MAESTRO: Understanding Multipath – Antenna – Receiver Interactions for Calibrating Code Phase Variations of GNSS Receiving Antennas

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Motivation

- DFG project ID 470510446 - Collaboration between Institut für Erdmessung (IfE) and German Aerospace Center (DLR).
- Understanding multipath within robot based antenna calibration.
- Eliminate multipath effects on robot with multipath maps based on ray tracing algorithm of DLR.
- Finding approaches to significant reduce codephase noise to improve robot based antenna calibration concept for codephase center corrections (CPC):
  - Optimized receiver settings,
  - Different estimation inputs.
- Comparison and validation strategies for CPC estimated in an anechoic chamber and a robot in the field.

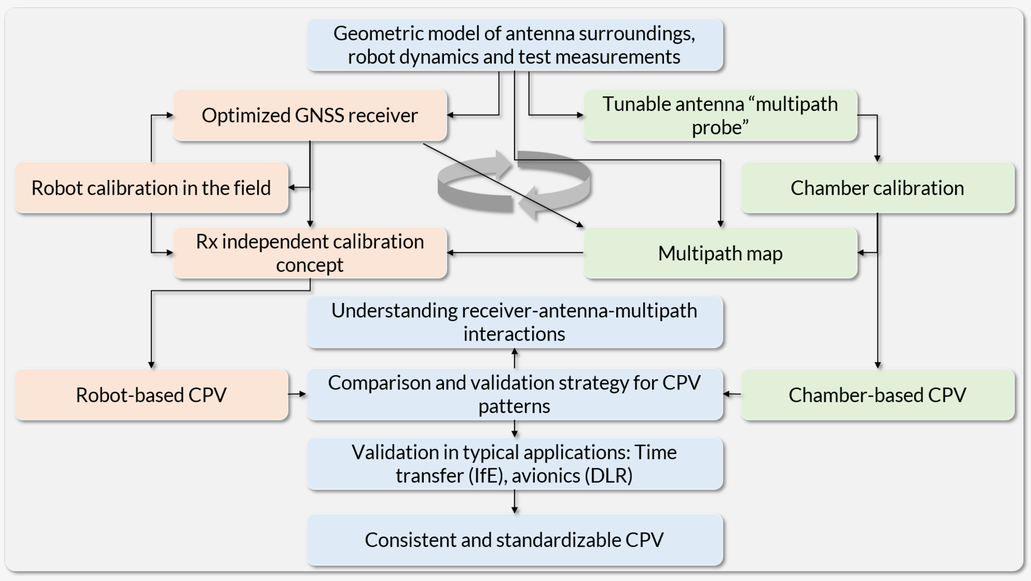

Figure 1: Overall workflow and interlinked investigations of IfE (orange), DLR (green) and common investigations (blue).

Digital Model of Robot Environment

- Survey of the robot environment on the laboratory rooftop of IfE with tacheometer with millimeter accuracy.
- Calculation of all missing required points in MATLAB.
- Model of infrastructures as three-dimensional bodies in AutoCAD.
- Export as standardized step format for DLR ray tracing algorithm.

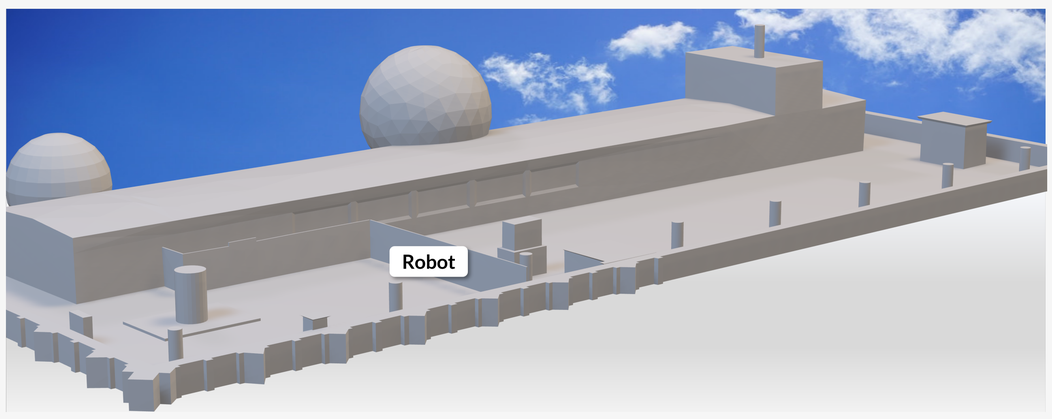

Figure 2: Digital model of the laboratory rooftop of IfE, based on tacheometer measurements.

