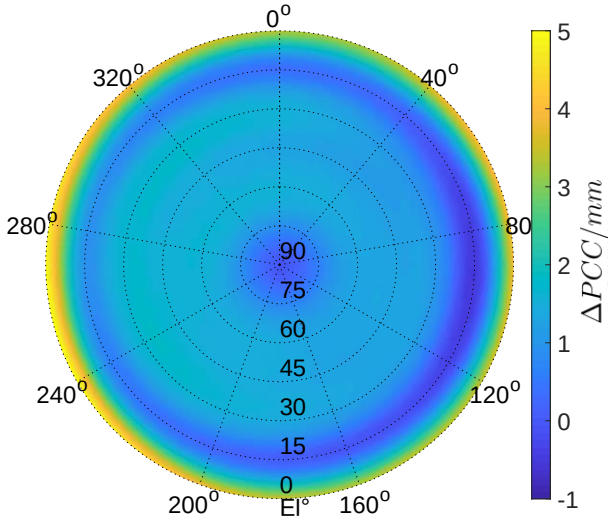




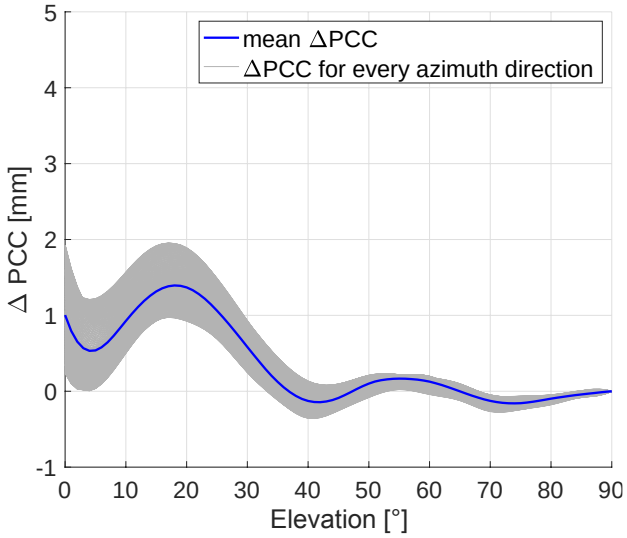
IGS vs. IGG type-mean
(LEIAR25.R4_LEIT)

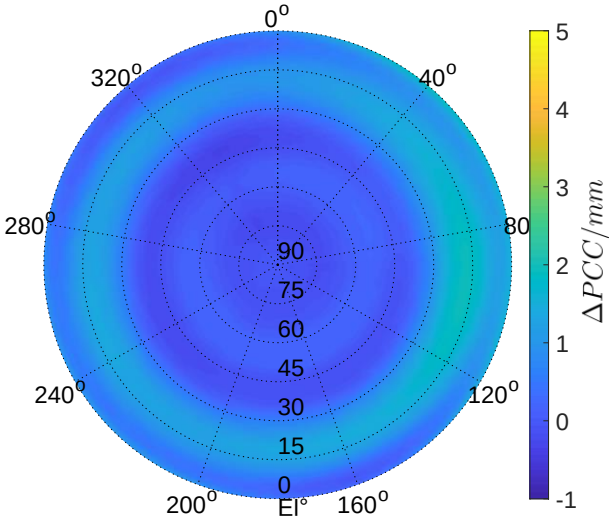
G01



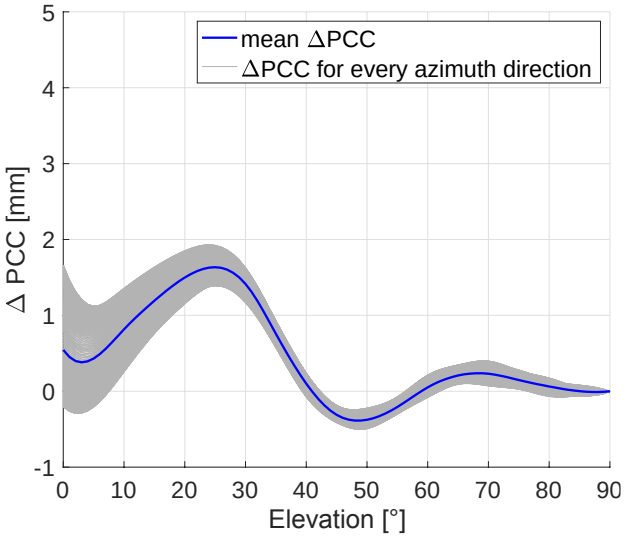


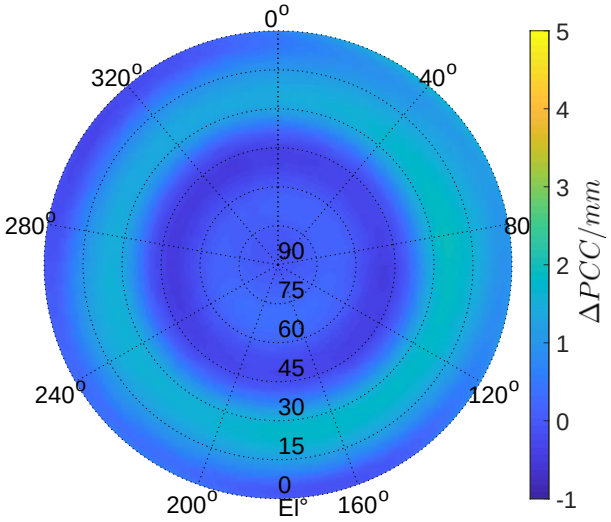
G02





G05





Summary

- **Precision/accuracy of chamber calibrations?**
  - Precision in the range of **0.3mm to 0.5/0.6mm**
  - Slightly decreasing for lower elevations and lower frequencies
- **Consistency between chamber and robot calibrations?**
  - Differences in the range of **-3mm to 3mm**
  - Small but systematic
- **Precision/accuracy of chamber type-means?**
  - Precision in the range of **0.5mm to 1.1mm**
  - Differences to IGS type mean in the range of **-1mm to 5mm**
  - Systematic effects apparent

Thank you!

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