On the Error Sources in Absolute Individual Antenna Calibrations

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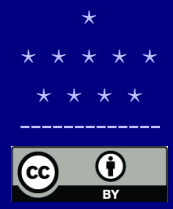
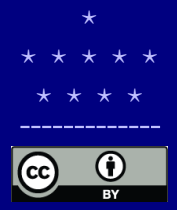
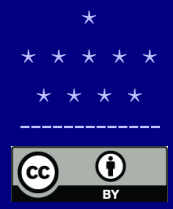


Outline

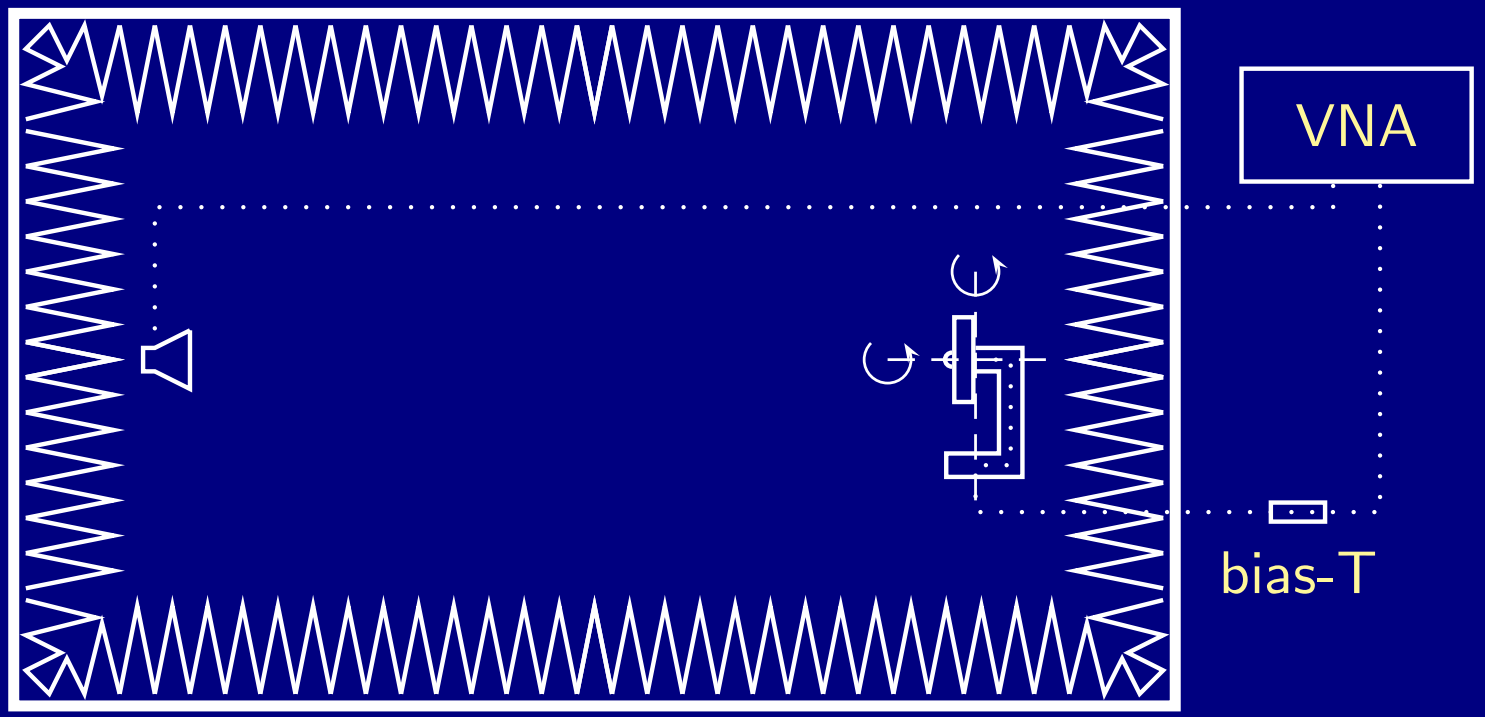


Antenna Calibration

- Antenna $\neq$ point source, rather current carrying surface
  Wheeler limit:
$$\frac{\Delta f}{f}\eta = \frac{4\pi^2}{3}\frac{V}{\lambda^3}$$