Multipath Maps

- Multipath maps created through digital twin, making use of antenna measurement and electromagnetic simulation.
- 3 exemplary antennas (choke ring/geodetic, rover, low cost) measured in anechoic chamber and used in digital twin.
- For each antenna, generation of multipath maps, showing directions affected by strong multipath, for each robot orientation.
- Multipath maps then used in robot estimation process to eliminate measurements affected by strong multipath.

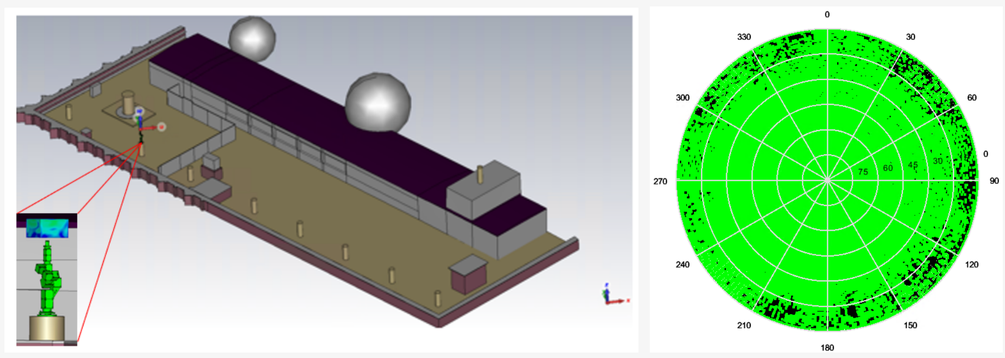

Figure 3: Digital Twin of IfE rooftop, with antenna measurement data integrated in it for multipath calculation

Estimation of Codephase Center Corrections

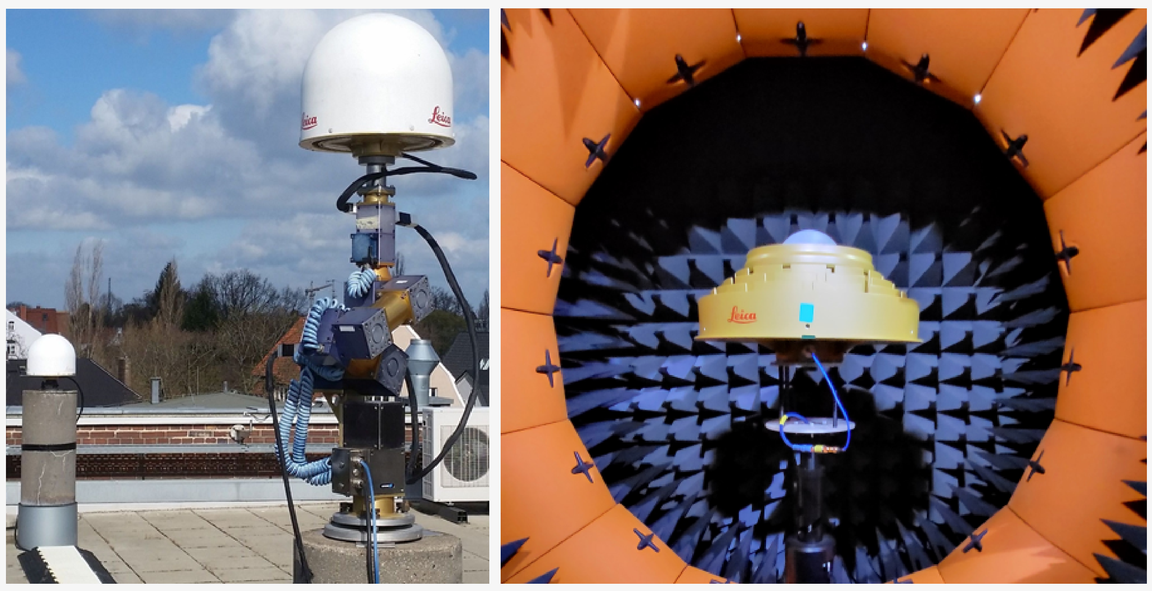

Figure 4: (Left) Infrastructure at IfE. Short-baseline common-clock setup allows forming time differenced single differences (dSD) between AUT and reference antenna so that almost all error sources are neglected (except phase-wind up, remaining multipath and antenna pattern from AUT). dSD are used as estimation inputs for hemispherical harmonics (8,8). (Right) Antenna near field chamber at DLR