- phase at connector depends on incidence angle $\Rightarrow$ calibration
- Absolute versus Relative
- From Antex 1.4 Syntax: METHOD
  - 'CHAMBER', 'FIELD', 'ROBOT',
  - 'COPIED' from other antenna,
  - 'CONVERTED' from igs_01.pcv or blank

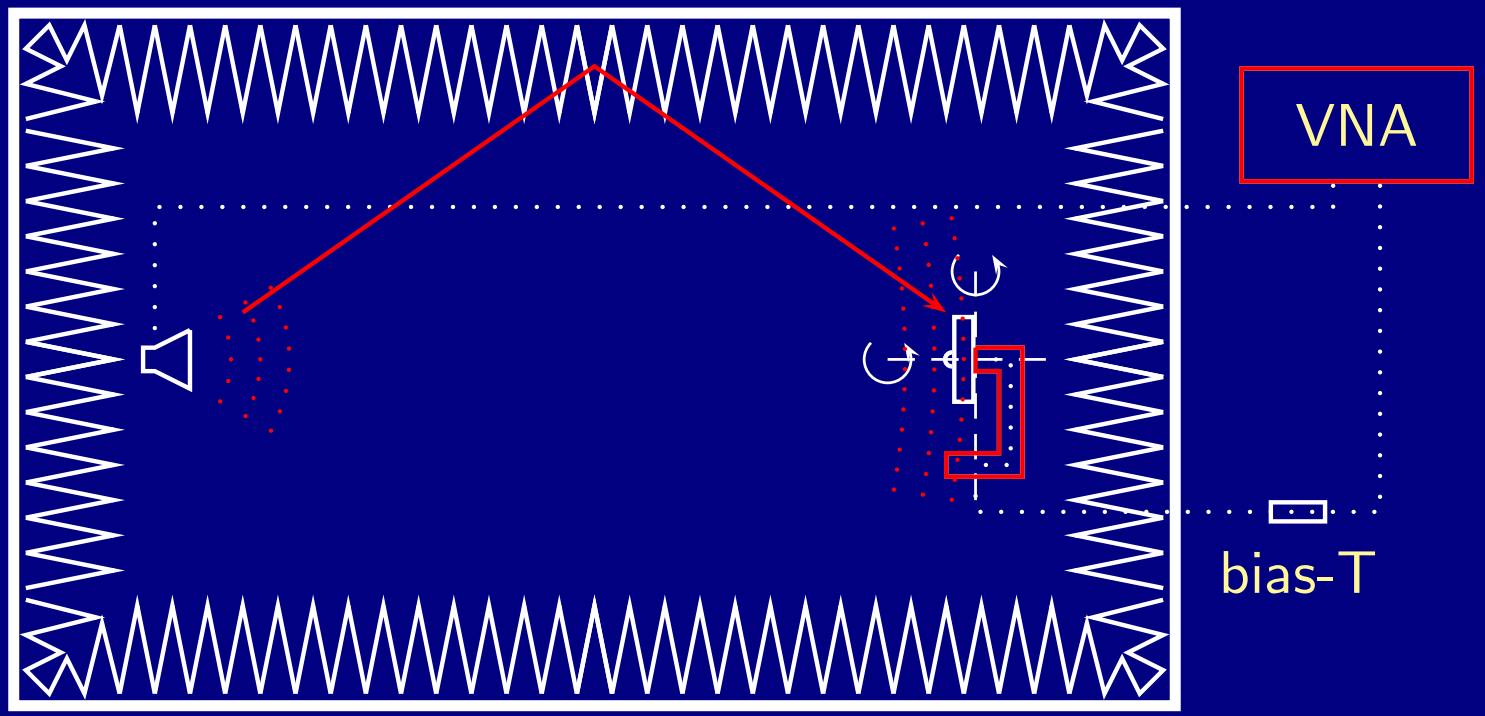


Working Principle



- cable flexing $\Rightarrow$ rotary joints
- temperature changes $\Rightarrow$ phase stable cable

Error Sources



- reflections on walls
- no plane wave at AUT
- VNA measurement errors
- near field of positioner

Error Sources

Reflection on walls:

- worst case combination of direct and reflected signal
- depends on (effective) attenuation of wall absorbers
- error on G02 (GPS L2) in good chamber is ≈ 0.1 mm (calculated with -25 dB effective attenuation)

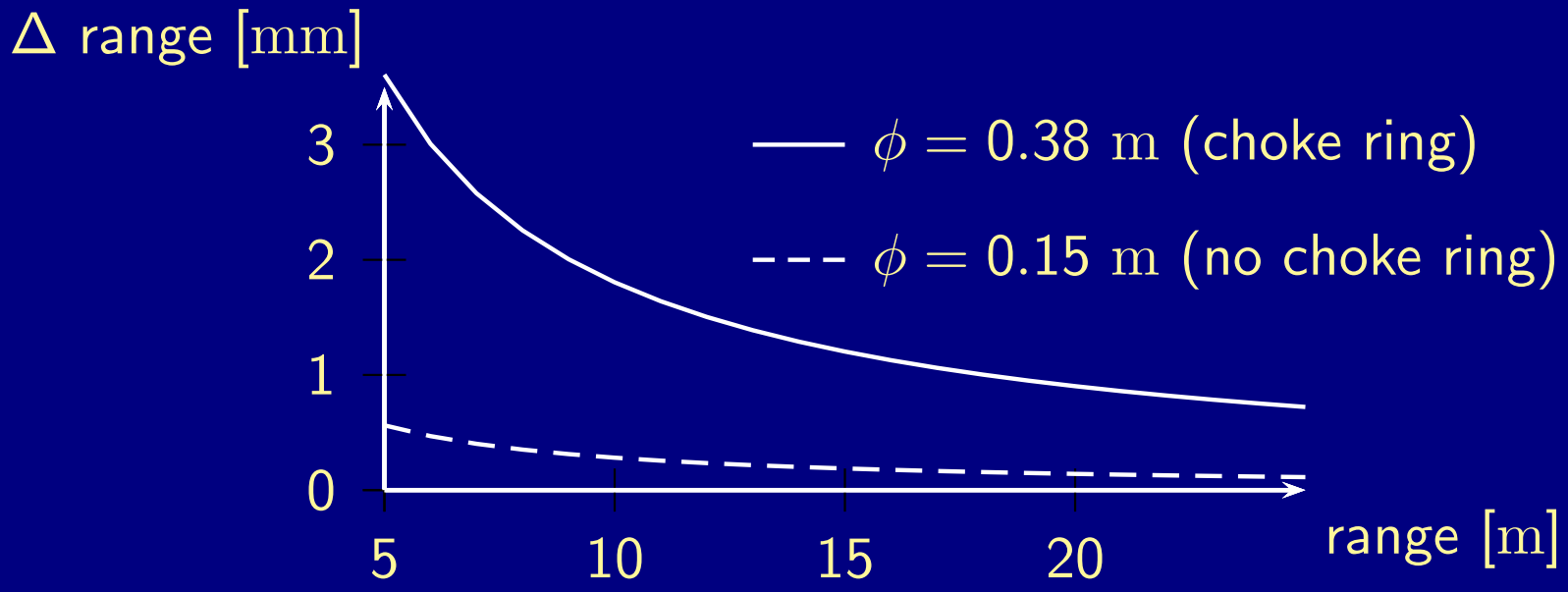
Vector Network Analyzer (VNA) measurement error:

- for calibrated VNA
- depends on received power level (worst for low elevation)
- error on G02 (GPS L2) with good VNA is $\ll 0.3$ mm (based on 0.4° S_{21} phase uncertainty; e.g. Anritsu MS4642A)
- [Zeimetz,2008] indicates $\approx 0.1^\circ$ after temperature correction
- resolution rather than accuracy is expected to matter

Error Sources

No plane wave at Antenna Under Test (AUT)

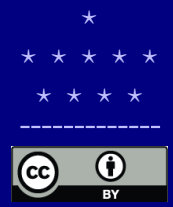
- relation between phase variation over antenna and phase error on connector unclear



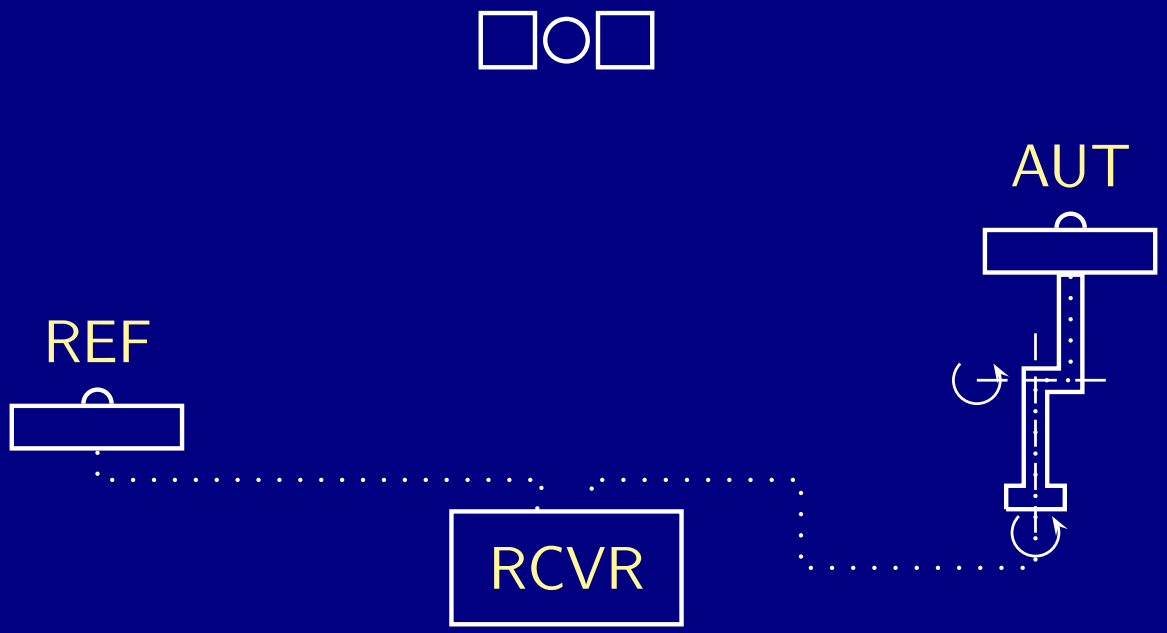
Error Sources

Near field effect of the positioner:

- any material in (reactive) near field causes change in current profile and (output) phase
- effect strongly depends on antenna type
- [Zeimetz,2008] reports difference of 1.2 mm on G02 (GPS L2) at low elevation for a change of antenna cabling geometry (for LEI AX1202GG)