- Estimation of CPC with two different approaches (Fig. 4).
- Definition: $CPC^k = -CCO^k + CPV^k + r$

Recent Results

- DLL bandwidth controls noise behavior of time differenced single differences (dSD), but a too small bandwidth results in pattern information loss.
- Multipath maps successfully eliminate multipath effect within the calibration, but has less impact on the CPC estimation with dSD as inputs.
- Use of time differenced multipath linear combination (dMPLC) approach
  - PCC of two carrier frequencies (initial run with dSD approach)
  - PWU of two carrier frequencies (modelled)
  - Multipath effects (eliminated, thanks to multipath maps)
  - CPC of codephase frequency
- Codephase noise is significantly reduced by using dMPLC and optimal receiver settings

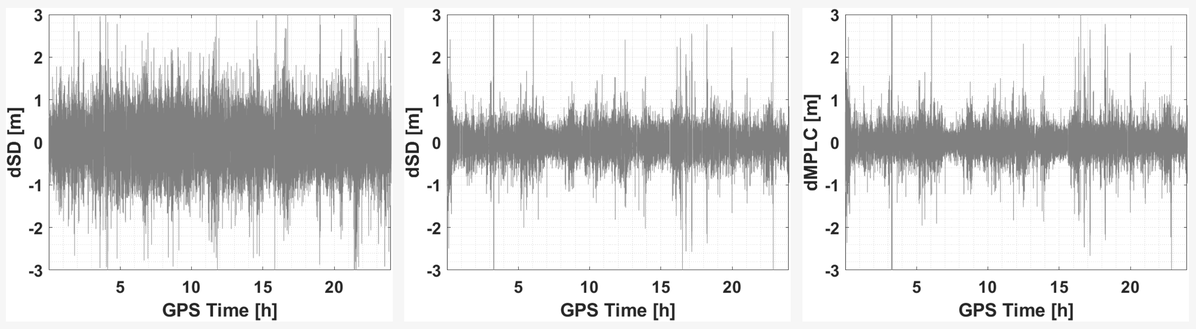

Figure 5: (Left) Standard dSD approach with default receiver settings. (Middle) Standard dSD approach with optimized receiver settings. (Right) dMPLC approach with multipath maps. **Note:** CPC information still included. LEIAR25.R3 NONE S/N:9330001 - EC1X.

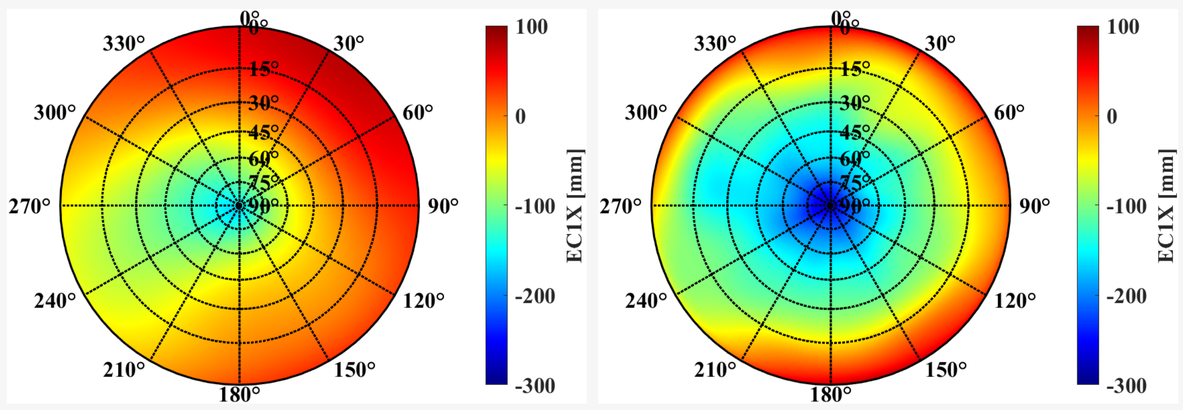

Figure 6: EC1X CPC of LEIAR25.R3 NONE S/N:9330001 estimated (Left) in the anechoic chamber from DLR and (right) with dMPLC approach and optimized settings from IfE.

Conclusion

- Multipath is not the dominating factor within the robot based antenna calibration, but noise is.
- Codephase noise can significant be reduced by optimized receiver settings (reduce DLL bandwidth) or by using dMPLC as estimation inputs.
- In dMPLC approach, multipath maps eliminates the remaining multipath within the linear combination.

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