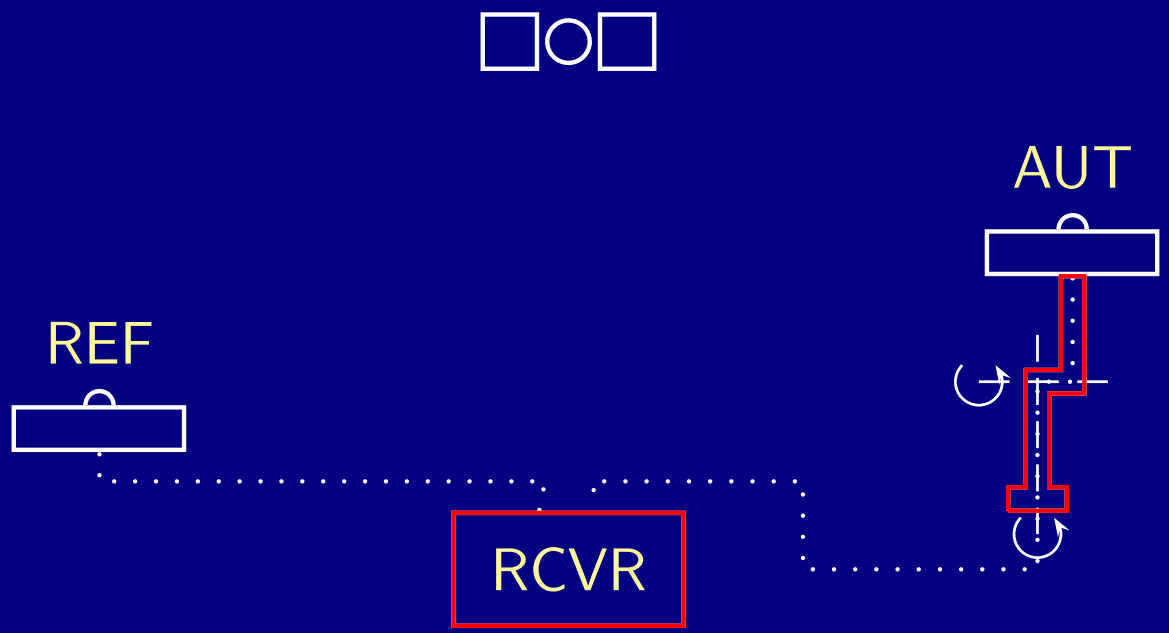


Working Principle



- cable flexing $\Rightarrow$ rotary joints
- temperature changes $\Rightarrow$ identical cables of identical length

Error Sources



- GNSS receiver measurement errors
- near field of the robot

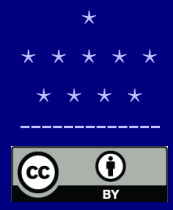
Error Sources

GNSS receiver measurement error:

- depends on received C/N_0
- resolution rather than accuracy is expected to matter
- error on G02 for contemporary receivers is ≈ 0.25 mm (based on 1 mm accuracy and 0.001 cycle resolution on G02 from SEPT POLARX4PRO data sheet)

Near field effect of the positioner:

- see also: chamber calibration
- typically robot geometry differs from positioner geometry



Order of Magnitude of Errors

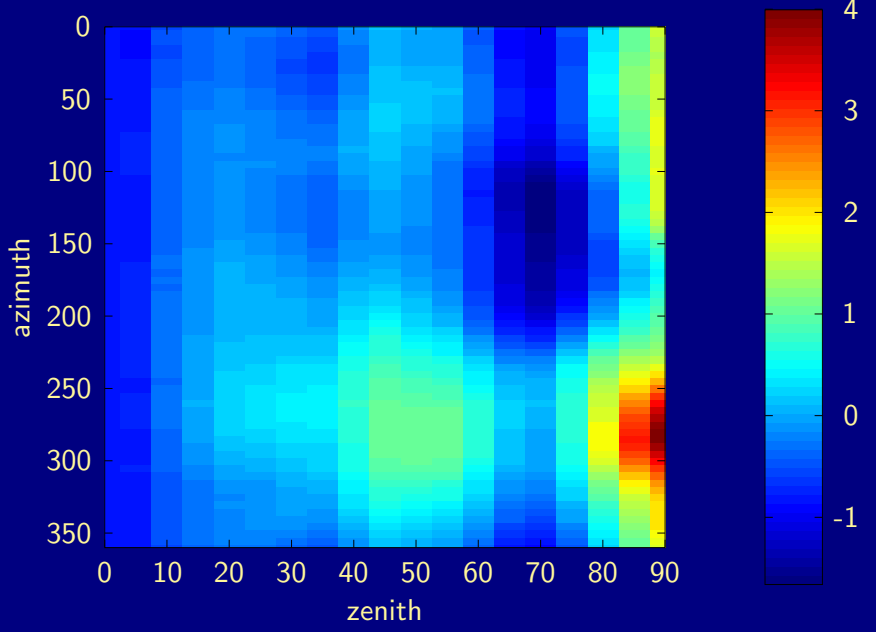
Errors on G02 in order of magnitude for both calibration methods:

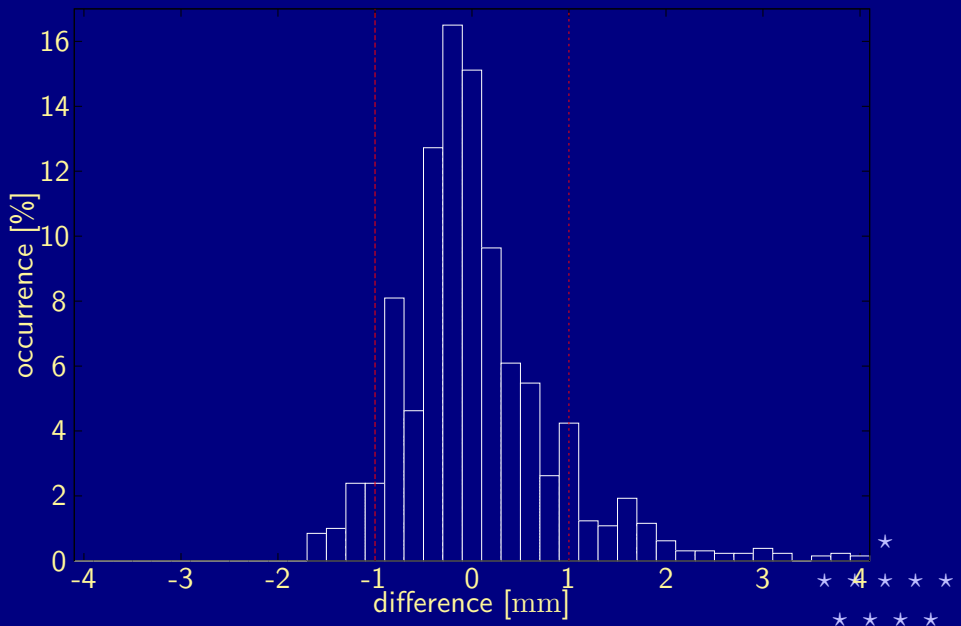
	CHAMBER	ROBOT
reflections	≈ 0.1 mm	$\rightarrow 0$
measurement device	$\ll 0.3$ mm	≈ 0.25 mm
repeatability same setup	0.3 mm [Zeimetz,2008]	??
no plane wave	??	NA
near field	≥ 1.2 mm	??
repeatability different setup	1.5 mm [Zeimetz,2008]	1 mm [Wübbena,2006]

Robot measurements in [Wübbena,2003] reveal up to 5 mm change in PCC for different antenna mounts.
Robot and chamber in [Zeimetz,2009] differ by at most 4 mm.

LEIAR25.R3 09300021

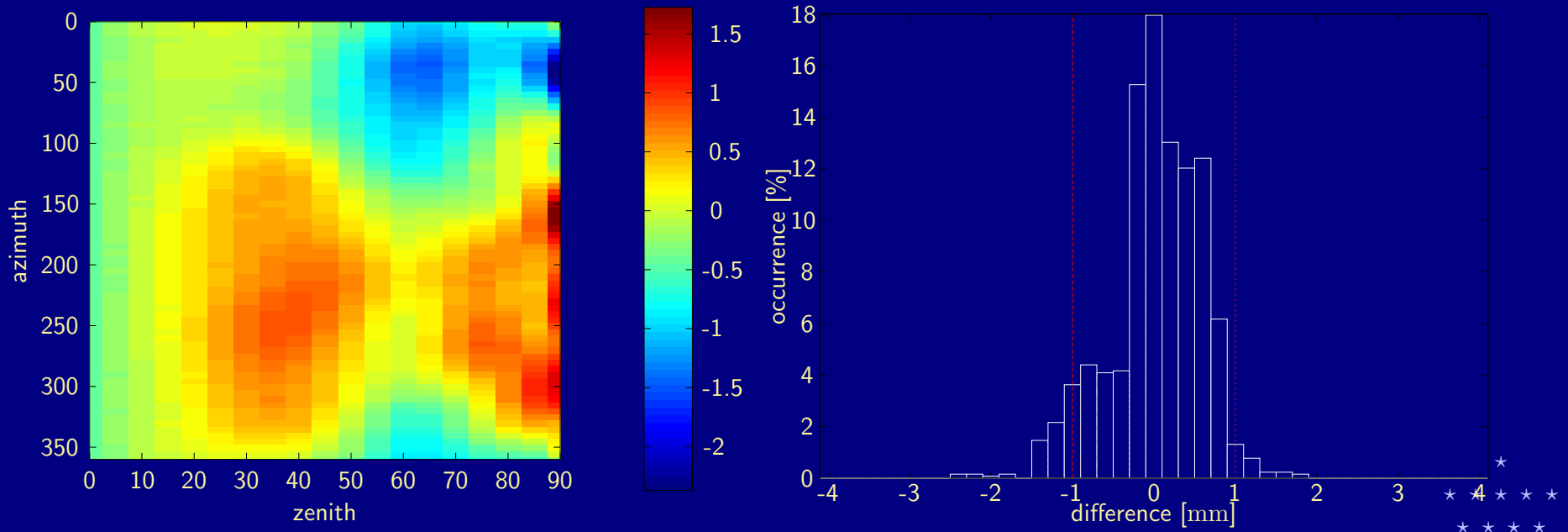
Difference between Geo++ and UniBonn PCC (PCO and PCV) calibration on G02 for LEIAR25.R3 antenna 09300021:





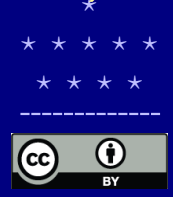
TRM59800.00 5115354099

Difference between Geo++ and UniBonn PCC (PCO and PCV) calibration on G02 for TRM59800.00 antenna 5115354099:



Conclusion

- the dominant error for chamber and robot calibration is near field multipath
- repeatability (different setup, same method) is better than inter-method difference
- difference between calibration setup and station setup has same order of magnitude as inter-method difference
- (sub-)millimeter absolute positioning with GNSS will only be possible after solving this near field issue (in calibration and site installation)



Acknowledgments

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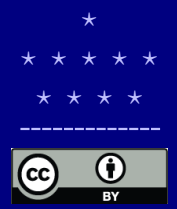
- Holger Milz, Martin Schmitz, Philipp Zeimetz, ...



References

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[Wübbena,2006] "Absolute GNSS Antenna Calibration with a Robot: Repeatability of Phase Variations, Calibration of GLONASS and Determination of Carrier-to-Noise Pattern", G. Wübenna, M. Schmitz, G. Boettcher and C. Schumann, IGS Workshop 2006, Germany.

[Zeimetz,2008] "On the Accuracy of Absolute GNSS Antenna Calibration and the Conception of a New Anechoic Chamber", P. Zeimetz and H. Kuhlmann, FIG Working Week 2008, Sweden.

[Zeimetz,2009] "Ringversuch 2009", P. Zeimetz, H. Kuhlmann, L. Wanninger, V. Frevert, S. Schön and K. Strauch, 7 GNSS-Antennen-Workshop 2009, Germany